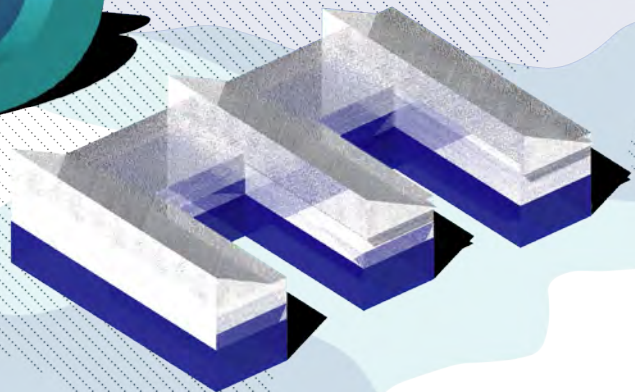
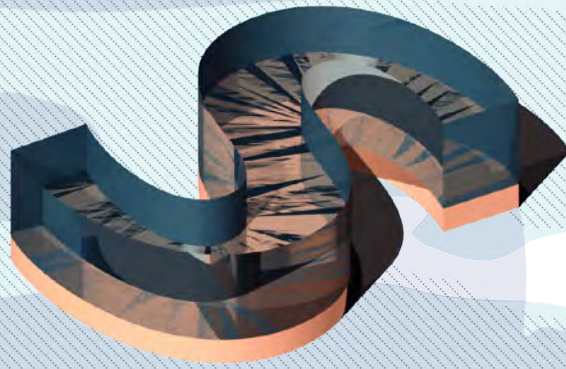
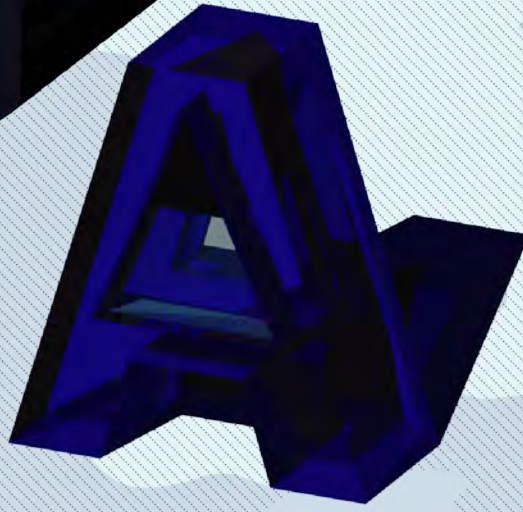
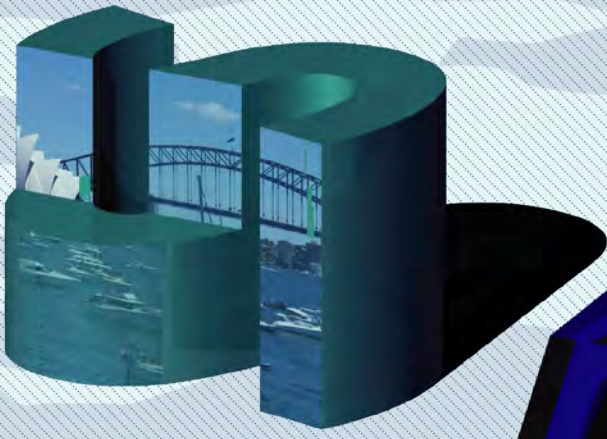


# SASBE 2018 SYDNEY

**SMART & SUSTAINABLE  
BUILT ENVIRONMENTS**

**6TH CIB INTERNATIONAL CONFERENCE**





**WE ACKNOWLEDGE THE TRADITIONAL  
CUSTODIANS OF THE LAND ON WHICH THE  
INSTITUTION IS LOCATED, THE GADIGAL  
PEOPLE OF THE EORA NATION.**

**WE HONOUR AND CELEBRATE THEIR ELDERS AND  
THE ELDERS OF ALL ABORIGINAL AND TORRES  
STRAIT ISLANDER NATIONS PAST AND PRESENT.**

## FOREWORD

The 6th Smart and Sustainable Built Environments conference returns to its origin. With the first conference being organized in Brisbane, followed by Shanghai, Delft, Sao Paulo and Pretoria, Sydney is the 2018 host of researchers and practitioners in the field of Smart and Sustainable Built Environments (SASBE).

This year's conference is lucky to have a large response of high-quality papers which will all be presented at the conference. It becomes clear that the traditional group of academics, interested in technologies, buildings and modelling indoor climates and energy performance is now balanced with a growing group interested in the sustainability and smartness of planning and design of cities. Though it has always been the ambition of SASBE it is good to see this development continuing and leading to a real broad community.

This year's conference pays tribute to the traditional custodians of the land. This is important to acknowledge, and not in the way it often is practiced in Australia: with an aunty or elder that welcomes the delegates on the first morning on their traditional land. After which he or she can leave and the conference, or meeting, can really start. Especially when we speak about sustainable development it is a very Western attitude to neglect history, in particular when this history is over 40,000 years. Did you know that aboriginal people built settlements, practiced agriculture and developed smart and sensitive relationships with nature. They even made a deal with killer whales to jointly hunt for fish. After catching the fish, they were so smart to share the catch with the killer whales, who then would drive the fish into the aboriginal settlement next time. This mutually beneficial model ended the moment one of the English first settlers shot a killer whale. They never returned again. This and many other stories, exemplifying the relationship of Aboriginals with land, and nature is captured in the book 'Dark Emu' by Bruce Pascoe. A real recommended read!

This also gave us reason to develop the conference as a real mutual experience. The welcome is more than superficial and will give all delegates an impression of traditional Aboriginal thinking. We are extremely happy that Chels Marshall will induct us in some of the basic rituals and thought leadership. Throughout the conference we will have Aboriginal food and reminders of the traditional values and sustainability of treating the land and our built environment. I truly hope that this will be an experience you will always remember. Not only because it is impressive, but because it will influence your daily working life.

In this document you will find all the papers that will be presented during the conference. It gives you an overview over the most recent research into Smart and Sustainable Built Environments, at the scale of individual buildings and cities alike. Selections of the submitted papers will be published in a book, published by Springer, and two special issues of the SASBE journal. Hence, not only during the conference the research is presented but also afterwards this research will find its way to the academic channels as appropriate. We also will honor two best papers, one for academic rigor and one for the best practice. Each will be awarded with a prize, provided by Springer and Emerald Publishing.

Sydney in December is an excellent time for a visit and we have worked hard to make the conference a success. I sincerely hope you will enjoy the conference, the city and your fellow delegates. Here, I want to thank all that have played an important role in preparing for the conference: all the reviewers, members of the organizing committee, members of the scientific committee, and Stewart Monti, who has worked tirelessly to communicate, organize, email, call, skype and who knows what else to create a silken smooth conference. In the meantime, he finished his Masters of Architecture, which is something to applaud! Please meet up with him, thank him and if you can hire him!

I hope you have a great time in Sydney, enjoy the talks, the food, the company and the weather! I wish you the best of success during the conference and after.

Yours sincerely,



Rob Roggema  
Conference Chair, SASBE 2018

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CSIR, South Africa  
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Nimish Bilorla  
Rob Roggema  
Stewart Monti



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Prof. Dr. ir. Henk Visscher | Delft University of Technology, The Netherlands  
Nori Yokoo, PhD | Utsunomiya University, Japan

## PROGRAM

### Day Zero: Tuesday 4 December 2018

5:00 - 7:00 pm	<b>Reception and Registration</b> <i>UTS Design Innovation Research Centre Building 15, Level 2, 622-623 Harris Street Ultimo, 2007</i>
<b>Welcome</b>	

### Day One: Wednesday 5 December 2018

9:00 - 10:30 am	Welcome to Country <b>Aunty Ann Weldon</b>	
<b>Opening Session</b>	Welcome to SASBE 2018 <b>Chair: Rob Roggema</b>	
	Keynote: Removing the brown stains from sustainability <b>Chels Marshall, Australian National University</b>	
	Keynote: Towards Sustainable Cities: about Redundancy, Emptiness and the Potentials of the Land <b>Rob Roggema, chair SASBE2018</b>	
10:30 - 11:00 am	<b>Morning Tea</b>	
11:00 am - 12:30 pm	<div> <b>Session A: Inclusivity</b>  <i>Chair: Sumita Ghosh</i> </div> <div> A model for assessing the social impacts of building upgrades in China  <b>Chenyang Li, University of Technology Sydney</b> </div> <div> The role of public participation in the future of Sydney Olympic Park as a sustainable place  <b>Eveline Mussi, University of New South Wales</b> </div> <div> Adaptation of "participatory method" in design "for/with/by" the poor community in Tam Thanh, Quang Nam, Vietnam  <b>Nguyen Hanh Nguyen, Ho Chi Minh City University of Architecture</b> </div> <div> Fifty years of inclusive transport  <b>John Harding, WSP</b> </div> <div> Enabling smart participatory local government: preliminary findings  <b>Tooran Alizadeh, University of Sydney</b> </div>	
<b>Parallel Sessions</b>	<div> <b>Session B: Energy</b>  <i>Chair: Andy van den Dobbelsteen</i> </div> <div> The total cost of living in relation to energy efficiency upgrades in the Dutch, multi-residential building stock  <b>Thaleia Konstantinou, Delft University of Technology</b> </div> <div> The optimization of active/passive energy-saving in the hotel atrium  <b>Guan Yaming, South China University of Technology</b> </div> <div> Sharing urban renewable energy generation systems as private energy commons  <b>Craig Burton, University of Melbourne</b> </div> <div> Identifying bottlenecks in the photovoltaic systems innovation ecosystem – an initial study  <b>Kristian Widén, Halmstad University</b> </div>	
12:30 - 1:45 pm	<b>Lunch</b>	

1:45 - 3:15 pm <b>Parallel Sessions</b>	<p><b>Session C: Resilient City</b> <i>Chair: Rob Roggema</i></p> <hr/> <p>The influence of landscape architecture on landscape construction health and safety <b>John Smallwood, Nelson Mandela University</b></p> <hr/> <p>Globalization and transformations of the city of Sydney <b>Shahadat Hossain, Western Sydney University</b></p> <hr/> <p>Post-earthquake recovery in nepal, a study and analysis of post disaster perception and needs for housing recovery after 2015 earthquake <b>Rupesh Shrestha, Kathmandu Valley Preservation Trust</b></p> <hr/> <p>Towards a circular economy in the built environment: an integral design framework for circular building components <b>Anne van Stijn, Delft University of Technology</b></p>	<p><b>Session D: Comfort</b> <i>Chair: Michiel Smits</i></p> <hr/> <p>Outdoor comfort in metro Manila: mitigating thermal stress in typical urban blocks by design <b>Juanito de la Rosa, Architectural Association</b></p> <hr/> <p>Markov logic network based group activity recognition in smart building <b>Hao Chen, Incheon National University</b></p> <hr/> <p>Impacts of highly reflective building façade on the thermal and visual performance of one surrounding office building in Singapore <b>Jianxiu Wen, National University of Singapore</b></p> <hr/> <p>A field study on occupants' comfort and cold stress in CLT school buildings <b>Timothy Adekunle, University of Hartford</b></p>
3:15 - 3:45 pm	<b>Afternoon Tea</b>	
3:45 - 5:30 pm <b>Parallel Sessions</b>	<p><b>Session E: Urbanity</b> <i>Chair: Dominique Hes</i></p> <hr/> <p>Evaluating factors influencing the uncontrolled growth of urban-rural belt – a case study of Delhi, India <b>Mukesh Ray, University of Technology Sydney</b></p> <hr/> <p>Implementing a new human settlement theory: strategic planning for a network of circular economy innovation hubs <b>Steven Liaros, University of Sydney</b></p> <hr/> <p>Density and quality of life in Mashhad, Iran <b>Fereshteh Moradi, University of Technology Sydney</b></p> <hr/> <p>The city-zen urban energy transition methodology – the Amsterdam roadmap towards a zero-carbon city <b>Andy van den Dobbelsteen, Delft University of Technology</b></p>	
5:30 - 6:15 pm	Keynote: Smart and Liveable Cities: A socio-technical perspective <b>Nimish Biloria, University of Technology Sydney</b>	
7:00 - 10:00 pm	<b>Conference Dinner</b>	

## Day Two: Thursday 6 December 2018

9:30 - 10:15 am <b>Opening Session</b>	Keynote: Walking country: landscape and walkability as the basis for urbanity <b>Rod Simpson, Greater Sydney Commission</b>
10:15 - 10:45 am	<b>Morning Tea</b>



10:45 am - 12:15 pm <b>Parallel Sessions</b>	<b>Session F: Smart cities</b> <i>Chair: Nimish Bitoria</i> <hr/> Application of Fuzzy AHP for ranking and selection of innovation in infrastructure project management <i>Mohammadali Noktehdan, , University of Isfahan</i> <hr/> Smart city initiatives: a catalyst for meaningful collaboration <i>Homa Rahmat, University of New South Wales</i> <hr/> A techno-economic analysis on applying smart distribution network for solar photovoltaic systems in educational buildings <i>Hongying Zhao, RMIT</i> <hr/> A user-led approach to smart campus design at a university of technology <i>Alfred Ngowi, Central University of Technology</i>	<b>Session G: Green Building</b> <i>Chair: John Smallwood</i> <hr/> Data management using computational building information modelling for building envelope retrofitting <i>Taki Eddine Seghier, University of Technology Malaysia</i> <hr/> Towards self-reliant development: capacity gap within the built environment of Mt. Elgon rural inhabitants <i>Michiel Smits, Delft University of Technology</i> <hr/> Mainstreaming real sustainability in architecture <i>Luke Middleton, EME Design</i> <hr/> Green buildings in australia: explaining the difference of drivers in commercial and residential sector <i>Tayyab Ahmad, University of Melbourne</i>
12:15 - 1:15 pm	<b>Lunch</b>	
1:15 - 2:45 pm <b>Parallel Sessions</b>	<b>Session H: Urban Ecology</b> <i>Chair: Greg Keeffe</i> <hr/> Australia's urban biodiversity: how is adaptive governance influencing land-use policy <i>Hugh Stanford</i> <hr/> Mapping the permeability of urban landscapes as stepping stones for forest migration <i>Qiyao Han, Queens University Belfast</i> <hr/> Potential of trees to mitigate climate change impacts in a railway corridor case study in sydney <i>Sumita Ghosh, University of Technology Sydney</i> <hr/> Urban agricultural practices in the megacities of Dhaka and Mumbai <i>Tazy Momtaz, University of Technology Sydney</i>	<b>Session I: Construction</b> <i>Chair: Luke Middleton</i> <hr/> Challenges to the implementation of sustainable waste management practice in the construction industry <i>John Smallwood, Nelson Mandela University</i> <hr/> Producing work-ready graduate for the construction industry <i>Sadeq Aliakbarlou, Unitec Institute of Technology</i> <hr/> Cradle to cradle building components via the cloud: a case study <i>Adam Jenkins, University of South Australia</i> <hr/> The impact of leadership on innovative culture in the construction industry <i>Hossein Sadeghzadeh, University of Auckland</i>
2:45 - 3:15 pm	<b>Afternoon Tea</b>	
3:15 - 4:45 pm <b>Parallel Sessions</b>	<b>Session J: Space and Place</b> <i>Chair: Kiran Kashyap</i> <hr/> A multiple criteria analysis-based framework to evaluate public space quality <i>Peijun He, Singapore-ETH Centre</i> <hr/> Preventing urban open space encroachment: the case of Bloemfontein, South Africa <i>Lindelwa Toba, Central University of Technology</i> <hr/> A new model for place development – bringing together regenerative and placemaking processes <i>Dominique Hes, University of Melbourne</i> <hr/> Re-imagining urban leftover spaces <i>Jasim Azhar, Victoria University of Wellington</i>	<b>Session K: Performance</b> <i>Chair: Anne van Stijn</i> <hr/> Tower blocks in groups of different patterns -the aspects of daylight and view <i>Bengt Sundborg, Norwegian University of Science and Technology</i> <hr/> Assessing the lighting performance of an innovative core sunlighting system <i>Liliana Beltran, Texas A&amp;M University</i> <hr/> Vertical light pipe potentiality for buildings in Surabaya, Indonesia <i>Hanny Pratama, Khon Kaen University</i> <hr/> Energy efficiency of a high-rise office building in the Mediterranean climate with the use of a double skin façade <i>Tanya Saroglou, Ben-Gurion University of the Negev</i>
4:45 - 5:00 pm	<b>Contemporary Urban Design Thinking, The Australian Approach - Book Launch</b>	
5:00 - 5:45 pm	Keynote: Born and not made: designing the productive city <i>Greg Keeffe, Queens University Belfast</i>	

5:45 - 6:00 pm	Prize ceremony and closing
6:00 - 7:30 pm	Farewell Drinks

### Day Three: Friday 7 December 2018

10:00 - 2:00 pm <b>Technical Tours</b>	<b>Central Park</b> <i>Central Park Mall, 28 Broadway Chippendale, 2008</i>	<b>Parramatta Ferry</b> <i>Wharf 5, Circular Quay, 2000</i>	<b>The 'Paper Bag Building'</b> <i>Dr Chau Chak Wing Building Building 8, 14 - 28 Ultimo Road Ultimo, 2007</i>
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## KEYNOTE SPEAKERS

### CHELS MARSHALL

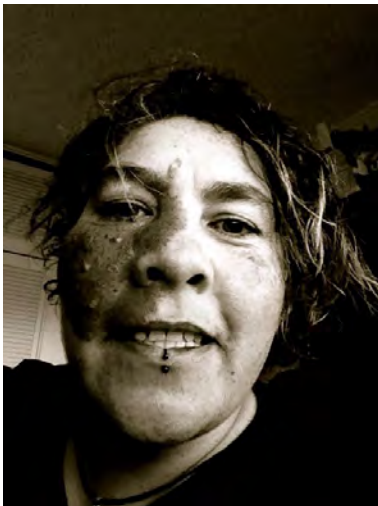
#### Removing the brown stains from sustainability

In uncertain times of global capital, political uncertainty, environmental instability, food insecurity, profound species loss and ecosystem breakdowns in natural systems essential to our existence and survival such as forests, oceans, rivers and air, continue to decline and diminish on our watch!

The unknown factors are too much to ignore, or to leave to someone else to fix or deal with, we are now at the point where mass social paradigm shift through mind frame and actions are required to bring balance back to eco centric lifestyles and existence.

In our Western timeframe we think we are working on sustainability, and using all kinds of performance systems on energy efficiency, indoor climate and comfort, waste management, while the real sustainability is almost out of sight; namely that the land, earth and sea which all consists of a holistic and whole systems approach. This is the system Indigenous people have thrived and survived in sustainably for thousands of years through social practices and structures which placed the environment and its species in levels of equity and of superior creation, with the notion of cyclic existence in which everything relates to each other, in which collaboration is more important than ownership, and that if you give you will get back.

In design and planning owning land should not be the main goal, and will definitely not lead to sustainability, as there is only a very few people that profit from developing land. Shared ownership will automatically conserve the land and together the 'owners' will make sure that the land will give back for eternity. It is now time for those with innovative intellect in design and the built environment to step up in altering the perspectives from individual wealth to that of a shared ownership and a holistic acknowledgement of land, nature, humans, all as part of one system.



*Chels is a leading Indigenous ecologist in cultural landscape management and design. Having over 27 years of professional experience in cultural ecology & integrated environmental planning, design and management, within government agencies, research institutes, Indigenous communities, environmental consulting companies and industry. Chels has spent many years investigating, developing, writing and implementing policy and governance frameworks for indigenous bio-science, cultural ecology, co-management, partnerships and traditional cultural knowledge principles. Chels is an expert in her field of cultural ecology and has spent 25 years in interpretation and design of public spaces in cultural contexts, developing cultural protocols for community partnerships and designing governance frameworks and methodologies for cultural knowledge exchange and application.*



## **Towards Sustainable Cities: about Redundancy, Emptiness and the Potentials of the Land**

In our western society we are used to plan. Plan for the future. After analyzing problems, the cure is then determined, and we can build the city in a way that we want. Much is based on power relations, land-ownership and maximization of profit. Over the years this has led to cities that are completely fixed and inflexible and build according a development model that consists of the built typology offered by developers. Consumers just have to take it or leave it. Sustainability is limited within this frame, we will adjust housing to make them more energy efficient, limit the use of water resources and try to design a public space that offers people enough space to exercise.

How different a real sustainable city looks like. This city incorporates future uncertainties by increasing its flexibility and conserves space for future uses. This calls for emptiness, redundant spaces and using landscape according its best potentials. The analysis should chart the best possible collective use of land providing resources to the community, and safeguarding supplies being regenerated. The design of the city will then no longer be determined by land prices and short-term benefits but be focused on building a long-term relationship with what the land has to offer. By sharing resources and returning to the natural system what it requires to recover, people can develop a longstanding relationship with their environment. This city will look different from the ones we currently know as it has to open its urban systems to change.



*Prof. dr. ir. Rob Roggema (1964), Landscape Architect, is an international renowned design-expert on sustainable urbanism, climate adaptation, renewable energy landscapes and the design of urban agriculture. He held positions at several universities in the Netherlands and Australia, State and Municipal governments and design consultancies. Per 1 January 2019 he is appointed as Professor Sustainable Spatial Transformations at Hanze University Groningen, the Netherlands. In 2010 he became the inaugural visiting fellow at the Victorian Centre for Climate Change Adaptation Research, in 2014 he was the Chair of the 6th International AESOP Conference on Sustainable Food Planning in Leeuwarden and in 2018 Chair of the 6th Smart and Sustainable Built Environment (SASBE) conference in Sydney. His PhD-thesis has been selected for publication in*

*Springer's 'Recognising Outstanding Research'-series (2013). He is Global Distinguished Professor at KEIO University, Japan (2019), Lead Expert in the URBACT III program, expert for RESURBE, Editor-in-Chief of SABE-journal (Emerald Publishing), member of several Editorial Boards, Guest-Editorships and acts as external monitor for different Universities, processes and projects.*

## **Smart and Liveable Cities: A socio-technical perspective**

Rapid urbanisation globally has resulted in the insatiable demand for developing cities. Such large scale built environments consume 75% of the world's natural resources, 80% of the global energy supply and produce approximately 75% of the global carbon emissions. This, comes with a baggage of associated complexities in the domains of urban mobility, spatial density, sustainable energy production and consumption as well as urban health and wellbeing. Maintaining a healthy ecological balance between the built and the natural while aiming for equitable and participatory urban growth are thus becoming issues of serious concerns in both the developing and the developed world. Within this context, the usage of smart tools, techniques and methodologies to envision Liveable Cities or rather cities which, are humane, resilient and joyful, which, focuses on addressing/identifying broader performance criteria such as 'Quality of Life' and 'Wellbeing' and thus provides a more user centric perspective on cities are becoming increasingly important. The lecture shall try and dissect the term 'Smart' and its implications within the existing urban landscape to envision Liveable Cities. Understanding and treating the city as a Laboratory where competitive growth and informed development from a social, spatial, economic and environmental perspective is deemed essential shall thus be discussed and elaborated upon. This, in essence implies a democratic view towards building our cities wherein a balance between qualitative and quantitative aspects of a city and its related user centric key performance indicators are aimed at promoting a healthy and equitable society. The lecture shall encourage us to collaboratively explore novel data-driven research and design approaches for identifying and establishing synergies between factors that add up to a community's quality of life including the built and natural environments, economic prosperity, social stability and equity, educational opportunity, and cultural, entertainment and recreation possibilities.



*Dr. Nimish Bitoria is an Associate Professor at the, Faculty of Design Architecture and Building at the University of Technology Sydney, Australia. Prior to this, he served as an Assistant Professor at the world-renowned Faculty of Architecture and the Built Environment, Delft University of Technology, The Netherlands. He has over 15 yrs of experience in the Emergent Technologies and Creative Industry sectors across Europe and Asia and is currently leveraging his global network and expertise within the Australian context. Dr. Bitoria holds a PhD from the Delft University of Technology, The Netherlands, in Real-time interactive environments and a Master in Architecture in Emergent Technologies and Design from the prestigious Architectural Association, London, UK.*

*Dr. Bitoria firmly believes in digitally driven bottom-up methodologies for developing performance driven sustainable and energy efficient design solutions at variable scale. He has designed and implemented various inter-disciplinary education and research agendas in the areas of Smart Cities & Urban Informatics, Computational Design, Urban Health and Wellbeing, Social Robotics, and Real-time Interactive Environments. These interests are clubbed under his research and education umbrella 'S.M.A.R.T. Environments' - acronym for 'Systems and Materials in Architectural Research and Technology', which investigates the intricate relationships between information flow and associative material formations. Investigations under this research umbrella include: Smart and Liveable Cities, Interactive Architectural Systems, Interaction Models and Cognitive Systems, Material Systems, and Performative Architecture. He has lectured and published his inter-disciplinary research and design deductions at several prestigious institutes, in scientific journals, design and technology conferences, scientific books, and magazines globally. His latest book offering comes in the form of a five-year Springer book series on S.M.A.R.T. Environments.*

## ROD SIMPSON

### **Walking country: landscape and walkability as the basis for urbanity**

Roderick Simpson, the inaugural Environment Commissioner of the Greater Sydney Commission, will present on how and why starting with a consideration of landscape is both a necessity and an aspiration for the remaking, improvement and planning of cities.

‘Starting with landscape’ through an ethos of ‘caring for country’, consideration of the ‘blue and green grids’ and prioritising walkability is a true challenge for Western Sydney. Treating the West as an ‘urban lab’ to develop new and improved planning processes will also inform the remaking and improvement of the existing city.



*Roderick is an architect and urban designer, an Adjunct Professor in the Faculty of Design Architecture and Building at UTS after directing the masters of Urbanism and Urban Design Programs at the University of Sydney.*

*He has been an advocate of sustainable development since first winning equal first place in the international design competition for the Olympic Village for the 2000 games, and first place in a national housing design competition on behalf of Greenpeace in the early 1990s. Rod is a Member of the*

*Australian Institute of Architects, Australian Institute of Landscape Architects and the Planning Institute of Australia and a Trustee of Sydney Living Museums.*



## GREG KEEFFE

### Born and not made: designing the productive city

The city is changing: no longer is it an aesthetic creation, nor purely an industrial powerhouse. It is becoming a living, breathing super-organism, with a myriad of multiple, competing functions enabling the city to dwell within its particular ecology. As a super-organism, the future city will be defined more by its metabolism, than purely its primary function or spatial form. These biospheric flows of energy and materials will drive the new city and create new synergies for living.

In the future, we will need to see the city as the technology by which we live: not as a landscape full of technologies. The old city is a mechanical/cultural hybrid, the new city is different: it will be a geological/biological/informational/technical/cultural landscape, a productive environment so complete that it will be indistinguishable from nature. This smart city of the future will become as essential as a smart-phone: life without it is unimaginable, because we will need it in every aspect of life.

In order to be so complete and essential, its constituent parts: transport, industry, commerce, social functions etc, must fit within it and be seamless in use. Urban designers must view the city as a body or super-organism: a whole, rather than a collection of parts.

Process-based, this new city will be born and not made.



*Greg Keefe is an academic and urban designer with 25 years experience in sustainability, energy use and its impact on the design of built form and urban space . He currently is Professor of Architecture + Urbanism and Head of the School of Natural and Built Environment at Queen's University, Belfast UK.*

*Greg has extensive experience of working closely with architects and planners to develop exciting ways of re-invigorating the city through the application of innovative sustainable technologies, informing his work on the sustainable city as synergistic super-organism. In this way, he has sought to develop a series of theoretical hypotheses about our future existence on the planet, through a series of technological and spatial interventions. Most of his work comes out of a free-thinking open-ended discussion about how things should be.*

*He is author of the books 'Means Means Means' and 'Urban Evolutionary Morphology'; which develop a model of a new city, one that is a cyborg created out of mutually compatible, technological and biological functional elements.*

## CONTENTS

<b>foreword .....</b>	<b>iii</b>
<b>Steering Committee .....</b>	<b>iv</b>
<b>Scientific Board.....</b>	<b>iv</b>
<b>Organising Committee.....</b>	<b>iv</b>
<b>International Scientific Committee.....</b>	<b>v</b>
<b>Program.....</b>	<b>vi</b>
<b>Keynote Speakers .....</b>	<b>x</b>

## INCLUSIVITY

<b>A Model for Assessing the Social Impacts of Building Upgrades in China</b> Chenyang Li, Grace Ding, Goran Runeson.....	21
<b>The role of public participation in the future of Sydney Olympic Park as a sustainable place</b> Eveline Mussi, Christine Steinmetz, Catherine Evans, Linda Corkery.....	30
<b>Adaptation of “participatory method” in design “for/with/by” the poor community in Tam Thanh, Quang Nam, Vietnam</b> Nguyen Hanh Nguyen, Hung Thanh Dang.....	42
<b>Fifty years of inclusive transport building design research</b> John Harding .....	52
<b>Enabling smart participatory local government: preliminary findings</b> Tooran Alizadeh, Somwrita Sarkar , Sandy Burgoyne, Alex Elton-Pym, Robyn Dowling.....	62

## RESILIENT CITY

<b>The influence of landscape architecture on landscape construction health and safety</b> John Smallwood .....	78
<b>Towards a circular economy in the built environment: an integral design framework for circular building components</b> Anne Van Stijn, Vincent H. Gruis .....	87

<b>Resilient spatial planning for drought-flood coexistence (“DFC”): outlook towards smart cities</b>	
Nguyen Quoc Vinh, Tran Thi Van .....	104

<b>Analyzing the potential of land use transformation in the urban structuring and transformation axes in São Paulo: a case study in the Belenzinho neighbourhood</b>	
Rafael Barreto Castelo Da Cruz, Karin Regina De Castro Marins, Larrisa Santoro Dias Macedo ....	115

## URBANITY

<b>Evaluating factors influencing the uncontrolled growth of urban-rural belt – a case study of Delhi, India</b>	
Mukesh Ray, Sumita Ghosh, Sara Wilkinson .....	126

<b>Implementing a new human settlement theory: strategic planning for a network of circular economy innovation hubs</b>	
Steven Liaros .....	135

<b>Density and quality of life in Mashhad, Iran</b>	
Fereshteh Moradi, Rob Roggema .....	146

<b>The city-zen urban energy transition methodology – the Amsterdam roadmap towards a zero-carbon city</b>	
Andy van den Dobbelsteen, Siebe Broersma, Michiel Fremouw, Tess Blom, Jelle Sturkenboom, Craig Lee Martin .....	164

<b>Deep renovation in sustainable cities: zero energy, zero urban sprawl at zero costs in the ABRACADABRA strategy</b>	
Annarita Ferrante, Anastasia Fotopoulou, Lorna Dragonetti, Giovanni Semprini .....	177

## SMART CITIES

<b>Application of Fuzzy AHP for ranking and selection of innovation in infrastructure project management</b>	
Mohammadali Nokhtedan, Mohammad Reza Zare, Johnson Adafin, Suzanne Wilkinson, Mehdi Shahbazpour .....	188

<b>Smart city initiatives: a catalyst for meaningful collaboration</b>	
Homa Rahmat, Nancy Marshall, Christine Steinmetz, Miles Park, Christian Tietz, Kate Bishop, Susan Thompson, Linda Corkery .....	205

<b>A techno-economic analysis on applying smart distribution network for solar photovoltaic systems in educational buildings</b>	
Chengyang Liu, Rebecca Yang, Hongying Zhao .....	215



<b>A user-led approach to smart campus design at a university of technology</b>	
Alfred B. Ngowi, Bankole O. Awuzie .....	225

## URBAN ECOLOGY

<b>Australia's urban biodiversity: how is adaptive governance influencing land-use policy?</b>	
Hugh Stanford, Judy Bush .....	235

<b>Mapping the permeability of urban landscapes as stepping stones for forest migration</b>	
Qiyao Han, Greg Keeffe .....	248

<b>Potential of trees to mitigate climate change impacts in a railway corridor case study in Sydney</b>	
Sumita Ghosh, Ferdaus Khan .....	259

<b>Urban agricultural practices in the megacities of Dhaka and Mumbai</b>	
Tazy Sharmin Momtaz .....	268

<b>Contemporary urban biotopes: lessons learned from four recent European urban design plans</b>	
Martin Knuijt .....	276

## SPACE AND PLACE

<b>A multi-criteria decision analysis based framework to evaluate public space quality</b>	
Peijun He, Pieter Herthogs, Marco Cinelli, Ludovica Tomarchio, Bige Tunçer .....	286

<b>Factors influencing urban open space encroachment: the case of Bloemfontein, South Africa</b>	
Lindelwa Toba, Maléne Campbell .....	298

<b>A new model for place development – bringing together regenerative and placemaking processes</b>	
Dominique Hes, Cristina Hernandez-Santin, Lewis Lo .....	307

<b>Re-imagining urban leftover spaces</b>	
Jasim Azhar, Morten Gjerde, Brenda Vale .....	317

## ENERGY

### **The total cost of living in relation to energy efficiency upgrades in the Dutch, multi-residential building stock**

Thaleia Konstantinou, Tim de Jonge, Leo Oorschot, Sabira El Messlaki, Clarine van Oel, Thijs Asselbergs..... 328

### **Analysis of the Energy-saving in the Conference Center Atrium**

Y M (Jamin) Guan, Y M Sun, K X Xia..... 338

### **Sharing urban renewable energy generation systems as private energy commons**

Craig Burton, Seona Candy , Behzad Rismanchi..... 351

### **Identifying bottlenecks in the photovoltaic systems innovation ecosystem – an initial study**

Kristian Widén, Charlotta Winkler ..... 360

## COMFORT

### **Outdoor comfort in metro Manila: mitigating thermal stress in typical urban blocks by design**

Juanito Alipio A. De La Rosa ..... 369

### **Markov logic network based group activity recognition in smart building**

Hao Chen, Tae Wan Kim..... 379

### **Impacts of highly reflective building façade on the thermal and visual performance of one surrounding office building in Singapore**

Jianxiu Wen, Nyuk Hien Wong, Marcel Ignatius, Xinzhu Chen..... 387

### **A field study on occupants' comfort and cold stress in CLT school buildings**

Timothy O. Adekunle ..... 396

## GREEN BUILDING

### **Data management using computational building information modeling for building envelope retrofitting**

Taki Eddine Seghier, Mohd Hamdan Ahmad, Lim Yaik-Wah, Muhamad Farhin Harun ..... 408

### **Towards self-reliant development: capacity gap within the built environment of Mt. Elgon rural inhabitants**

Michiel Smits ..... 418

## **Mainstreaming *real* sustainability in architecture**

Luke Middleton ..... 434

## **Green buildings in australia: explaining the difference of drivers in commercial and residential sector**

Tayyab Ahmad, Ajibade A. Aibinu, André Stephan..... 446

## **CONSTRUCTION**

### **Challenges to the implementation of sustainable waste management practice in the construction industry**

Mandisi George, Eric Simpeh, John Smallwood ..... 457

### **Producing work-ready graduate for the construction industry**

Sadegh Aliakbarlou, Suzanne Wilkinson, Seosamh B. Costello, Hyounseung Jang, Hamid Aliakbarlou..... 469

### **Cradle to cradle building components via the cloud: a case study**

David Ness, Ki Kim, John Swift, Adam Jenkins, Ke Xing, Nick Roach..... 478

### **The impact of leadership on innovative culture in the construction industry**

Hossein Sadeghzadeh Fasaghandis, Suzanne Wilkinson, Johnson Adafi..... 488

## **PERFORMANCE**

### **Assessing the lighting performance of an innovative core sunlighting system**

Liliana O. Beltran ..... 509

### **Vertical light pipe potentiality for buildings in Surabaya, Indonesia**

Hanny Chandra Pratama, Yingsawad Chaiyakul ..... 518

### **Energy efficiency of a high-rise office building in the Mediterranean climate with the use of different envelope scenarios**

Soultana (Tanya) Saroglou, Isaac A. Meir, Theodoros Theodosiou..... 525

### **Impact of window effective opening area on thermal and energy performance of mixed-mode office buildings**

Fernanda Alves Pereira, Leticia De Oliveira Neves ..... 534





**INCLUSIVITY**



## A MODEL FOR ASSESSING THE SOCIAL IMPACTS OF BUILDING UPGRADES IN CHINA

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### Summary

Existing office buildings have been recognised as one of the largest energy consumers due to the relatively poor sustainable performance. However, the rate of increase of new buildings around the world is only 1%~2%, which means it will take a century to reduce the negative impacts of existing buildings on the environment. For this reason, the need to upgrade old buildings is urgent to improve not only the environmental and economic performance but also the social aspects. However, the social impacts of existing buildings have not got the attention that environmental and economic impacts have, leading to a lack of study of social impacts of existing buildings. This research aims at developing a framework to assess social aspects of existing office building upgrades in China using a polygon evaluation approach. The paper examines the literature and the social assessment guidelines of EN16309 and uses semi-structured interviews to develop social indicators that are applicable to China to assess the social performance of existing office building upgrade. The research shows that China is still at an early stage of building upgrade and the related social impact assessments are largely unavailable. Effort is needed to standardise and motivate the current market for upgrading buildings and results also indicate that social assessment models and methods are in high demand.

Keywords: building upgrade, social impact, polygon evaluation framework



## **1. Introduction**

The existing building stock attracts attention nowadays due to its relatively poor performance and its size. A considerable amount of materials, energy, water, and other natural resources are invested into the building sector annually, contributing to the generation of waste and greenhouse gas (GHG) emissions (Mikulić, Bakarić & Slijepčević 2016). The office building stock is one of the largest GHG emitters. This is due to the complex systems used in office buildings, including heating, ventilation and air-conditioning, lighting, security systems, etc. that require large amounts of energy and natural resources to maintain their normal functions. Besides, system failures in office buildings may result in the demand for extra energy and other resources during the operating stage (Juan, Gao & Wang 2010).

According to Wilkinson (2012a), most urban building stock in Australia was constructed without the consideration of sustainability. The situation is similar in China. The new building construction in China takes up about 50% of total construction in the world, but over 85% of these new buildings have not had sustainability consideration in their design and construction process (Hong 2009). Furthermore, approximately 95% of the existing buildings in China do not reach the national standard of energy conservation (Feng et al. 2014). For this reason, office buildings in China is one of the biggest potential retrofitting markets. Building upgrade, as a remedy for building obsolescence, is the key to achieving environmental, economic and social sustainability (Wilkinson 2012b). The past few decades have witnessed the rapid growth of sustainable building development, and the outcomes of environmental and economic aspects are quite impressive due to the emergence and development of environmental and economic assessment tools and relevant regulations. However, the importance of social impacts does not give sufficient attention, leading to the fact that the main obstacle to improve the sustainability of existing buildings is social and psychological (Santos et al. 2017; Zuo & Zhao 2014).

The research by Sharifi & Murayama (2013) shows that the percentage of mandatory social assessment indicators contained in the Building Research Establishment Environmental Assessment Method (BREEAM) is only 6 %, and it is not even included in the Leadership in Energy and Environmental Design for Neighbourhood Development (LEED-ND), which are two of the most popular green building tools. Due to the “soft” characteristics and complex relationships among different stakeholders, there is no consensus on the definition and content of social impact assessment (Dendena & Corsi 2015). Nevertheless, the benefits of social sustainability can be demonstrated in many ways that may add value to improve the performance of existing buildings in addition to environmental and economic performance (Samandar 2015). For this reason, it is essential to identify the social content of existing buildings. This research aims at developing a model to assess social impact of existing office buildings in China using a polygon evaluation approach. The paper begins with a literature review on social impacts and to identify the content of social impact assessments for existing office buildings. The polygon framework of social assessment is presented and followed by research design and a discussion of research findings.

## **2. Social Impact of Existing Buildings**

Social sustainability of construction activities has been getting more attention during recent decades (Zuo & Zhao 2014). However it is apparent that the social impacts have not received sufficient consideration around the world compared to environmental and economic aspects (Santos et al. 2017). In China, the rapid urban development and the lack of social study of construction projects have become the main obstacle of improving sustainability in the built environment (Yuan et al. 2018). Samandar (2015) stated that even though the importance of social sustainability is intangible, these benefits could be returned in many ways. For example, the study by Chau, Tse & Chung (2010) report that the social efforts on public education that the benefit gains of sustainability are mainly for themselves instead of environment can encourage the positive attitude and behaviour of occupants to pay more attention on energy efficiency measures

than other green building features. Therefore, it is essential to pursue the social sustainability of buildings.

The efficiency of social performance assessment should include an effective engagement of different stakeholders to increase understanding of change and capacities to respond to changes, and to help enhance the lives of vulnerable and disadvantaged people (Esteves, Franks & Vanclay 2012). The social context can be expressed as building user group dynamics, which is an integration of institutional norms, culture, and management (Watson et al. 2016). Vanclay (2003) introduced eight categories of social assessment under the international principle, which are way of life, people's culture, community, political systems, environment, health and well-being, as well as personal and property rights. It is obvious that the social assessment is human-centred. Mateus & Bragança (2011) stated that three social aspects should be included, which are occupants' health and comfort, accessibility, and education and awareness of sustainability. Based on that, Kyllili, Fokaides & Jimenez (2016) added another five aspects for complying with the context of building upgrade. They are cultural heritage, public access, public perception, functionality and occupational safety.

In 2014, the first comprehensive social sustainability assessment methods, EN 16309+A12014-12 Sustainability of construction works – Assessment of the social performance of buildings – Calculation methodology (BSI 2014), was established by the European Committee for Standardization (CEN). It provides requirements and methodology for assessing buildings' social performance (Orłowski, Radziejowska & Orłowski 2017). There are six main categories in EN 16309, which are (1) Accessibility; (2) Adaptability; (3) Health and comfort; (4) Impacts on the neighbourhood; (5) Maintenance and maintainability; and (6) Safety and security. However, this standard is designed for both new and existing buildings, resulting in the too broad a content.

There are assessment models or frameworks developed to capture the broad context of social impact in building. The polygon evaluation framework is one of them and this framework can be used to develop the social performance assessment of existing building upgrades in China due to its flexibility to contain as many indicators as needed. The polygon evaluation framework was originally developed as a response-inducing sustainability evaluation (RISE) for assessing the sustainability of farming operations by the Swiss College of Agriculture (Grenz et al. 2012). This evaluation framework provides an approach that allows a multi-dimensional assessment. The number of the polygon edges is decided by the number of assessment indicators. The lines between the centre point of the polygon and each vertex can be regarded as the rating axes. Based on the selected rating scale, the axes will be equally divided into several segments, and the direction from the centre point to each vertex means the better performance (centre point = poor performance; vertex = best performance). This framework has been developed for evaluating the results of a life cycle inventory (LCI) analysis for years, and the single index value provided facilitates a clear and objective comparison, which enables deeper evaluation of selected parameters (Georgakellos 2006). Besides, this evaluation approach allows a clear understanding of the strengths and weakness of the sustainability performance (Häni et al. 2007). Therefore, the multi-dimensional form of this evaluation framework can be used to assess different social concerns and analyse the relationship of different indicators by comparing the rating scores that each assessment indicator is assigned.

Based on the literature, it can be concluded that the building upgrade is a significant strategy to improve the sustainable performance of existing buildings, and social sustainability is one of the indispensable parts. To understand the social problems of existing buildings, the polygon evaluation approach is used to develop the assessment model for evaluating the social impacts of building upgrades due to its inherent flexible nature.

### **3. Research Methods**

Esteves, Franks & Vanclay (2012) stated that social impact assessment is an interdisciplinary social science, which needs not only the understanding of various core concepts like sociology and

anthropology, but also the understanding of how these concepts can be organised and analysed in an effective way. The first social assessment guidelines of EN 16309 are designed for both new and existing buildings at the global scale, so that not all of indicators are equally applicable for assessing the social content of building upgrades in China. To gain a better understanding of social impacts, the research design is using semi-structured interviews as a preliminary study to assess social impacts of building upgrades in the severe cold zone of China. The extreme weather condition in this climate zone— cool summers and severely cold winters – makes the building system different from the buildings in other climate zones (GB 50178-93). For example, the heating system is an essential facility for buildings in this climate zone. Besides, most cities in the severe cold zone are small cities which do not get enough attention compared to big cities like Beijing and Shanghai, leading to the performance of buildings in this temperature zone are relatively substandard. Inner Mongolia is the focus of the study and it is the biggest province in the severe cold zone situated in northern China.

The indicators to be incorporated in the social assessment framework are based on the EN 16309 and supplemented with semi-structured interviews to allow for region specific indicators. The semi-structured interviews were undertaken in January 2018 to two architects and four engineers. The participants work for design institutes that work on cases in the severe cold zone, and they are randomly selected within the institute. The interview questions include social concerns, social impacts of building upgrades and assessment methods of social impacts. The interviews were conducted at the office of participants and each interview was approximately 60 minutes. By analysing the transcripts of the interviews and combining the review of the literature, the understanding of the social content of building upgrades can be summarised as research findings shown in the following parts.

## **4. Research Findings**

### **4.1. The Social Concerns of Building Upgrades**

Interviewees were firstly asked to define what social impacts are in the context of China. However, they did not give a uniform definition of social impacts, but they reached the consensus that the social impacts of building upgrades cannot be considered as an independent factor. They believe that the social dimension covers a wide range of contents because some financial benefits and environmental benefits can be achieved if the social performance of buildings is improved. For this reason, the enhancement of social performance is the key to having the overall improvement of buildings' sustainability. The social concerns of building upgrades can be summarised as: the needs of different stakeholders; the relationship with the adjoining buildings; the interrelationship among stakeholders; the acceptance level of the upgraded building by the public; the impacts of upgrade activities; the artistic destruction of existing buildings; and the cultural heritage of buildings.

### **4.2. Drivers of Building Upgrades in China**

The interviewees consider technology advancement and government intervention are two main drivers of building upgrades in China. Building upgrade is preferred mainly because it is more costs and time effective compared to demolishing the existing building and constructing a new one. However, the complicated process and the involvement of different stakeholders tend to deter people from building upgrades. With the development of technology, some of these problems have been solved. There are two main ways – new materials and new technologies. For most existing buildings in China built before the year 2000, steel pipes are widely used. However, steel pipes rust, leading to leaks, and are difficult to replace. Nowadays, the steel pipes in old buildings are being replaced by PVC pipes. PVC is recognised as a safe material that has many benefits including low weight, no corrosion, fracture resistance, flame resistance and flexibility. As for new technologies, adding extra insulation on the outer side of walls for existing buildings

is widely applied in northern China. This method does not disturb the normal life of occupants but improves indoor thermal performance. For this reason, with the development of technology, the new and advanced methods and materials can improve the feasibility of building upgrades by reducing the complexity and the cost of construction.

Another main driver is the support from the government. Sustainable building upgrade is still at an early stage in China. Due to the complex process, the building upgrade is usually not the first choice by investors and developers. In this case, related government regulations and policies become extremely significant to motivate building upgrades. In China, some building upgrade-related laws, government regulations, and policies have been released to encourage and standardise building upgrades since 2015. However these laws, regulations and policies do not work as expected due to lack of financial support (Li et al. 2017). For this reason, transferring social values to economic values via the government's support is the key to building upgrades. Related laws, regulations and policies can offer the standard and direction for the sustainable building upgrade development, and the financial support cannot only assist the realisation of building upgrades, but also provide the stimulus for building upgrades. It is a trend to develop building upgrade as a standardised product, so that the government support becomes the major motivation of implementing building upgrades.

The understanding why technology and government supports are main drivers and what their limitations are is essential to identify the social problems of building upgrades. The improved social context can be used to solve these problems, like the lack of financial support; then it is expected to assist these drivers in effectively promoting the development of sustainable building upgrades.

#### **4.3. Evaluation of Social Impacts of Building Upgrades**

The development of social indicators for the assessment of building upgrades in China was developed according to the EN 16309 guideline and supplemented by the research findings from the interviews. As discussed previously EN 16309 has been developed for both new and existing buildings. Therefore, when developing a social assessment framework for China, only those indicators that are applicable to existing buildings are selected. As the EN16309 is developed for an international perspective, therefore the social assessment framework has been supplemented from outcomes of the interviews and new indicators are added to suit the situations in China. New indicators include the harmonisation of building exterior with neighbourhoods and the preservation of cultural heritage.

In the research, the polygon evaluation framework is used to assess social impacts. By combining the indicators from the EN16309 and interviews, the indicators for the social impacts of building upgrades in the severe cold zone in China is presented in Table 1. The social assessment framework includes seven categories and a total of nineteen indicators. The seven categories may have different level of importance to stakeholders. Therefore, it is important to develop weighting to reflect the level of importance for each category. The Analytic Hierarchy Process (AHP) method is used to develop the weight of each indicator to a total of 10. Each indicator is rated using a five-point Likert scale (1 = very poor; 5 = excellent). The rating score of indicators in each category are averaged and multiplied with the weight respectively to get the final assessment score. The final step is to use the polygon diagram to show the assessment result as illustrated in Figure 1. To more clearly demonstrate the assessment method, an example is given shown in Table 1 and Figure 1. The given rating scores and weights are randomly assigned based on a five-point Likert scale and the 10-total-weighting score respectively.

Table 1. Assessment indicators of social performance assessment for existing buildings

Category	Assessment indicator	Rating score					Average score	Weight	Final score
		1	2	3	4	5			
Accessibility	Access to building facilities			✓			3.33	1.5	5.00
	Access to building services			✓					
	Access to building facilities and services for people with additional needs				✓				
Adaptability	Building's ability to accommodate users' requirement		✓				2.50	0.3	0.75
	Building's ability to accommodate changes			✓					
Health and comfort	Thermal comfort				✓		3.50	2.6	9.10
	Visual comfort			✓					
	Acoustic comfort			✓					
	Indoor air quality				✓				
Safety and security	Resistance to accidental actions					✓	4.50	2.7	12.15
	Personal safety and security against intruders and vandalism				✓				
Impact on the neighbourhood	Noise impact			✓			4.00	0.9	3.60
	Emission to outdoor air, water and soil				✓				
	Impact from glare/overshadowing					✓			
	Harmonisation of building exterior with neighbourhood				✓				
Maintenance and maintainability	Health and comfort impacts for the users during building upgrades		✓				2.00	1.7	3.40
	Safety for users during building upgrades			✓					
	The usability of the building while upgrade tasks are being carried out		✓						
Cultural value	The usability of the building while upgrade tasks are being carried out		✓				2.00	0.3	0.60
Total								10.0	34.60



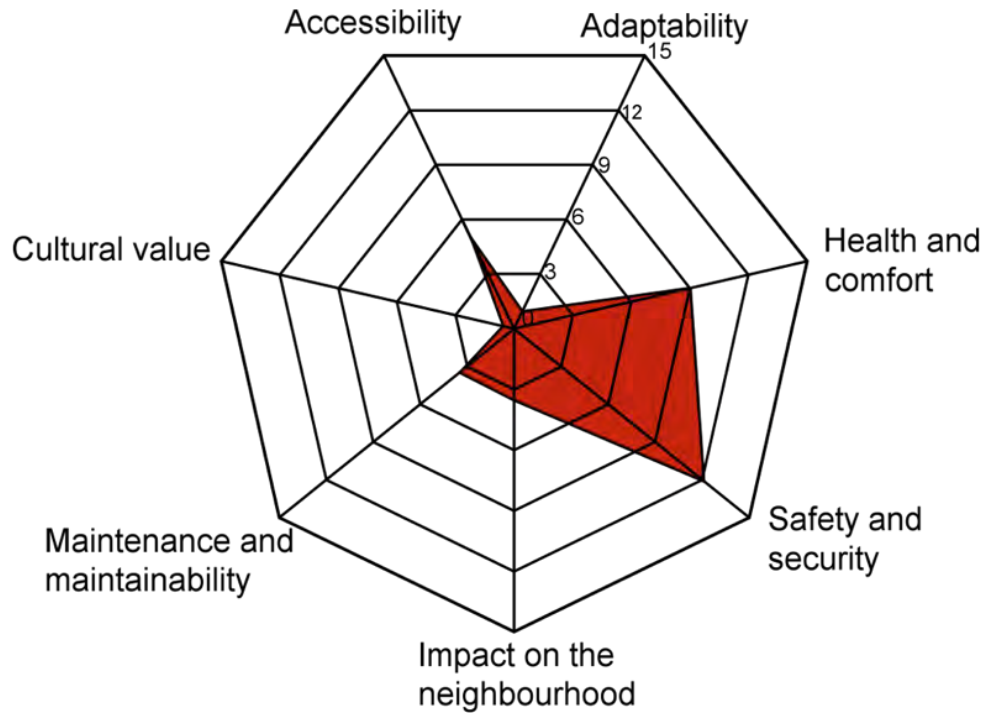


Figure 1 The polygon evaluation framework for social performance assessment of existing buildings

## 5. Discussion and Conclusion

Social impact assessment of existing building upgrading is indispensable for improving buildings' performance. It is a complicated process to identify the different factors involved, so it cannot be simply judged as sound or weak. Due to the increasing number of building upgrades in China, the social impact assessment for existing buildings are urgently needed, and more comprehensive social assessment models are desired. Even though this study is a preliminary study, it is still helpful to understand the current situation of building upgrades in China and provide some background information for further research.

As a result, this research identifies the general assessment indicators for social performance evaluation of building upgrades in China, and the polygon evaluation approach is used to develop an assessment model for assessing and diagnosing the social problems of the assessed building. However, this study will not be limited to this stage. With the consideration of the specific situation of different cases, other indicators may be added which makes the evaluation framework more flexible. In other words, the research provides a basis for social performance assessment indicators and evaluation method. Based on it, other potentials and development for further study can be realised.

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# THE ROLE OF PUBLIC PARTICIPATION IN THE FUTURE OF SYDNEY OLYMPIC PARK AS A SUSTAINABLE PLACE

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## Summary

Since the 1980s, plans for Sydney Olympic Park (SOP) have been underway to transform the heavily contaminated brownfield site of Homebush Bay into a thriving urban precinct of residential neighbourhoods, business districts and a regional parklands. This transformation has been underpinned by Environmentally Sustainable Development (ESD) principles, as established by Sydney Olympic organisers in the bid for the 2000 Olympic Games. The Sydney Olympic Park Master Plan 2030 envisions 23,500 residents and a doubling of office spaces, responding to state goals for the growth of Western Sydney region. Such population growth challenges SOP's management to remain loyal to sustainable development, maintaining a 'local' level of engagement and participation with residents and balancing competing interests from businesses who view themselves as integral stakeholders in SOP. The importance of public participation to sustainable development and contemporary challenges to its application, especially in public-private mega-projects, is the focus of this paper. The paper will discuss findings from a PhD which investigated the social sustainability of SOP and how public participation has been considered and implemented in the process of developing SOP, post-Games. Findings emerged from an analysis of SOP-specific planning documents, in-depth interviews with experts who have been or are working on the development of SOP and focus groups with residents living in the neighbouring communities of Newington and Wentworth Point. The paper will first set out the problem of Olympic parks and establish the definition of sustainable development as a social problem, thus bringing attention to the importance of public participation. It briefly introduces the methodology used, the context of SOP and presents the findings, unpacking the reality of public participation in the post-Games development of SOP and how it has been perceived by experts and residents. Findings reveal a 'watered down' approach to social participation strategies, as perceived by residents, despite the increasing importance of social participation in state and local planning instruments. Some of the barriers in applying strategies for social participation are discussed by experts in relation to difficulties in defining local communities, especially in a project of regional importance and the limited legal responsibility of the Sydney Olympic Park Authority for communities around its boundaries. This is taking a toll on how residents engage with SOP and how they connect to an ethos of shared values for sustainability. Novel approaches to social engagement with residents living within and around SOP's boundaries will be critical to the ongoing management of SOP as an icon of sustainability, especially with the expected population growth.

**Keywords:** Sustainable development, social sustainability, public participation, Olympic parks, Olympic legacy, mega-projects.

## **1. Literature Review**

### **1.1. Sustainable Olympic parks**

Often referred to as “white elephants”, Olympic parks can be problematic mega-projects for host cities. In *The Olympic Cities* (2013), Jon Pack and Gary Hustwit document a pattern of underutilised or abandoned large urban spaces as defining characteristics of the Olympic legacy, with key examples including empty public spaces among impressive architectural structures such as Beijing’s green Olympic park and the deteriorated aquatic centre at the OAKA site from the Athens 2004 Olympics. The combination of mega-sized architectural projects, onerous costs and the underutilisation of these large infrastructures post-Games suggests that Olympic parks are unsustainable mega-projects.

Given this recurring problem and with the increasing concerns for sustainability and legacy, Olympic parks have been rebranded by host cities and the International Olympic Committee as sustainable urban-regeneration mega-projects. Sydney Olympic Park, developed for the 2000 Olympic Games, set the benchmark, planned as an environmentally sustainable site, to become a thriving urban centre, long-term. The IOC later directed that Olympic parks should become “accommodation, entertainment and tourism districts”, with “new housing, retail and leisure outlets, and extensive sport, recreation, transport and other infrastructure developments” (IOC 2012, p. 88). However, despite promising discourses, problems with sustainability and legacy of Olympic infrastructure persist (Gold and Gold 2011).

The key to a successful legacy of Olympic parks, according to Shirai (2009, p. 4), “lies in the long-term relationship between the Olympic Park, as a distinct economic and political entity, and its very different pre-existing surrounding neighbourhood.” As with other contemporary mega-projects that have proliferated around the world, Olympic parks are developed and managed to attract investment, tourism, and new populations that can afford their attractions (Lehrer & Laidley 2008). This pattern reflects urban entrepreneurial strategies that emerged in the 1980s in response to the increasing influence of private corporate power in urban development (Harvey 1989) and corresponding changes to cultural planning strategies in redefining cities’ landscapes towards international competitiveness (Friedmann 1986). Such mega-projects have a tendency of becoming “Machiavellian formulas” of unattained promises (Flyvbjerg 2005), while spaces are created to the exclusion of local communities, with the undesirable consequence of lacking a vibrant urban life (Woodcraft et al. 2011). Shirai (2009) proposes physical and programmatic attributes, such as better access and social activities, to integrate Olympic parks to their urban context. However, the extent to which Olympic parks, post-Games, are sustainable places and how management considers local voices and needs through public participation strategies, remains an issue.

### **1.2. Sustainable development as a social problem**

Public participation has been a recurring theme in the sustainable development debate, especially under the umbrella of social sustainability. The widely accepted definition of sustainable development announced in 1987 by The Brundtland Commission, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987, p. 43), has been criticized as problematic (Lélé 1991; Jacobs 1999; Fergus & Rowney 2005; Shiva 2012). While its breadth might allow irreconcilable positions to find common ground, it also leaves the concept vulnerable to opportunistic interpretations and the perpetuation of unsustainable practices (Lélé 1991; Jacobs 1999), particularly in the built environment (Krueger & Gibbs 2007). Fergus and Rowney (2005) suggest that the unchallenged economic-scientific rationalistic framework through which the term has been defined leaves little space for diverse perspectives, perpetuating the unsustainable condition of contemporary global society (Basiago 1999; Adams 2006). As Keough (2008) concludes:



[Sustainable development] has been handicapped from birth by its association with “sustained yield resource management” and the international development paradigm, whose practice and philosophy have been eloquently and passionately critiqued (Keough 2008, p. 65).

Thus, because of the narrow interpretation, and despite the widely adopted environmental initiatives, sustainable development has failed to mitigate the deepening global environmental, economic and social crisis (Shiva 2012). An alternative proposition suggests a social interpretation to the sustainable development challenge (Stefanovic 2000; Littig & Grießler 2005; Keough 2008; Vallance et al. 2011) viewing sustainable development as “socio-scientific subject matter, not just a question of natural sciences” (Littig & Grießler 2005, p. 69). From this perspective, achieving sustainable development requires public involvement to promote open debate and inclusion of different views. It is in this sense that public participation gains importance as a strategy for sustainability (Fergus and Rowney 2005; Keough 2008).

### **1.3. The importance of public participation for sustainable urban development**

Public participation, as a collaborative process, brings together experts’ and communities’ knowledge in order to develop places that are inclusive, diverse and vibrant. While the application of strategies for public participation in sustainable urban development has been questionable, especially in the context of mega-projects for the Olympic Games, in theory, the importance of public participation is emphasized to promote the design of vibrant places for people, local wellbeing (Woodcraft 2011), and even a city’s prosperity (UN-Habitat 2016).

The campaign for the development of cities for people has a long history. For instance, Jane Jacobs (1961) discussed and actively campaigned against the negative impacts of massive urban redevelopment and top-down urban planning on community life and wellbeing. Jan Gehl (1971) talks about “life between buildings”, as he argues that it is of greater importance to discuss the social rather than the spatial, given that it is life which must define the physical quality of public spaces. Carr et al. (1992) suggested that the emphasis given by built environment professionals on the physical attributes of spaces often results in a “simplistic, deterministic conception of the functioning of public places, one that has turned out to be limiting in many respects” (1992, p. 85). Hester (2006) proposed processes of ecological democracy, which would result in very different urban forms from the current emphasis “in extravagant architecture”; there would be a renewed “search for roots, foundations, and fundamentals--the basics of satisfying life” (Hester 2006, p. 7). What is evident from these perspectives is the common theme that vibrant and authentic public spaces depend on understanding the local environmental-social context, the activities taking place, and local values, alongside strategies such as immersion, observation and public participation.

However, public participation remains largely problematic, especially in the context of public-private partnerships for urban regeneration (i.e. Olympic parks). Research reports that, even the more in-depth process of public participation runs the risk of being co-opted by private stakeholders in ways that conveniently legitimises public involvement, while not necessarily accounting for participants’ views, especially if challenging the established urban agenda (Kaethler et al. 2017). The conflict between recognition and resistance to implementing appropriate approaches to public participation asks for an examination of how approaches are perceived to result in vibrant, meaningful and sustainable places.

## **2. Research method**

As case study research, this paper draws from a PhD study which investigated the social sustainability of Olympic parks, using SOP as an in-depth case-study. Through the in-depth case-study method, it was possible to investigate the views and experiences of different stakeholders involved with SOP, particularly the views of residents and experts responsible for its development. SOP is an ideal case study for examining issues relating to social sustainability of mega projects

following key criteria. First, SOP was developed in response to ESD principles, introduced in the documents for the 2000 Olympic bid and crystallised post-Games in the *Sydney Olympic Park Authority Act* (NSW 2001). Second, it has been over well over fifteen years since the 2000 Olympic Games, and, as Furrer (2002) argues, it can take at least a decade for an Olympic site to achieve its legacy intentions. Third, SOP is an active urban space. Annual reports from the Sydney Olympic Park Authority (SOPA) show that SOP is attracting an increasing number of visitors annually and generating greater interest in the area as a site of commercial and business development. A recent PricewaterhouseCoopers report states the economic attractiveness of SOP, ranked twentieth in the local economies in Australia (Wade 2014). Thomas Bach, president of the IOC, referred to it as a benchmark for other Olympic cities (SOPA 2015). Despite official reports, there have been persisting criticism of SOP as an underutilised space (Irvine 2012). Given such legacy reports, external conflicting perceptions, and sustainability ideals, SOP is a best case-scenario to investigate if and how local residents are engaging and participate with its planning and development.

The study of SOP was based on a social sustainability framework revolving around three principles: local empowerment, identity and community. Public participation is a key strategy for local empowerment. The analysis of public participation in the development of SOP involved a triangulation of qualitative methods, to validate the information interpreted from the different sources. First, the research relied on the analysis of planning instruments, official publications and newspaper articles, extracting terms and narratives that pointed to processes of public involvement. The analysis of documents also informed the guide for in-depth interviews with twelve experts who were or have been working in the development of SOP, including planners, managers and members of SOPA's Board of Directors. Finally, five focus groups were conducted with the residents of the local residential communities adjacent to SOP, Newington and Wentworth Point, to explore the reality of public participation from the perspective and experiences of these local communities. The triangulation of data, and more significantly the data collected from local residents, validated or questioned the approaches proposed in documents and applied by SOPA in the development of SOP as a sustainable place. Newington and Wentworth Point were selected because of their proximity to SOP, longer-term development, and managerial considerations by SOPA. At the time of the research, residents living within the boundaries of SOPA only just moved in, and therefore were not present long enough to experience different processes, changes and current approaches to public involvement. The data collected were transcribed and analysed using NVivo qualitative data analysis software.

### **3. Background to Sydney Olympic Park (SOP)**

SOP is envisioned, in state planning instruments, as a specialised precinct, set to become “a major location for employment and high-density housing while remaining a major sports and entertainment centre” (NSW Government 2014, p. 23). *Sydney Olympic Park 2030 Master Plan* (MP2030) responds to the metropolitan vision, projecting that the 760 hectares of the park, including the 460 hectares of the Millennium Parklands conservation area, will become a “vibrant and sustainable township” with 14,000 residents, 31,500 workers and 5000 students, remaining a major events space (SOPA 2010, p. 22). This vision for SOP, former Homebush Bay, has been evolving long before the 2000 Olympics, as part of state planning strategies for Sydney's competitiveness as a global city (Waitt 2003).

Homebush Bay was a large, mostly state-owned, industrial site, which included factories, brickfields and abattoirs. With the closing down of industries, Homebush became a dumping ground for residential waste and, more critically, harmful chemical waste from neighbouring industries. As a vacant, large, state-owned site, it became the ideal location for an Olympic park, to direct Sydney's expansion towards its Western suburbs through the development of urban infrastructure and rebranding of a long stigmatized area. Since the late 1970s, a number of NSW state level planning schemes and policies for Homebush Bay, reflected global entrepreneurial aspirations and relied to various degrees on privatisation and urban aesthetic improvements, including environmental remediation (Freestone & Gibson 2006; Hu 2012). These planning

proposals envisioned the removal of most of the previous and obsolete industrial activities, adding new sports, recreation and entertainment facilities, business and technology, housing, and extensive areas of urban parklands. The *Sydney Regional Environmental Plan No. 24: Homebush Bay* (SREP 24), gazetted in 1989, solidified these visions and new public-private state government institutions were established to deliver the state vision for the site. In 1991, the Sydney Olympics 2000 Bid Limited (SOBL) was formed to prepare the documents for the 2000 Olympic Games bid (Cashman 2011). SOBL was constituted of influential figures from the private and public sectors (McGeoch 1994), who worked closely with the Homebush Bay Development Corporation (HBDC), established in 1992 as part of a new centralised public-private planning system.

In a pre-bid design competition for the Olympic Village, one of the winning entries by Greenpeace-allied architects proposed a sustainable Olympic village. This shifted the theme of the Sydney bid to the “Green Games”, including an innovative *Environmental Guidelines for the Summer Olympic Games* (1993), proposed by Greenpeace in collaboration with the NSW Government and SOBL. Despite the promises for sustainability, the alliance of Greenpeace with the government and private organisations was criticised for potentially conditioning the use of sustainable development to intrinsic political-economic interests (Beder 1999). After being awarded the Games, the Olympic Coordination Authority (OCA) was established to develop the infrastructure for the Olympics. Accountable to the Minister for the Olympic, this centralised governance system persisted after the games with the OCA replaced by the Sydney Olympic Park Authority (SOPA), a state development corporation committed to the management of SOP as a technology centre for global Sydney.

SOP is now a growing, active urban area, catering for almost 5500 large events each year and a daily working population of more than 19,000 people. Such population growth and new urban functions led to the recognition of SOP as a new suburb in 2009. In 2012, SOP's first residents moved into the newly opened Australia Towers, adding a permanent population of over 600 to the site. The site is also surrounded by other residential areas such as Carter Street, Wentworth Point, and Newington, the former Olympic Village. Wentworth Point and Carter Street are designated by the New South Wales Planning Department as Urban Activation Precincts (UAP), high-density residential and commercial priority growth areas. The development of SOP as a specialised centre, to accommodate a total of 23,500 residents and a doubling of office space, bordering other high-density residential areas, challenges the management of SOP as an events precinct and its ideological commitment to sustainable development, adding pressure to the importance of public participation and engagement with SOP.

## **4. Findings: The *who* and *how* of public participation**

### **4.1. Expert's view**

Expert's views of sustainability, social sustainability, and the principle of public participation are usually directed by official policies and documents. Overall, policies refer to the Brundtland Commission's interpretation of sustainability, as specified in the literature. However, there is very limited explicit reference to the concept of social sustainability.

Consequently, a series of in-depth interviews with SOPA's executive of major projects, member of the board of directors, and management staff, revealed an uneven understanding of social sustainability, despite the common reference to the Brundtland interpretation of sustainability, as well as the three pillar model: “it needs to be environmental, economic and social, otherwise it doesn't work”, as referred Peter Duncan, Director of Estate Management for the OCA). For some participants, social sustainability is linked to the presence of diverse communities at SOP. For others, it is about promoting the environmental values of SOP. Others assert that limited public participation implied that “the social component was almost not considered at all” during the phase of developing SOP for the Olympic Games, as states Sue Holliday, director general of the

NSW Planning Department between 1997 and 2003, firmly linking social sustainability to public participation.

Despite the conceptual issues around social sustainability, public participation has been referred in planning policies as a guiding principle to support the sustainability agenda, specifically in the 1993 *Environmental Guidelines*. In 2008, public participation was to some extent reinforced and complemented in the revision of the *Guidelines*. However, differently from the original version, public participation was not directly stated as a planning strategy. The revised 2008 *Guidelines* use terms such as “community involvement” with the local identity or “participation” in different activities to encourage an appreciation for the place (SOPA 2008, p.10). In terms of planning strategy, there is indirect reference to public participation by highlighting the importance of responsive governance to local community’s needs:

*[SOPA] will promote a sustainable place to support the changing business, event, visitation, worker and resident needs of the precinct in the future (SOPA 2008, p. 11).*

Paramount to responding to changing social needs is to define strategies for communication and participation. However, the 2008 *Guidelines* offered limited specifications in that regard, other than “involvement”, “responsiveness”, and broadly referring to the different users of SOP, as in the above quote. Therefore, the ‘who’ and ‘how’ of responsive governance and public participation is left to experts’ scrutiny. However, one of the apparent issues that emerged from interviews with experts is the lack of clarity regarding *who* are the communities to whom SOPA must be responsive, and *how* should public participation happen.

In Craig Bagley’s planning capacity as executive manager of Major Projects at SOPA, the ‘who’ of public participation relates to those within SOP’s boundary. However, as he further discussed, there is also “a huge growing population around us and we know that they all see this more like their backyard than a regional open space”, making specific reference to the green areas of the Millennium Parklands. There is, therefore, a conflict with managing SOP in response to the growing number of residents around its boundaries, particularly regarding the appropriate environmental management of the parklands. A communications strategist for SOPA adds that it is not only about how communities outside SOP’s boundaries use the site, but also how SOP’s activities influence the communities around it. As explained, because the influence of SOP’s activities reach beyond its boundaries, “I view the residents inside SOP in the same light as the residents on our boundaries” (Interviewee 2, 2014, pers. comm.). There is an uneven but general view that residential communities adjacent to SOP’s boundaries affect and are affected by the places and activities at SOP, conflicting with SOPA’s official responsibility for the area within SOP’s boundaries.

The lack of clarity regarding who SOPA must include in managing SOP as a sustainable place has affected approaches to participation. Bagley (2013, pers. comm.) explained that in the first few years post-Games, public participation strategies were not considered because “there was no community”; community would arrive during the lifetime of the plan. However, there was already a growing community living in the surrounding areas. Up until 2012, the large majority of SOP’s population, meaning those within its boundaries, consisted of growing businesses and its employees. And, as Bagley (2013, pers. comm.) pointed out: “We [at SOPA] have done quite well with the business community and the workers”. SOPA has put the effort to participate in the meetings of the Sydney Olympic Park Business Association (SOPBA), and to have representatives present in SOPA’s planning meetings, as experts explained. David Baffsky, who has been on the board of SOPA since 2009, explained that the re-assessment of SOP’s master plan was largely based on consulting local businesses and understanding their needs and challenges in operating at SOP. Baffsky further commented that there are also differences in how SOPA responds to the needs of different businesses: “Each business is different ... different size, different priority ... different level of involvement and capacity, but that’s not unnatural” (2014, pers. comm.). As businesses can often be an anchor for urban precincts, priorities of the area could largely be



influenced by businesses themselves and not the residents. Richard Cashman, professor at the University of Technology Sydney and founding director of the Centre for Olympic Studies in 1996, also noted that business stakeholders have been the “louder voice” in the planning process of SOP; “they are an important group, because they bring money to the park, and they also bring people” (2013, pers. comm.). Not uncommon, the reality of ‘voice’ within a community can become the issue of contention often overtaking the real priority of the SOP— sustainable values for an entire community.

There is, nonetheless, an effort from SOPA to inform communities around its borders about events and activities at SOP, particularly as it helps to create a harmonious relationship with SOP as an events precinct. The intent to keep local communities informed is for “setting expectation around what this park needs to do, because, at the end of the day, the park was created for major events” (Interviewee 2, 2014, pers. comm.). In addition, those informative tools are also about “building relationships, so that open communication can happen, and we can tell people what we’re doing, what we’re thinking, what we’re planning” (Interviewee 2, 2014, pers. comm.). While such an informative strategy is potentially positive and ensures that residents are accustomed to the nature of SOP as an events’ space, it does not facilitate responsive management to local needs. Plans for SOP’s development and how SOP is managed as a sustainable place does not involve the participation of local stakeholders beyond its borders, particularly local residents. This approach to participation reflects a corporate view to place management, based on responsiveness to businesses rather than the broader community. Conclusively, James Weirick, professor of landscape architecture at the University of New South Wales and a critical voice of the Olympic Games, remarked that SOP is evolving as a “successful business park” (2013, pers. comm.), rather than a urban precinct with daily local activities, vibrant and promoting sustainable values locally.

#### **4.2. Local residents’ view**

In five focus group discussions, thirty-seven residents from Newington and Wentworth Point shared their perceptions about the type of communication and engagement they have with SOPA, acknowledging its effect on how local residents’ use the park and, importantly, on how they connect, identify and respect SOP’s sustainability values.

First, while social sustainability is also an unclear concept among residents, it became evident in the group discussions that the presence of community and shared values for place are elements that support quality of life. Community and value are aspects that emerge from daily experiences and perceptions of the local natural and built environment, services, activities and informal socialization. Governance strategies to promote local engagement and responsibility for place have a significant role to play in promoting community, shared values and, therefore, social sustainability, as evident through the group discussion.

Participants talked about two types of engagement approaches implemented by SOPA. One approach focuses on providing information to residents, through flyers and notes on local newsletter, about management matters such as the events program, road closures and other temporary changes in the area. In general, participants shared a positive view about being kept up-to-date about potential traffic issues in their area. This allowed residents to “plan ahead” (Resident 1, N2) or “work around” (Resident 2, WP2) these changes in their daily routines. As intended, informing adjacent and local communities of events and management issues helps create a harmonious relationship between the reality of SOP as an events place and the everyday routine of people living around it. SOPA’s efforts to inform residents about events and programs at SOP also encourages local use of the facilities and offerings of the park, while promoting the presence of residents from adjacent communities.

While participants talked positively about these communication strategies, they also remarked that there is a diminishing frequency of communication from SOPA over time. A participant from Wentworth Point explained: “you would get a letter drop once a month. They used to open the



tennis; they used to advertise the music, the movie. You used to get a flyer on your letter drop quite regularly” (Resident 6, WP1). Another added: “I haven’t seen that for years. Before, they were very, very keen to advertise what they were doing” (Resident 3, WP1). Others agreed that efforts from SOPA in engaging with residents were better in the early post-Games years. The discontinuation of SOPA’s engagement strategies is perceived as a disinterest towards local communities, viewed as a loss to both SOP and local residents. As a participant from Wentworth Point commented: “I think they are doing their businesses a disservice by not actively promoting to us out here” (Resident 3, WP2). Another participant from Newington also said: “I don’t think they [SOPA] are sufficiently proactive with us, and perhaps they should be more engaging” (Resident 2, N3). From the residents’ point of view, maintaining communication with local residents promotes local engagement, their presence at the site, greater use of local businesses and, consequently, better activation of SOP’s urban precinct. Potentially, the limited presence of these local communities in the park has consequences to the everyday diversity and vibrancy of SOP’s public urban space, and the external view that SOP lacks vibrancy and social life (Irvine 2012).

Participants also spoke to SOPA’s limited efforts to inform residents about planning schemes and the future development of the area. As a resident from Newington explained, “[SOPA] never tells us what they are doing ... what they are going to do in development” (Resident 2, N3). Similarly, Wentworth participants stated: “I don’t know how we become aware of future plans and changes (Resident 2, WP1). The limited communication regarding planning matters, and therefore the lack of awareness about future development, was identified as unfavorable to promoting a sense of security regarding residents’ expectations and aspirations for the area they live. Another resident from Wentworth Point continued:

*When we went to a meeting, when we first came here, we only knew about this section here being developed. And now they’ve told us they are going to be developing another section across this side as well (R5, WP1).*

The development site the resident is referring to, located in front of Wentworth Point and within SOPA’s boundary, was not part of the initial plans for the development of the area. The initial plan was to maintain the site as part of the Millennium Parklands. As other participants agreed, this presents a conflict with what they expect for the area, as it imposes greater number of people and more density in a site reserved for environmental conservation. This also indicates that the new plans are not only not communicated, but, more importantly, they are not based on initial consultation and understanding of contextual information on how residents identify with the place they invested and live in—for them, it is about quality of life.

#### **4.3. Loss of the sustainability identity**

The limited engagement of local residents with SOP is having an impact particularly on their association with the sustainability identity of the area. This is evident by the striking differences on how participants from Newington and Wentworth Point talked about sustainability. Identity with sustainability is associated with the community areas, and not the SOP.

At Wentworth Point, most participants commented that, while they feel a strong sense of community within the residential area, especially as it has been promoted by developers through different strategies, “sustainability was not influential in our decision” to move into the area (Resident 1, WP1). A review of real estate marketing campaigns and design plans makes evident that the site is not being developed based on sustainability principles. Wentworth is characterised by high-rise apartment buildings on a waterfront setting, with small and few community areas, rather showcasing an usual upper-market waterfront development character. The local physical qualities, together with lack of marketing strategies by developers to promote the area’s sustainability, and the weak engagement of residents with SOPA, potentially explains the limited shared identity of residents of Wentworth Point with the sustainability values of the broader area.

In contrast, Newington was the former Olympic Village for the Sydney Games; essentially, the original project through which principles of sustainability became integral to the Green Games. Sustainability was “the ethos of creating this suburb”, a participant noted (Resident 4, N2). An ethos of a sustainable community both in natural and built form was at the heart of the residential design brief. Other participants shared an appreciation for how the physical attributes of Newington reflected principles for sustainable development; for example, the “blend of the natural environment”, referring to the integration of the site with the Parklands vegetation and local topography, “as well as the sustainable environment” (Resident 8, N1), referring to the extensive use of solar panels throughout the area and an integrated water-management system. For many, sustainability was, by large, a determinant in their decision to live in Newington:

*I was drawn here because it was a sustainable house, and I felt this was one unique—at that stage—chance to move into a village that stood for sustainability. That was the thing that attracted me most (Resident 1, N2).*

Many of the long-term residents in Newington who moved into the suburb, aware of its sustainability ethos, discussed this as a strong reason for moving there. However, at the same time, the group of longer-term residents also discussed that the local shared identity for sustainability is weakening through time. As remarked, “I think if you called this a green suburb now people might laugh at you” (Resident 1, N3). The noted diminishing interest for sustainability among Newington residents was discussed in relation to changes in residents’ behaviour, with less care for the green infrastructure of their units and the physical attributes of Newington as an environmentally sustainable place. For some, this is also having an impact on a shared sense of care for the place, and therefore a sense of community.

The deteriorating shared values for sustainability in Newington was also discussed in relation to the management arrangements in Newington, organised around five precinct committees constituted of volunteering residents. Committees lack authority and expertise to impose established regulations among residents and other stakeholders (i.e. real estate agents). Residents are very concerned that the shared value for sustainability in Newington has become watered down through time. Therefore, governance strategies ensuring residents’ engagement and participation with the place’s values long-term is having an impact on the area’s sustainability, environmentally and socially.

It is possible to highlight that social sustainability for residents, means that in their daily practice of living and experiencing the natural and built surrounds of the area they live, individually and as a community, they would have a more intimate relationship between their lived experience physically and eventually, develop some level, or inkling of a sense of stewardship towards the overall place, both environmentally and socially. Something that is only possible if one is living and doing and being in place. Therefore, strategies for participation and engagement need go beyond informing or just merely engagement, but also tapping into residents’ experiences, values and expectations.

Importantly, in the case of Newington and Wentworth Point, the shared identity for sustainability, or lack thereof, is not associated with the SOP. Besides management issues within the residential area, this problem is potentially due to residents’ limited engagement and participation with SOP’s spaces, activities and limited voice towards the future development of the area.

#### **4.4. Discussion and conclusion**

The analysis of SOP shows that the long-term vision of SOP becoming a feature of the global city—enhanced competitiveness to attract investment and capital—has framed approaches to sustainability. This directed the more usual focus on principles for resource management, including the extensive use of solar power, water catchment system, among other technical measures to mitigate environmental impacts. Sustainability did not imply changes to that global vision and related entrepreneurial strategies. In this context, social sustainability remains a less

clear dimension of sustainable development, and public participation strategies are, to some extent, aligned to the main corporate agenda.

Public participation is supporting the development of SOP in response, primarily, to the needs of its local businesses. While this is anchoring the long-term goal of developing SOP as a successful, environmentally sustainable, business park, it is not encouraging the local surrounding communities to engage with the area. In the views of participants from Newington and Wentworth Point, SOPA's diminishing efforts to communicate with local residents has been detrimental to their presence at SOP, to the loss of its local businesses and of generating more diverse, inclusive and vibrant public spaces. Importantly, the limited engagement of adjacent communities with SOP is having an effect on how residents associate with the identity of the area, thus failing to promote a sustainability culture, locally. This will become increasingly problematic for the management of SOP as a sustainable place with the number of residents in the area growing exponentially, as envisioned in planning policies for the densification of the area.

Problems with conceptualizing the social dimension of sustainable development persists, especially where its environmental principles continue to support urban entrepreneurial visions and processes (Krueger & Gibbs 2007) and public participation is not applied as a platform for open debate, but instead is used to inform and re-enforce established agendas (Kaethler et al. 2017). If public participation is used as a platform to encourage debate and share views among local communities and experts, perhaps SOP would look different. It would still host large events, but would also have smaller active areas to support daily life of local communities. In this way, SOPA could promote its sustainability ideals by reflecting a renewed search for fundamentals to satisfying local community life, which Hester (2006) and others have long argued is critical the development of places for people.

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# ADAPTATION OF “PARTICIPATORY METHOD” IN DESIGN “FOR/WITH/ BY” THE POOR COMMUNITY IN TAM THANH, QUANG NAM, VIETNAM

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## Summary

It is likely that many projects related to residential planning and resettlement for the group of low-income people have faced many challenges not only in Vietnam but also in many countries around the world. Those projects are regarded and granted by the governments in order to provide the more comfortable and healthier living conditions and the better facilities for the impoverished communities. Nevertheless, these efforts do not show sufficiency and much effectiveness, even lack of sustainability, for example, the appearance of “Ghost” cities in some countries or the desolate villages that are relocated for the farmers in flooding regions in the south of Vietnam. In reality, after the process of resettlement and relocation, people cannot naturally adapt to the new living environments where they do not see or go to their familiar daily conditions. As a result, their new life rapidly becomes boring; without stable jobs and income, the household economic condition is in poverty and they find any ways to go back to their comfort zone before. Most projects designed for the poor people usually indicate an impasse because they themselves cannot self-revitalise and develop after the projects and supports finish. The insufficiency or failure of several community programs results from lack or ignore of understandings of needs of everyone in a community and their involvements. In the field of architectural design and urban planning, a fairly common method as known as “participatory design” is a useful tool in designing the well-being of the community. However, the shallow understanding of this method’s application can lead to not many achievements in practice. The paper uses a successful project for an impoverished residential neighbourhood in Tam Thanh, Tam Ky, Quang Nam, Vietnam to show how to implement the principles of “participatory” design in the real environment through listening and understanding the local people’s conceptions and demands. Furthermore, the paper shows the adaptation of participatory concept: “from passive to active community” which is the key point to achieve successes of this project. Three principal steps were employed including identifying core issues in the community, creating changes in human perceptions and living conditions, and demanding operation and maintenance of the community further. This inspiring project attracted a positive involvement of local people, volunteers, and experts in all stages: analysis, design, and implementation. Now, the impoverished commune in Tam Thanh is revitalised by a model of a lively ecotourism village, which results in the household income’s improvement, a delightful life for everyone, and sustainable social development. The successes of the regenerative project in Tam Thanh are significant and inspirable for many similar poor communities across Vietnam. The participatory designing model is initiated and implemented by the ideas and huge contributions of the local people in efforts to transform their habitat better and more sustainable in long-term.

**Keywords:** low-income people, passive and active community, participatory design, Tam Thanh, Vietnam.

## **1. Introduction**

The direct and active participation of communities in local development plans is a recent trend due to getting positive and far-reaching effects for long-term. It is convinced that community is the principal object that uses and operates results of the plans after finishing. Local people entirely comprehend the issues and needs of the region where they live so that they have the effective contributions to the plans' achievements (improvements in the environment and living quality for themselves). The essence of "Design for the community" means "involvement"; however, this theory is not easy to approach and apply by architects/researchers in the best way. The common problems are that most practitioners often impose the expert thoughts and the subjective views on the core values of projects. Even most of the projects that won in the competitions related to "design for the community" also show the subjective thinking of the authors without the proper "involvement" of the public. In other words, the way in which we are operating may imply with a charity or a gift of a designable product to tell the characteristics and visions of an individual or a group of professionals. Origination of these projects is to serve everyone, but they do not propose the desires of the community; therefore, they lose connection to the public.

According to the current observations for the community programs, most architects are focusing on designing buildings based on the logical thinking of facilities and the sparkle appearance of subjectivism. Meanwhile, the real needs, stabilisation of life and improvement of income, of the poor receive fewer concerns. Thus, those products titled "design for the community" should be questioned. It is certain that to achieve the aim (improving the living conditions of the poor neighbourhoods) is the access by "orientation" will be more appropriate than the "installation".

From that point of view, we developed an idea for a case study: "Community-based ecotourism plan in Tam Thanh, Tam Ky". The project goal is to engage the active role of people in freeing themselves from poverty and in building a stable life. We came up with a right approach for right objects: participation of everyone from the beginning steps and a key role of them in the proposal of the ideas, development, organisation, management and maintenance of the project's consequences. Professionals and managers only undertook to guide and provide the necessary knowledge/supports in order to help them realise and solve their problems. The project went through three principal stages: Problem detection, Concept building, and Construction development. The "Co-doing" method including Co-analysis, Co-design, and Co-implementation was applied for all phases.

## **2. Literature Review**

Since the early 21st century, the conception of "liveability" has been used as a measure for quality of the urban life in a city/country around the world (To, 2018). Apart from the factor of economy, a great city for the living is a lively enjoyable place where promotes the human values, benefits, and inspirations for the citizens. An achievement of a liveable place/city requires a combination of many factors, in this, the organisation of public or community spaces is vital in urban spatial structural planning. However, the approach and implementation of the public/community spaces significantly depend on considerations of location, activities, and everyone's needs and excitement. And their success is ensured by the means for everyone that uses them and they are not violated and abandoned.

According to Kevin Lynch 1960, he pointed out three approaches for making a place including "top-down", "bottom-up", and "participatory". "Top-down" manner is a traditional perspective; the local people do not contribute to the ideas, efforts, or properties to build up the project. Therefore, that approach's effect is not predictive while the employment of "bottom-up" way shows creation and innovation. The importance is that the community involves in generating and developing the concept of public or community places, and then uses them. The methodology of "bottom-up" is adequate; however, there are still some restrictions: application on a larger urban scale, ability of dissemination, and high agreement of the community. In the large cities of Vietnam, we can find

the interesting small public spaces for people's daily activities such as a book street, a corner of beer, a little space to enjoy a glass/cup of Vietnamese coffee, playground for kids or dancing.

The last approach is "participation" that combines both above methods. The participatory principle raises as a new approach for the entirely active involvement of the community for long-term (To, 2018) (Lynch, 1960). The community participation in the public projects implies the involvement of people in a community in the different phases; and they together contribute their thinking, effort, even money for the project's achievements. Furthermore, they not only propose the detailed plans but also solve the unexpected problems of each stage (Dayaratme, 2016) (European Commission, 2012). The transformative changes in the urban design show that the design for the community (passive community) is replaced by design with the community (participation of community) and design by the community (community involvement is active in all project phases). However, to get the successful projects for community complies with huge participation and union of local people, patience, and connectivity of the whole community and individuals. Across Vietnam, some of the plans for the community development have fulfilled since the 2000s, for example, "Regeneration and Preservation of the Ancient Hanoi Quarter" in 2004-2007; "Community Project" with participation of local people in An Giang and Soc Trang (2005-2009); "Artistic Village" in Tam Thanh, Tam Ky (2016-present) (To, 2018).

In 1999, Nguyen T. H. Nguyen studied on the self-build houses by people in the ancient town of Hanoi. In the beginning step – site analysis, the participation of households in the examined region was considered as a significant factor for applicability of the project. Although the model of self-build houses was enhanced, due to the limit of the budget along with under evaluation of people's desires the housing prototype was likely abandoned and downgraded quickly after the short-term use. Between 2004 and 2007, a pilot project of the participatory design – "Regeneration and Preservation of the Ancient Hanoi Quarter" was proposed and developed but getting the fewer results (Nguyen, 2005). The project was to find a good solution for resettlement of the Hanoi people in the ancient quarter. The failure of that project was the neglect of the factor of household income when the families moved to a new residential place. Moreover, the resettlement links to the changes in habits even the living and working environment of people; however, these were not mentioned in the process.

Another scheme for an impoverished community was operated along to the canals in Binh Dong 1, Tan An, Long An, Vietnam in 2014. It was a pretty success due to understanding and using the appropriate solutions for the real problems and needs of the low-income families here. The wonky shelters and the deprived living environment were replaced by the new houses and the public spaces for the families. The planning and designing schemes based on the opinion of all individuals. Moreover, a budget for the construction of the buildings and public facilities was launched and contributed.

From the previous experiences, Le, 2016 questioned "Why do we need differences?" for the community development in Tam Ky, Quang Nam. She explained the significance of "participation" and how to approach this method in the community projects. The operation of these projects asks a harmonious and sophisticated combination of two methods of "bottom-up" and "participatory" under the developing economic condition as Vietnam.

### **3. Research Methods**

#### **3.1. Case Study**

Tam Thanh (Tam Ky, Quang Nam) is a poor coastal commune in the central part of Vietnam with more than 3,000 households of 12,000 populations across seven villages. The geographic features here are unique: a 3km eastern beach from north to south, western border facing Truong Giang River. All villages are connected by only 6km central road. The primary mean of local people's living is fishing with the uncertainty of income.

In early 2016, “Tam Thanh Mural Village” was born in collaboration of Tam Ky Council and The Korea Foundation. In seven villages in Tam Thanh, Trung Thanh village in the middle of the whole commune was selected for development of this project. Many successes of “Tam Thanh Mural Village” are phenomenal that a poor village is vividly revitalised, becomes a new attraction of travellers, and delivers inspirations to the other poor communities and young Vietnamese generation (Duong, 2017). However, one restriction seems that lack of facilities for visitors when staying here for more days. The firstly tourism services were very fundamental including vehicle keepers and some drink kiosks. Some questions for the development of sustainable tourism are addressed: how to create long-lasting benefits for local low-income people not only in Trung Thanh but also in all seven villages, how to welcome visitors for more days. Tam Ky Council devises a long-term plan for sustainable tourism based on the successes of Tam Thanh mural village. An idea for a project: “Community-based ecotourism development in Tam Thanh, Tam Ky” was born.



*Figure 1 Mural village in Tam Thanh*

Based on the basic principle of community design is to channel the weak areas and everyone; however, what the main problems of a poor community are and what they need for changes. The local people are the principal object of the project, so all activities devised relate to them. Profoundly analysing the influences of nature and society was developed. Some potential of Tam Thanh was found: 7 km of coastline with quiet and less sloping white sand beaches that are suitable for swimming and resting activities, a unique geographical and ecological characteristic. Villages are wrapped by sea at one side and river at another side. Furthermore, human resources are a beneficial factor. Local people are so warm and friendly, and they are conserving many vernacular cultural values. Local cuisine is an identity because of available specialities from sea and lands around.

From the beginning, a volunteer team consisted of more than 30 people: experts in urban and community development/architecture/planning/landscape (UN-Habitat, UNESCO, Cities Alliance) and involvement of students of universities in HCMC, Da Nang, and Singapore. Then, in the later stage of the project, the number of volunteers rose up to 60 members and more than 130 volunteers of various backgrounds.

Concerning the core that local people are the main object, their active participation is the key to this project. Therefore, at the very first stages, the leading targets were planned: any tourism products must be simple for people to operate and achieve, the critical goal is benefits for people's livelihoods and improvable income, the traditional values and local lifestyle do not deform, and natural environment is not affected.

*Table 1 Involvement of local people, authorities, volunteers in all phases of the project*

No	Phases	Local people	Commune authorities	City authorities	Project steering committee	Experts	Students
1	Survey, potential, detection	•	•	•	•	•	
2	Project's preparation, students' invitation					•	•
3	Workshop 1: Co-Analysis	Training			•	•	•
		Field survey	•	•	•	•	•
		Needs' survey	•		•	•	•
		Presentation	•	•	•	•	•
4	Workshop 2: Co-Design	Planning idea	•	•	•	•	•
		Architecture idea	•	•	•	•	•
		Experience activities	•	•	•	•	•
		Media & fundraising	•	•	•	•	•
5	Workshop 3: Co-Implementing	Planning & landscape	•	•	•	•	•
		Architecture	•	•	•	•	•
		Experience activities	•		•	•	•
		Media activities		•	•	•	

### 3.2. Phases of the project

In order to achieve harmony and sustainable development goals, the appropriate approach was that local people involved in the project from the beginning and act a key role in building the idea, handling, organizing and managing the results. The experts should guide and orient, and provide the knowledge and tools to assist them in implementing their “problems”. The project went through the stages: survey, problem discovery, workshops (workshop 1: Co-analysis and training; workshop 2: Co-design; and workshop 3: Co-implementing) as shown in Table 1.

## 4. Results

### 4.1. Movement of the “Design for the Community” concept:

In the field of community design, the change of design method is gradually shifting from “Design for Community” - a completely passive community to “Design with Community” – community’s participation in phases of the project towards the final aim of “Design by Community” – ideas’ generation and implementation by community actively. The last two operative methods seem to be progressive and corresponding to the sustainable development of philosophy: “Give a man a fish, and he will eat for a day”.

This philosophy was introduced to the project in Tam Ky to make significant changes in the lives of regional people. The real evidence showed an inevitable movement in the design method. The changes in that movement were as follows:



Table 2 Movement in “Design by Community” model

Phases	Step 1	Step 2	Step 3
	Popular in Asia and Vietnam	Less popular, several projects are using and getting high efficiency	Desirable model in the future
Approaching	Design for Community	Design with Community	Design by Community
Characteristics of involvement	Community is entirely passive	Community involves in design	Community generates ideas and fulfills them
Attitude of attendance	Architects and other parties consider difficulties of community	Architects and other parties share with community and build up the connection and belief in community	Every member of the project understands inner problems of community and be responsible, enthusiastic and cooperative
Effects	Getting immediate impacts but less efficiency for long-term, local people do not see long-lasting values to remain the project after leaving of sponsors	Community maintains products of project because they are their achievements of “Co-Design”	Community is active, responsible for remaining and developing more to achieve all items of projects for long-term even after leaving of sponsors

In step 2 and step 3, the authors employed a model of “Co-Design” that is a collaborative and participatory design concept for local people. It is likely that this is an effective and sustainable concept for community development projects according to the principle is that the community is merely the “owner”, the “client”, the operator and the manager of project’s categories. Therefore, the transformation of approach from “for the community” to “with the community” achieves effects on the community and real changes in the regeneration of residential neighbourhood.

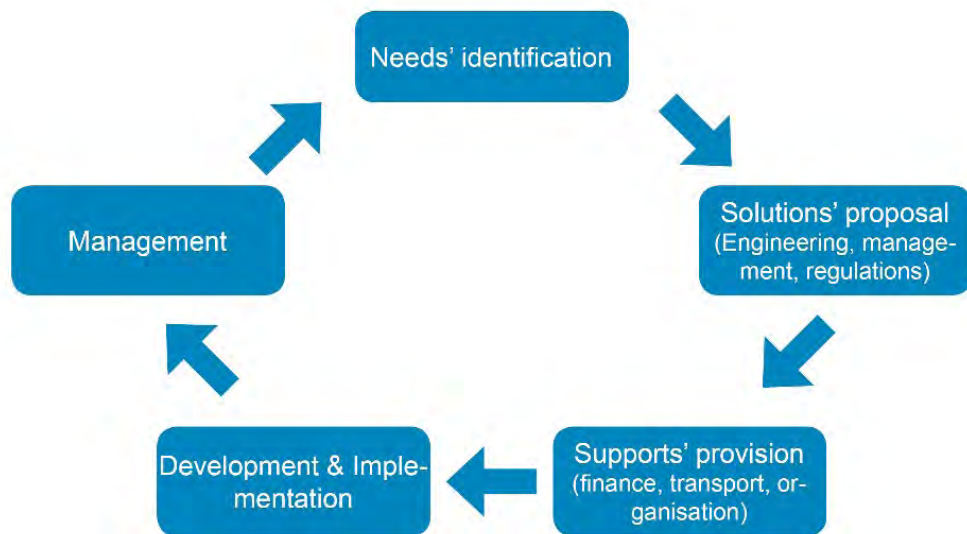
The process of community participation included five categories: Identification of needs – Proposal of solutions (technique, legality, institution) – Support of means (finance, organization) – Development - Management. The project’s decisions were made by all members of the community instead of the acceptance of the individual opinions. As shown in Figure 2, the architects could participate in three out of all activities including I. Determination of needs, II. The suggestion of solutions (the major support to provide design solutions which are based on the needs of the community), IV. Implementation. Listening to the expectations of local people and provoking passion in them was very important to engage their efforts and involvement in the project. In that way, they correctly perceive their benefits and responsibilities during the whole project process even after that, so they are ready for changes not only for them but also for the community.

## 4.2. Unique tourism concepts

The travelling concepts that formed “in” Tam Thanh and “for” Tam Thanh become the unique products that are positive results of the project. They are as follows:

### The art road of vernacular transports

Boats and coracles that are familiar transports of regional people were used to create the artistic works of painting and installation created. Volunteers who are famous artists instructed people to decorate and place 111 boats around Tam Thanh (pathways and riverside) to create the special landscape points for the region. The paintings on the boats introduce lovely images of the motherland and vernacular lives/culture in Tam Thanh. In May 2017, the art road of coracles was certificated in Vietnam Guinness Book of Records.



*Figure 2 Steps in “Design by the community”*

### **Garbage free village**

Understanding the impacts of garbage on the environmental quality and long-term development of tourism is that an international volunteer generated an idea of a free rubbish village in Workshop 1. By the observations, much rubbish was disposed around the village (roads and coasts) after starting to welcome travellers. The commitments to using plastic products were formed for both local people and tourists. In particular, the plastic bags are not allowed to use here. The drinking plastic bottles are collected and recycled after utilising. The small changes in daily awareness and habits of people will inspire and help them understand their responsibilities for their homeland.



*Figure 3 Co-analysis stage of Tam Thanh project*



*Figure 4 Co-Design stage of Tam Thanh project*

### **The village of flowers**

Cacti are an identical plant type found in the coastal village. The regional people mix them with some wildflowers to create a naturally fascinated landscape for all visitors when coming here. The model of that landscape can be employed widely within the village by more flowers and cacti. The villagers register to plant trees and flowers, which are consulted by landscape experts and commit to looking after them.

### **Tam Thanh “Village-stay”**

The same as the conception of “Homestay”, Tam Thanh “Village-stay” is devised for the model of eating, sleeping, and resting services under village scale. This discovery is due to poor condition of local people. They are not able to organise a homestay; therefore, the combination of the services (bathing, sleeping, eating) based on the family circumstances can make a perfect and exciting package accommodation.

### **Amazing experience activities in Tam Thanh**

The enjoyable rowing and biking experience is attractive the visitors’ attention. Two cooperative groups propose these two activities. The coracles and bikes are available in households. Furthermore, they are so familiar with people’s life. Thus, they voluntarily register according to a specific team (biking or rowing). The activities and instructions for the visitors are taken over by people in the village. Besides the experience of space and natural landscapes, the short experiential tours associated with local culture and specialities are to promote the traditional values and chic hand-made products, which are gradually lost.

Initially, the project was funded by donors after operating. One part of that fund was deducted for the poor households in order to help them change their career.

### **4.3. Facilities of the tourism concept:**

To support needs of tourism development is that some facilities were planned and designed according to methods of Co-Design and design “with” community. They are as follows:

- A reception space includes greeting gate, parking area, and an information desk.
- The playground is at cultural houses. Seven cultural houses over all seven villages were proposed for the renovation of the existing playground.
- To build a new cultural house in Trung Thanh village
- To arrange the observatories along to river and beaches
- A sustainable concept is for Tam Thanh Community Arts Village. Tam Thanh will be an interesting place of artists and artworks. The artists can come to enjoy and explore new experiments and experiences for their creations to the community.



*Figure 5 Co-Implementation of Tam Thanh project*

## 5. Discussion

Under the encourageable results and the positive effects on the principal object of the project, the awareness of local people in Tam Thanh is significantly transformative. It is certain that they want to participate more actively in all actions and become a part of the project. They perceive positive changes in their environment and lives. Previously, when given money or home from the benefactors, the households could not use or preserve it well for long-term and poverty still covered their life later. For the project for the community in Tam Thanh, the people contribute to building up the facilities by their efforts, passions even their money (even if that money is borrowed). Therefore, they understand and catch how to maintain what they build and to develop the new categories. The more important thing is that they find delight and inspiration in the community activities to serve not only for their lives but also for their homeland and tourists when coming here. All participants including the experts and lecturers/students from many universities also improved the practical experiences in designing the projects for the community. They can hold the core values to get successes of a community project through communicating and listening to needs and issues of local people. In collaboration with the community and the successes of the “bottom-up” approach, the participants can open new paths in the field of “design for the community” to undertake more realistic and more effective follow-up projects.

## 6. Conclusion

The practical experience of a design project by the community:

Along with the success of “Tam Thanh Mural Village”, the community projects attached later in Tam Thanh initially transform a poor commune by a liveable and attractive place for not only the local families but also the travellers. Tam Thanh is recognised on the tourism map and worthy to get the Asian Townscape Award 2017.

Collaboration for success: The collaborative support between volunteer experts, architects, and students from different backgrounds provoked the self-confidence of the poor local people to seek the realistic solutions for problems by their resources and efforts.

The local people who involve in the community projects are often the most deprived group. Thus, the experts and practitioners need to understand and employ the correct approach, for example, “bottom-up” method (where people come from). As a result, people transform from the passive condition (people usually wait for external support) to the active participation to hold chances for changes in their life. Holding the active empowerment contributes to reduce the construction costs and promote the community connection.

The local government is a significant factor in supporting and facilitating the actualisation and success of the project. The supports of authority include an open-minded vision, acceptance for new better changes, belief in responsibility and implementation of people in the local area. These factors effectively contribute to the feasibility of the project.

In a collaborative relationship with the community, the patience, comprehension, and sympathy are necessary personalities to build a good relationship and belief in the community, as well as, to require the dedicated and highly responsible participation of each member.

The architects involving the projects for the community should be aware of their role that gives supports and engages the participation of people to come up with the idea instead of proposing strict ideas/solutions. When considering and evaluating the design options with the community, the architects need to consider humanity and to choose an option that can work well “for” and “with” the community.

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## FIFTY YEARS OF INCLUSIVE TRANSPORT BUILDING DESIGN RESEARCH

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### Summary

Inclusivity is a core commitment of the New Urban Agenda of UN Habitat (adopted in 2016). Moreover, the Rail Sustainable Development Principles call for railway developments that are customer-driven, putting rail in reach of people, providing an end-to-end journey, being an employer of choice, reducing our environmental impact, carbon smart, supporting the economy, optimising the railway and being transparent (RSSB, 2016). However, research suggests there is still a long way to go before “we live and work in an inclusive world” (Clarkson and Coleman, 2015). To consider these matters, this review searched for on-line library sources employing keywords including transport, inclusivity, circulation, severance, level of service, pedestrian movement within journal articles, conference papers, theses, books and government papers. The review commences with a review of older views and goes on to critically assess potential innovations in contemporary scholarly literature. Earlier research discusses general factors that influence station design include context, location, platform, train length, and depth of construction, geological, engineering, property constraints and passenger demand (Harding, 2011). This critical review considers the scholarly literature concerning inclusive design issues in transport buildings. It explores, (i) gaps in canonical pedestrian movement theory affecting inclusivity, particularly vertical severance (VS), (ii) the size, shape and selection of circulation elements affecting Level of Service (LOS), and (iii) key measures of crowdedness and inclusivity. Potential innovations include, (i) new ‘designerly ways of knowing’ about lack of inclusivity, and, (ii) the use of Agent Based Modelling (ABM) for gaining insights into the movements of diverse agents over time (as well as the evaluation of rival cases). Anticipated benefits include a strengthened ‘transport chain’, less VS, enhanced empathy, and improved user experience and safety. More research is needed in this field, particularly owing to the significant cost and time in developing urban railway projects. This review identifies key research questions that require further investigation. It argues that integrating LOS theory and design praxis will result in safer and more inclusive stations that contribute more to society. It is hoped that this review contributes to this slowly growing body of knowledge of inclusivity within the field of transport.

**Keywords:** Inclusive Design, Service Design, Transport, congestion, severance, Agent Based Modelling

**Abbreviations.** ABM-Agent Based Modelling, LOS-Level of Service, PRM-Persons with Restricted Mobility, SD-Service Design, VS-Vertical Severance.

## **1. Introduction: First Generation Wheelchair Accessible Transport Buildings**

Many passengers experience a broken 'transport chain' (From Exclusion to Inclusion by the Disability Rights Task Force (DRTF), 1999 Cited in Bichard, 2014: 90) including those who travel with bags, prams or heavy luggage, or are elderly or frail or have medical issues (GLA, 2010). An 'end to end journey' (RSSB, 2016) is practically impossible for some groups of people who wish to use public transport in London (Harding, 2011). Only ten London Underground (LU) stations provide an unbroken, step-free journey from street to train (GLA, 2010), 61 out of 270 stations provide step-free entry from street to platform level (ibid), and three stations are accessible from street to train in the three busiest employment centres in London (Harding et al., 2016). Recent research findings are that boarding or alighting a train is impossible for some groups of people owing to gaps at the train-platform interface (Atkins, 2005). Findings are (i) staff are unavailable to help with a portable ramp, (ii) wheelchair users and assistants attempt to board or alight unaided, (iii) the ramp gradient is too steep, (iv) the platform vertical and horizontal gaps exceed the minimum distance (v) gaps are visible even when the most modern trains are employed, (vi) mobile ramps are forbidden at LU stations owing to a low LOS and frequent train service (GLA, 2010). However, the Disability Discrimination Act (1995) required wheelchair access in public buildings and soon after, the first generation of underground transport buildings had wheelchair access from street to platform for the first time (Harding, 2011). A possible reason for this delay is that earlier research claimed 'it was not essential' to make underground stations accessible for wheelchair users (Goldsmith, 1976: 401 item 77200). In his defence, Goldsmith, an influential researcher and architect who suffered from polio and used a walking stick, claimed the costs of lifts (US\$10m for lifts on the BART in San Francisco, and US\$44-60m for lifts on the Washington DC metro built in 1971) were excessive (1976: 60 para. 1411). He may have changed his mind owing to later editions of his book exclude these comments (cited in Harding, 2011). On the other hand his views were influential owing to his books formed the basis of the British Standard Code of Practice on Access for the Disabled to Buildings (CP96) in 1967, later revised to BS5810 (1979), that developed into Part M of the Building Regulations in 1987 (Coleman et al., 2003: 5). The Equality Act (2010) has a wider remit to promote inclusivity across gender, age, disability and sexual orientation. On the other hand, lifts afford limited benefits to many users owing to small size, minimal quantity and poor location (Harding, 2011).

### **1.1. Pedestrian Movement Theory**

Another reason to explain the poor uptake of lifts in stations is that current protocols and pedestrian movement calculations disregard the contribution lifts could make in moving people vertically (Network-Rail, 2011). The methodology to validate designs for station concourses (Network-Rail, 2011: 12) and also for pavement areas (Atkins, 2010) uses canonical theory (Fruin, 1971). Fruin's methodology allows building designers to determine the sizes and shapes and arrangement of spaces, concourses and pavements, airport terminals, bus interchanges and train stations (ibid: 77-78). Level of Service (LOS) provides a measure of six congestion levels; a low LOS (E-F) describes a highly congested density level where it is difficult to change direction; in contrast a high LOS (A-C) describes a free-flowing space where a rapid change of direction is possible (Fruin, 1971: 71). However, a low LOS creates concerns for disabled pedestrians including, (i) they may delay other passengers, (ii) that other passengers may be unaware of their impairments, and (iii) their slower pace makes them more likely to be pushed or tripped in busy, congested, fast-moving spaces (ibid 177-178). To improve the disabled pedestrian's comfort and confidence he suggests increasing the LOS in congested circulation areas (ibid 177-178). Fruin's (1971) theory contains two main problems for inclusivity, (i) he does not develop his idea to offer a higher LOS for disabled people (ibid 177-178), possibly owing to the thought that increasing LOS is only possible by increasing the size of the transport building and that would increase destruction of historic built environments that he was against (ibid: 2-11), (ii) in transferring and adapting evaluation methods from highway design theory to pedestrian movement theory in his PhD thesis (Highway Capacity Manual, Highway Research Board, Special Report 87, Washington, D.C. (1965) cited in Fruin, 1971: 71), he misses a critical difference that whilst a vehicle easily moves up or down a hill,

pedestrians face many difficulties moving vertically in train stations (GLA, 2010). Furthermore, current design guidance does not suggest increasing LOS in stations (Network-Rail, 2011: 12) or within the urban realm (Atkins, 2010) to improve inclusivity.

## 1.2. A 'Wicked' Problem

Designers need to know how many passengers would need to use a lift to ensure they specify the correct size and quantity of lifts (Al-Sharif and Al-Adem, 2014). The risk is, without knowing how many passengers would like to use a lift, designers may reuse past assumptions and prototypes owing to the lack of research (Harding, 2011), time pressures, and the Einstellung effect, or 'design fixation' (Crilly, 2015). Harding (2018a) claims knowing how many people require help with inclusivity is a 'wicked' problem that cannot be solved by traditional scientific and engineering methods (Cross, 2007). Next, we will review research that could address these concerns.

## 2. Researching Empathy

A possible explanation for the low take-up of inclusivity in transport buildings is that designers, clients and project managers who produce and control design all have differing experiences according to their age and gender (Harding, 2011). The problem, as Warburton (2003: 255-256) claims, is that mostly male young designers design primarily for themselves and other young people who they perceive as sexy. Similarly, younger transport planners design *'systems for the able-bodied, not for those who were frail. There was a desire for a gentler, more comfortable environment.'* (Marsden et al., 2008: 5). To investigate these claims, Harding (2011) quantitative study uses a questionnaire survey and a five-point Likert scale to study 'Tube' user experiences. All forty-seven respondents (34 men, 13 female) were frequent commuters, and influential participants who were employed to design and build several major new underground stations in London. The respondents were selected to reflect observed demographic composition of the organisation and the data were collected during a four-week period in 2010. None of the respondents claimed to have a disability. Findings are that a gentle journey affords clear announcements, low noise, lack of fear of being lost or splitting from a group, few changes of levels and easy orientation. Older men in influential positions were generally satisfied with their experience. Women and younger men have a poorer experience of security, confidence and comfort. Whilst all groups had confident experiences, their journeys were not gentle. Causes for concern are 17% of men experienced crime compared to 7% of women, whereas 76% women had a higher fear of crime, compared to 32% of men. Moreover, women talked to more strangers (46% compared to 20% of men) which suggests that men might be safer if they had greater awareness of crime and talked to strangers (Harding, 2011: 74). Interestingly, women experienced more anti-social behaviour (61%) than men (50%). That suggests anti-social behaviour might be less predictable and difficult to avoid (Harding, 2011: 74). Moreover, three gay male respondents completed survey forms. The data indicates no increased fear of crime or experience of crime for gay men compared to straight men. Thus, if both gay and straight men adopt female crime avoidance strategies by being warier both groups could experience less crime. Possible explanations for why males felt more secure were owing to, i) their physical strength, ability and confidence to deal with dangerous situations (Harding, 2011: 53), (ii) male respondents have the best experience of travelling on the Tube, (iii) males and engineers dominate the design of underground stations, (iv) males were more reluctant to learn about inclusivity (Harding, 2011: 83). Features that appear harmful, such as long, narrow or twisting corridors, may expose everyone to greater harm or fear of crime. However, men experienced less fear (17% Q13) and more crime (17% Q18). In contrast, women had more fear (53% Q13) and experienced less crime than men (7% Q18). Additional differences are women are around a third weaker than men, owing to their smaller physique and childbirth (Bassey, 1997: 289-297). As a consequence, specialists such as psychologist Huppert claim that 'older women should therefore be a priority in inclusive design' (2003: 35). However, safety guidelines disadvantage women who find it burdensome to carry a child and a folded pram and bags on an escalator (GLA, 2010). On the other hand, there is a risk and irony that men who may wish to develop designs that suit themselves, endanger themselves and others by

creating less safe circulation spaces within stations (Harding, 2011). Limitations of this research are that the respondents were unrepresentative of the public because most were professionals, working and held degrees. Nobody declared a disability. Harding (2011) suggests this could be owing to disabled people having trouble travelling, gaining and keeping a job, and keeping silent about their disability (Payling, 2003: 395 cited in Harding, 2010). Research suggests a negative reply to this question is common in surveys (ibid). Additionally, a known weakness of using positivistic questionnaires that use inductive and deductive logics of enquiry is that they remove important details and differences to produce simplistic explanations (Stainton-Rogers, 2006: 81). In summary, this study provides many interesting observations using a straightforward way to measure intangible comfort, security, gentleness, confidence experiences by comparing differences between demographic groups, (i) male, (ii) female, (iii) less than age 25, (iv) between age 25 and 55, (v) over age 55. A tool that compares experiences of different demographic groups, as Harding (2011) develops could promote reflexivity in practitioners who are working in uncertain, unstable, unique areas with conflicting requirements and values (Schon cited in Cross, 2007: 3) and inform designers that other groups may have different experiences than their own (Warburton, 2003; Marsden et al., 2008). Further research could probe how comfort, security, gentleness and confidence factors impact inclusivity (Harding, 2011) in praxis.

## 2.1. Understanding User Experience

The influence behind this study was to investigate inclusivity concerns in the context of a busy, urban underground station using mobile methods by leaving “... *the design office and becoming-if briefly-immersed in the lives, environments, attitudes, experiences and dreams of the future users*” (Battarbee, 2004). Participant observation studies are frequently used in the fields of anthropology and sociology using methods developed by Malinowski (cited in Buzard, 1997). This is the first time this methodology, is applied to investigating passengers within a crowded urban underground railway context (Harding et al., 2016). Their qualitative study investigates how people in the ‘rush hour’ circulate in a low LOS, typically shallow station, which is in a busy urban location with one lift (Harding et al., 2016). Research questions are, in what ways do we find train passengers suggestible as they move through congested underground train stations, and how do passengers protect themselves against suggestions that do not help them survive or be included within the design? (Harding et al., 2016). This method allows a researcher to collect video data, using a chest mounted camera, whilst moving within the station with other passengers. The video data was transferred from the camera onto a computer and analysed approximately a month after the data was collected. The good quality of the recording allowed the researcher to recollect events and analyse results in a detached way. This exploratory study stores and preserves video files as an innovation Crichton and Childs (2005) that clips audio recordings to preserve original participants’ voices and roughly codes audio files using Excel to store large files. Harding’s modified approach saves research time by reducing the amount of transcription, preserves the original materials until explication, and allows a ‘thick’ or wordy description of the event. This immersive method allows a researcher to move spontaneously within a busy station during the evening peak-hour commute to observe passenger experiences directly (Harding, 2016a). It focuses our attention upon the qualitative aspects of the ‘passenger journey’ and identifies, from the user viewpoint surprising design or behaviour issues. These include glare from bright lights shining into the eyes of passengers, noise from announcements and the quietness of crowds waiting patiently for their next train. Findings highlight the difficulty to reach and find a lift when it is small and poorly located at the end of a long and congested route at platform level. In contrast, the lift location at concourse level has a higher LOS and is visible adjacent to busy escalators, however, there is lack of space in the lift to accommodate all the passengers who wish to use it. Other negative factors result from confusion, congestion, glaring lights, noisy announcements and warnings. A typical island platform configuration results in significant queuing when trains are insufficiently frequent or too congested to board. Findings from indirect methods using a questionnaire (Harding, 2011) exclude such details. Other advantages are preserving the video data allows other researchers and participants to make their own interpretation. It reports on subtle details of ‘lived experiences’ that may otherwise be lost, and provides a voice for the



'silenced' which may improve the autonomy, survivability and perhaps their inclusion in a next generation of station designs. The analysis focuses upon how to improve mobility in the station from a user's perspective. The use of auto-ethnography is discussed as part of a broader methodological debate about how to explore universal design issues from a user's perspective, and in the context of empathetic design (Harding et al., 2016). The video data and analysis is useful to either a researcher, or a designer, not living in London, or in a country without a railway, who wishes to experience a journey in a busy train station and may be unable to travel and gain an insightful experience in a 'real' station. Difficulties with this research method are no significant data should be taken without consent (Oates, 2006) and findings are un-generalisable owing to the participant observer had no impairment, is male and middle aged that risks unconscious bias.

## 2.2. Safer Stations

Train stations are the riskiest place for accidents on the entire rail network in the UK and cost the industry approximately £90m per year (RSSB, 2015). Slips, trips and falls are common accidents. A 'fatality weighted index' (FWI) quantifies all the, albeit few, fatalities and the frequent minor and major injuries into approximately and occur most often on stairs (10), platforms (8), concourses (4), escalators (4) and other (2). There are approximately 30 FWI per year (excluding suicides). The data shows almost 50% (14) of FWIs occur on stairs and escalators (refer to Chart 39 RSSB, 2015). However interviews with station managers and traveller key station design issues regard vertical circulation as less important design factors to minimise slips trips and falls; instead flooring materials, waiting rooms, lighting; signage, cleaning and housekeeping are considered more important (Victoria; et al., 2014: 39 Table 8). In contrast worldwide research papers show that elderly people, children, women with high heels and inebriated people as the most at risk from slips, trips and falls on escalators. (Greenberg and Sherman, 2005). Unfortunately mixed methods studies from Hong Kong (Chi et al., 2006) and USA (O'Neil et al., 2008), where escalators are common, do not explain why these groups are most at risk; nor do they suggest measures that could prevent harm. Rubenstein (2006) identifies in a meta-analysis study the causes of falls in elderly adults, describes the interaction of environmental, medical and age factors that cause the falls (ibid ii38). Slips, trips and falls should be considered a significant issue in train station design because *'.... [unintentional] injuries are the fifth leading cause of death in older adults (after cardiovascular disease, cancer, stroke and pulmonary disorders), and falls constitute two-thirds of these deaths'* (ibid ii37). It is recommended that further design research probes factors including circulation and LOS that could result in safer stations.

## 2.3. Reduce Vertical Severance (VS)

To address the risks and issues of moving vertically, Harding (2013) synthesises earlier observations and literature (Harding, 2011) by defining this phenomenon as **Vertical Severance**. The *"... separation from ground level to the platform that creates spatial mobility and socio-economic concerns for individuals. VS results in less diversity and more exclusivity within transport modes and the cities they serve."* (Harding, 2013: 13). For new VS free transport buildings, Harding (2013) recommends the following solutions: *"....1) Accept Maynard's claim that well designed lifts are beneficial to almost all individuals (2007), consequently develop designs with more and faster lifts. 2) Consider other property types that solved VS, for example, Heathrow Terminal 5 [that provides many large lifts to serve passengers carrying luggage... 6) Consider [either] omitting or provid[ing] fewer spatially inefficient escalators to deeper stations, or where passenger exit and entrance numbers are relatively low, provide more space for lifts and evacuation stairs. Note that escalators cost more to build, maintain and consume far more energy than lifts. ... In summary, such changes require a paradigm shift to provide VS-free designs ..."* (Harding, 2013: 12). Some scholars argue that vertically separating the pedestrian from the vehicle is beneficial to pedestrian comfort and safety (Fruin, 1971: 183-196); others prefer active streets and pavements and oppose vertical segregation (Hillier, 2004: 45). Other scholars argue severance or the 'wrong side of the tracks' phenomenon barely exists (Mitchell and Lee, 2014) – they tentatively argue that socio-economic divisions in neighbourhoods on opposite sides of the Clyde River valley



in Glasgow are explained by their steep banks. Further research could probe how different circulation choices could satisfy either 10% or 25% of overall passenger numbers who may wish to use a lift at stations (Harding, 2013: 11), and identify actionable insights for LOS, inclusivity and VS theory and praxis.

## **2.4. New Disability Discourses**

No discussion of inclusivity would be complete without a brief review of recent discourses in disability studies that developed earlier medical and social models of disability to current interactional models (Riddle, 2013: 33-35). The Medical Model claims the “impaired body must be restored, adapted and cured” (Scullion(2009) quoted in Gomez et al., 2014: 272). In contrast, the Social Model of Disability claims society’s actions and inactions cause a person’s disability. The particular trouble with Social Model theory is that owing to its insistence that society causes disability it ignores the possibility that advances in medical technology developed within the medical and technological field may remove the impairment (e.g. glasses, wearable technology, or prosthetics) (Corker and French, 1999). Similarly, Watson and Woods (2005: 104) argue that wheelchair technology has an emancipatory impact upon the lives of wheelchair users and the use of technology is often neglected as an aid for social justice. The weakness in the social model argument is that “... *the horse before the disability studies carriage is often politics, not science*” (Vehmas, 2008: 21 Quoted in Riddle 2013:2028). Recent inclusive design (Boys, 2014) and interactional theory focuses upon removing the impairment from both the built environment and the body (Riddle, 2013). Interactional theory also expands the discourse to more complex socio-political contexts (not just disability) including feminist, racial, gender, ethnicity and sexual topics (Stainton, 2000); non-disabled concerns (Slack, 1999: 23) and challenges us to consider questions about sufficiency; and medical-socio-material-economic-political challenges (Slack, 1999). Socio-material-environmental thinking found in recent research takes a more holistic view (Richard, 2014). Consequently, many philosophers and bioethicists support this interactional approach (Riddle, 2013: 23). Further research could probe how different circulation choices that reflect social model logic vs. latest interactional logic may settle these rival discourses and may develop actionable insights in praxis.

## **2.5. ‘Next, Next Generation’ design research methods**

First generation design research methods that used ‘systematic, rational ‘scientific’ methods sought to optimise design, however these approaches did not solve ‘wicked’ design problems (Cross, 2007: 1). ‘Next, next generation’ methods are ‘more relevant to architecture and planning rather than engineering and industrial design’ (Horst Rittel (1973) cited in Cross, 2007: 1). These include an idea from business studies called ‘satisficing’ that aims to develop satisfactory and appropriate solutions and not ‘optimising’ solutions (Simon, 1979). ‘Service design’ (SD) research by the design and research company IDEO strengthens the ‘passenger journey’ by developing knowledge of each activity or ‘customer touch points’ as the passenger obtains information, plans the journey, travels to the station, enters the station, buys tickets, waits, boards the train, travels on the train, alights, and continues the journey (Bhavnani and Sosa, 2008). However, integrating this concept is untested in recent underground train station design research (Harding, 2018a). Further design research could probe how new ‘designerly’ methods (Cross, 2007) could address the aforementioned ‘wicked’ design problems of inclusivity by incorporating SD and the passenger journey concepts (Bhavnani and Sosa, 2008).

## **2.6. New Tools**

New research inquiry tools that could aid inclusivity research and praxis include, (i) ‘Bit Kit’ is a tool to assist visually impaired users with navigating in buildings (McIntyre and Hanson, 2014), (ii) Wayfindr is an assistive navigation tool useful for visually impaired people to navigate by themselves in unfamiliar buildings including transport buildings (Giannoumis G.A. et al., 2018), (iii)

Space Syntax is a tool that evaluates connectivity of streets within urban areas (Hillier, 2004) but does not model congestion, (iv) However, Legion is an ABM-based pedestrian modelling trusted by many transit authorities to interpret and validate train station design (Network-Rail, 2011: 53 ). Recent ABM research recommends further ‘*integration of simulation results with accessibility requirements for persons with restricted mobility [PRM] ...for all pedestrian simulation modelling to ensure an equitable assessment of transport interchanges*’ (Clifford et al., 2016: 16). However, restricting studies to PRM passengers appears to generate problems of exclusivity that this paper argues against. Instead this paper argues new ABM research should probe the ‘wicked’ problem of not knowing how many people require help with inclusivity (Harding, 2013), how rival circulation choices impact agents’ behaviour (Harding, 2018a).

### 3. Conclusion

Findings from this review suggest that researching inclusivity is a ‘wicked’ problem and that ‘design thinking’ and ‘next, next generation’ methods (Horst Rittel (1973) cited in Cross, 2007: 1) and Service Design (Bhavnani and Sosa, 2008) could advance ‘satisficing’ solutions (Simon, 1979) for inclusivity. This review also highlights the concern that VS is a problem that can be seen in transport buildings (Harding, 2013) and urban areas (Mitchell and Lee, 2014). The impact of congestion upon inclusivity in transport buildings and urban areas appear under researched suggesting that canonical pedestrian movement (Fruin, 1971) and VS (Harding, 2013) require further research to satisfy inclusivity needs in society. A future study aims to address these questions.

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## ENABLING SMART PARTICIPATORY LOCAL GOVERNMENT: PRELIMINARY FINDINGS

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### Summary

Social media and online communication has changed the way citizens engage in all aspects of their lives from shopping and education, to how their communities are being planned and developed. It is no longer one-way or two-way communication. Instead, via networked all-to-all communication channels, our citizens engage on urban issues in a complex and more connected way than ever before. So government needs new ways to listen to its citizens.

The paper comprises three components. Firstly, we build on the growing discussions in the literature focused on smart cities, in one hand, and social media research, in the other hand, to capture the diversity of citizen voices and better inform decision-making. Secondly, with the support of the Australian Federal Government and in collaboration with case study local governments, we collect citizen voices from social media platforms, on selected urban projects. Thirdly, we present preliminary findings in terms of quantity and quality of publicly available online data representing citizen concerns on the urban matters. Analyzing the sentiments of the citizen voices captured online and clustering them into topic areas, we elaborate the scope and value of technologically-enabled opportunities in terms of enabling participatory local government decision making processes.

Keywords: citizen engagement, crowdsourcing, social capital, social media

## 1. Introduction

Amidst the speedy growth of smart city promises and practices, there is an urgent need to take a critical approach and offer an integrated vision for an otherwise fragmented and sectoral concept. In particular, the literature warns about the lack of citizen voices in smart city decision making processes, and projects (Alizadeh, 2018; Lara et al., 2016; Niaros, 2016). Indeed, the current debates around smart cities are full of contradictions. On one hand, there are near-utopian notions around the concept of “smart”, with the big tech-companies projecting visions of perfectly optimized and smooth running lives in perfectly organized cities, a sort of a return to the concepts of the “city as a machine”. On the other hand, the same utopia-based vision turns dystopic, when it is pitched against the worst that it could become, the city turning into a sort of an omnipresent, omniscient Truman show or an Orwellian 1984, with ironically the big-smart-tech companies running the show (Valverde and Flinn, 2018). In the middle of both extremes is a worrying lack: there is no space in which the everyday messiness, and the infinite capacity that a “good”, “fair”, “just” or “sustainable” city must have for adaptability to collective actions, choices and lives of the citizens, is discussed, conceptualized, acknowledged, or captured. In other words, a framework for civic engagement in design and planning of a city is an essential need in a fully functioning healthy democracy (Dong et al., 2013). In reality, such a city would likely be a middle ground between being completely top down, system-driven versus completely bottom up, citizen-driven. This paper makes a beginning by acknowledging this middle space between the two extremes, a space where citizen voices may provide a bridge between the top-down, system-driven city and the bottom-up, people-driven city.

There are, however, serious questions about how collective citizen voices can be accounted for in the urban development processes already in place, using smart technological advances already at hand. In developing a response to such questions, this paper takes up a challenge to empower citizen voices in smart cities, with special attention to the potential of passive crowdsourcing based on the mostly untapped and unutilized available data in the public domain of social media. This is proposed to enable public engagement in smart city debates and decision making – especially at the local government level where the resources to actively build higher levels of citizen engagement are scarce.

The paper also builds upon the existing links between the two concepts of ‘smart cities’ in one hand, and ‘sustainable cities’ in another. It shifts the focus of attention away from the oversimplified technological focus on smart city concept, and puts the spotlight on smart cities empowered by smart governance, smart environment, smart living, and smart people (Papa et al., 2013; Yigitcanlar et al., 2015). In doing so, the smart city concept reaches out to the building of social sustainability, as accounting for people’s voices in urban decision making processes is targeted as a means of social empowerment; and ultimately increased collective social capital (Dale and Onyx, 2010; Dillard et al., 2009).

The paper starts with a portrayal of the bifurcated smart city landscape, presents the ways in which citizen voices can be captured via social media using crowdsourcing techniques, and identifies the shortcomings that motivated our study. This leads to the second part of the paper, in which the methodological details of our study – collecting citizen voices in collaboration with local government partners – are included. In the third part of the paper, we present some of the tentative findings in terms of quantity and quality of publicly available online data representing citizens’ voices and their concerns on local urban matters. The paper concludes by elaborating the scope and value of technologically-enabled opportunities in terms of enabling participatory local government decision making processes. Lessons learned, contribute to the fast-growing and yet understudied fields of empirical smart cities studies; and also social media research. Moreover, findings inform governments of all levels of the opportunities and challenges involved in capturing meaningful public insights online.

## **2. Broader View: Citizen Voices in Smart Cities**

### **2.1. Corporate smart cities vs. alternative smart cities**

Over the last few years, we have witnessed a spread of smart city projects around the world (Alizadeh, 2017) involving cities of all sizes (Kavta and Yadav, 2017; Watson, 2015) and diverse socio-economic status. (Sanseverino et al., 2016). Smart city projects cover an incredibly broad ranges of topics including e-governance (Bertot et al., 2014; Kumar, 2015), smart transport (Bodhani, 2012; Debnath et al., 2014), efficient urban services (Lee et al., 2015), and open data (Al-Ani, 2017).

Despite the heterogeneous smart city practices and projects worldwide, the critiques seem to be quite focused on what is labelled as 'corporate smart cities' (Hollands, 2015a; McNeill, 2016; Söderström et al., 2014; Vanolo, 2014). From a critical perspective, it is argued that smart city has crystallized into an image of a technology-led urban utopia permeated with centrally controlled technological infrastructure (Albino et al., 2015; Niaros, 2016). In fact, in the corporate vision of smart cities, citizens are often seen as barriers in the race towards smartness; and that they need to be educated as to the benefits smartification can bring (McNeill, 2015; Vanolo, 2014).

On a positive note, however, the absence of real citizen involvement and participation has encouraged a push for an alternative version of smart cities to provide a counter-point to the corporate vision (Hollands, 2015b; Kostakis et al., 2015). This alternative vision has emanated from small-scale and fledgling examples of participatory community-based type smart initiatives (Chatterton, 2013; Niaros, 2016; Radywyla and Biggs, 2013). Previous studies (Alizadeh, 2018), in search of common ground for the growing number of alternative smart initiatives, have put the below list as the core elements that tie together the alternative smart city vision:

- An emphasis on citizen engagement beyond the simple delivery of services
- A democratic bottom up approach: to promote participatory urban technologies, greater social inclusion, and a substantial shift in power from corporations to ordinary people and their communities
- Reliance on dynamic public-private partnership: with an emphasis on participatory governance rather than an entrepreneurial one
- A tendency to identifying the urban problem first, and only then reaching out for the relevant technological solution: with emphasis on the capacities of each city, and its distinct cultures, histories, and political economies
- Is associated with the free software and open access movement and
- Is in the preliminary phase: far from being mature; and mainly exist in seed form.

### **2.2. Power of crowd via social media**

An essential element of the alternative smart city vision is an emphasis on citizen engagement by empowering their voices (Lee et al., 2014; Papa et al., 2013). However, participatory planning literature acknowledges the difficulties involved in gathering people's voices in urban decision making processes (R.Davies et al., 2012; Umemoto, 2001). There are, however, two relatively new phenomena – social media and crowdsourcing – which provide opportunities for smart technologies and techniques to capture citizen voices via alternative channels (Kleinhans et al., 2015). Below we briefly discuss these two phenomena. It should be highlighted that the aim is not to offer an all-inclusive account but rather to provide the foundation for the further empirical parts of the paper:

#### **Social media**

Social media is an umbrella term, for so many different online platforms, mainly introduced and gained momentum in the last decade, including but not limited to twitter, Facebook and Instagram; with the key feature of allowing users to connect (Carr and Hayes, 2015; Fieseler and Fleck,

2013). Social media is broad reaching and allows dispersed groups and individuals to connect and share or promote information relating to common interests, concerns, or causes (LaRiviere et al., 2012; Minton et al., 2012; Walther and Jang, 2012). Social media has played an important role in a number of civic uprisings around the world including but not limited to Arab Spring, the Occupy Movement, and recent presidential election campaigns in the US (Farro and Demirhisar, 2014; Gleason, 2013; Morozov, 2009). This has prompted a new line of scholarship focusing on the role of social media in enabling participation, creating collective voice, and facilitating socio-political change (Comunello and Anzera, 2012; Howard and Parks, 2012; Kavada, 2015).

Social media is participatory and interactive, which is also what separates it from the traditional forms of media (Fieseler and Fleck, 2013; Minton et al., 2012; Walther and Jang, 2012). The user-generated content on social media provides avenues for building bottom-up movements and empowering collective voices (Juris, 2012; Linders, 2012; Scott and Liew, 2012; Willems and Alizadeh, 2015). In contrast to these possibilities of empowerment, there is also growing skepticism around the quality of online voices, sheer size of distracting noises online, claims of inherent bias towards the tech savvy citizen, and legitimacy of citizen voice captured online (Ferrara et al., 2016; McCafferty, 2011; Vitak et al., 2011).

Nevertheless, the complexity of the social media debate is, partially, due to its growing ability to provide an alternative voice (Fieseler and Fleck, 2013; Walther and Jang, 2012). Its dynamic nature allows for both bottom-up and top-down community involvement. From a bottom-up perspective, there is growing research on the use of community led groups to organize and coordinate via social media in opposition to planning, policy, and manufacturing or development processes (Alizadeh et al., 2018; Maireder and Schwarzenegger, 2012; Shav-Ami, 2013). In a top-down engagement perspective also, there is a growing line of literature (Afzalan and Evans-Cowley, 2015; Evans-Cowley, 2012) that argues planners can greatly utilize social media based opportunities to mobilize and organize citizens.

## **Crowdsourcing**

Howe (2006) first coined the term crowdsourcing in a Wired Magazine article as “the act of a company or institution taking a task once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call”. Since then there have been many attempts to revise and redefine crowdsourcing based on the diversity of its practices (Estellés-Arolas and González-Ladrón-De-Guevara, 2012; Zhao and Zhu, 2014). Some of the latest revisions have been proposed in response to the emergent crowdsourcing based on the eminence of social media (Kietzmann, 2017; Thapa et al., 2015).

However, the most significant evolution of crowdsourcing concept stems from a shift from the original ‘task-oriented’ approach to what can be described as ‘crowdsourcing of opinions’ (Alizadeh, 2018; Noveck, 2015). In this second approach, crowdsourcing is no longer about getting a certain task done by the help of the crowd. Instead, crowdsourcing of opinions is used to gauge opinions, ideas, or perceptions of the public in different forms of polling, sentiment analysis, and opinion mining. Sentiment analysis uses language processing and machine learning to identify which topics different groups talk and care about the most. Social media in general, and twitter, in particular, are rich sources of opinions; and have been used in crowdsourcing of opinions. There are, indeed, numerous examples of companies using crowdsourcing of opinions - via social media – in their marketing efforts (Dowson and Byngal, 2011; Willems and Alizadeh, 2015).

Crowdsourcing of opinions, in turn, then is categorized in two broad categories of active and passive. In terms of the difference between active and passive crowdsourcing, Loukis and Charalabidis (2015) argue that the active crowdsourcing of opinions is more like mainstream private sector crowdsourcing which actively stimulates discussions and content generation by citizens on specific topics. While passive crowdsourcing approach is more compatible for public sector; it passively collects information, knowledge, opinions and ideas concerning hot topics of the day and important public policies created by citizens without any initiation, stimulation

or moderation from government postings (Charalabidis et al., 2014; Charalabidis et al., 2012; Loukis and Charalabidis, 2015). Social Media Monitoring (SMM), as a systematic continuous observation and analysis of the data already available and mostly untapped, is the main source of passive crowdsourcing in the public sector (Loukis et al., 2017).

### **2.3. Shortcomings: crowdsourcing in urban decision making processes**

In principal, crowdsourcing has great potential in participatory urban planning; promotes many elements of smart cities including open government; and can be used as an expansion of e-governance to we-governance by facilitating citizen-to-government support, citizen reporting, and citizen-government coproduction of cities (Castelnovo, 2016; Linders, 2012; Schmidhuber and Hilgers, 2017).

Nevertheless, the problem is the scale of uptake of crowdsourcing in urban governments (Alizadeh, 2018; Berst et al., 2014; Bertot et al., 2014; Norris and Reddick, 2013). Indeed, the small but growing number of crowdsourcing in urban governments mostly falls into the category of active crowdsourcing; as a special question is posed to the public (e.g. in times of emergency responses in disaster management (Liu, 2014; Poblet et al., 2017)), or a new application/platform is introduced to reach the crowd (e.g. crowdsourcing of real-time data from the residents about the conditions of local roads (Harford, 2014)). This slow uptake may be further impacted by the perceived inherent bias that social media users are the domain of the tech savvy and not representative of the entire population.

This paper, motivated by the gap in the practice of crowdsourcing, takes a step towards using passive crowdsourcing to inform local urban planning processes. Below parts describe the ins and outs of the study behind this paper; and unfold some of the preliminary findings.

## **3. Our Study**

Our study builds upon the alternative smart city vision, discussed earlier in the paper, and puts citizens' voices at the center of smart city thinking. Indeed, the paper is part of a project funded in the first round of Smart Cities and Suburbs Program initiated by the Australian Government in 2017. The overall project involves investigating new ways of collecting citizen opinions from a range of online sources, including social media, about four urban infrastructure projects in two Australian cities: Sydney and Brisbane, based in the jurisdiction of two Local Government Areas (LGAs): Canada Bay (Sydney) and Logan (Brisbane). The paper, however, only focuses on two projects located in the Canada Bay revealing some preliminary findings.

Below outlines the scope of the study, and the methods adopted for data collection and analysis.

### **3.1. Scope of the Study**

As stated above, the broader study (funded by the federal government) focuses on four urban projects in two Australian metropolitan regions: Sydney and Brisbane, based in the jurisdiction of two Local Government Areas (LGAs): Canada Bay (Sydney) and Logan (Brisbane).

Following consultation with local government partners and preliminary data analysis the following pilot projects were selected. Consideration was given to the:

1. Scale and impact of the project; What was the financial investment, project duration, physical scale and potential disruption to the built environment and therefore citizen use?
2. Diversity in type and location of project; A master-planned development or major infrastructure? Inner city or peri-urban fringe?
3. Role of governments in the urban project; Who is the lead proponent? Local government or state government?



4. Viability of data; Is there sufficient volume of data for analysis? Is the data providing meaningful insights to urban issues?

The selected urban projects ranged from a state-led peri-urban master-planned smart community; local government led master-planned recreation park and urban revitalization precinct to a state-led major transport infrastructure project. For the purpose of this paper, the projects based in Sydney (City of Canada Bay) are further introduced in Table 1.

*Table 1 Summary of the Urban Projects at the core of the study – Located in the City of Canada Bay, NSW*

Project Name	Description
Parramatta Rd Transformation project	The Parramatta Road corridor is described as an important transport and movement route for people who live, work and travel in the area; is characterized by chronic traffic congestion, noise and as the connector of Sydney CBD to Parramatta, is a priority area for the long term growth of Sydney. Three renewal areas are identified within the City of Canada Bay LGA, including Homebush, Burwood and Kings Bay Precincts. These precincts are expected to provide an additional 17,000 dwellings to house approximately 36,100 people and provide up to 19,600 new jobs (Landcom, 2018).
Five Dock Urban Renewal	The Five Dock Town Centre Urban Urban Renewal project sets out a vision for Five Dock to ensure that the centre continues to provide a strong focus for the community, is a better place to live and work, creates improved opportunities for investment, is easy to get around and provides an enhanced built environment (City of Canada Bay, 2018).

### 3.2. Methods

#### Data acquisition

In the first phase, we mined Twitter feeds for targeted data on each of the projects discussed above. Meetings and informal interviews were conducted by the team members with council representatives, who outlined the key pieces of information and background described above for each project. Using this as the basis, and a pilot study of Twitter streams, the team developed a set of hashtags and keywords related to each project.

It should be noted here that using some of these keywords and hashtags returned data that may not be concerned directly to the projects, but could nonetheless reveal interesting and relevant information. For example, “five dock” could bring out the café culture activities, biking, and community meeting activities that seem common in the Five Dock area in Sydney, which in itself could be a sign of an active community that participates.

Repeated tweets were removed, and only unique tweets were preserved, though a record and count was kept of what was being removed. Retweets that appeared genuine were not removed. Further, any tweets that were filled with random data and appeared to be sourced from bots were also removed. This part of the processing made sure that a maximum amount of meaningful information was being captured.

#### Twitter: Data processing and cleaning

The quality of Twitter data depends on multiple factors: primarily, the query used and timing. For example, the query “five dock” sometimes returns incorrect results regarding boat docks, or for some content that may not be related to Sydney at all. Timing is another factor as certain events may cause a burstiness of tweets, followed by spans of silence. For example, “Parramatta road” would become particularly active during events of traffic congestion or accidents. The fluctuating popularity of topics is particularly prevalent with Twitter due to its “trending topics” feature. For this paper, we have collected tweets over a period of 7 years.

Table 2 shows counts of the numbers of tweets and the time frames for which tweet data was captured. As is evident, the volume of information and flow of information over time is relatively low. Yet, surprisingly most of the tweet content was very meaningful (further information on this follows). Below table also shows a snapshot of 7 days in order to provide an idea of how many relevant tweets are made in a week, though, this can vary depending on the burstiness of event related tweets.

*Table 2 Tweet counts*

Project	13/08/18-20/08/18 (Snapshot of 7 days)	Complete tweet repository
Parramatta Rd	68	2015
Five Dock	143	2392

### Sentiment analysis

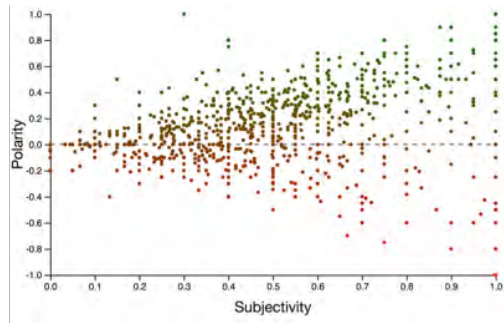
Tweets are then analyzed to assess their overall sentiment, either positive or negative. We first remove meaningless words such as Twitter handles, URLs and stopwords. The remaining, meaningful words are then individually assigned a sentiment score. Words such as “happy”, “good” and “sun” are given a positive score while words such as “angry”, “traffic” or “lost” are given negative scores. The sentiment analysis is performed using a standard Python based library that uses a Naïve Bayes and bag-of-words approach. These individual scores are combined using the Pattern library’s PatternAnalyzer to give a combined sentiment score between -1 and 1. An additional feature of the Python library is that it provides a measure of subjectivity versus objectivity of information: if a tweet contains factual information, it is classified as less subjective, whereas tweets with more opinion based information are rated more on the subjectivity score. It is to be noted here that given any algorithmic limitations (too technical and out of scope of discussion for this paper), the results would not be perfect, though they are reliable.

### Clustering analysis

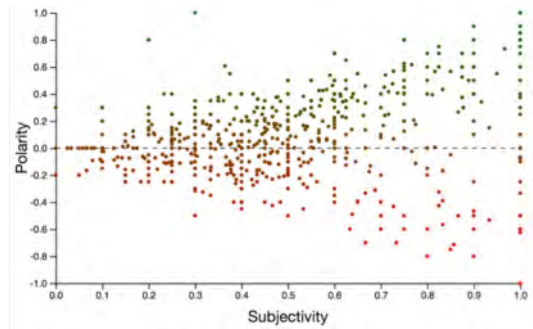
The final stage in analyzing the data was clustering the tweets, that is, putting the tweets together in clustering that brought out information on a particular recurrent topic that was getting repeated attention. We used a technique called Latent Semantic Analysis (LSA), similar to graph clustering (Sarkar and Dong, 2011). First, we created a term-by-document (TDM) matrix. As mentioned above in the case of sentiment analysis, all stop words were already removed from the tweets, and all meaningful non-stop words extracted. Each of these unique  $m$  words formed a row in the TDM matrix,  $i = 1, 2, \dots, m$ . Each column formed one of the  $n$  tweets,  $j = 1, 2, \dots, n$ . Each matrix entry is a record of the number of times the word  $i$  occurs in tweet  $j$ . We then perform the Singular Value Decomposition based algorithm to cluster the data (Sarkar and Dong, 2011). This algorithm extracts a lower-dimensional representation for the high-dimensional tweet data. In this lower-dimensional representation, words and tweets that frequently co-occur with each other lie “close to each other” in this abstract mathematical space. The extracted clusters were then examined by counting the top words in each cluster in order to identify the topics.

## 4. Preliminary Findings

Figures 1 to 4 show the preliminary results of the analysis. Figures 1 and 2 show the results of the sentiment analysis for Parramatta Road and Five Dock, respectively. Each dot represents a tweet, the x-axis plots the subjectivity of the tweet, and the y-axis measures the polarity (or the positive-negative sentiment). The more green the color of a dot, the more positive the tweet, and the more red the color of a dot, the more negative the tweet.



*Figure 1: Sentiment analysis for the Parramatta Road tweets*



*Figure 2: Sentiment analysis for the Five Dock tweets*

It is interesting to observe the spread of the data across both urban projects (Parramatta Rd., and Five Dock). It is important to remember that, here, data refers to the diversity of topics discussed by the citizens in their tweets about the two urban projects. First, there is an equal distribution of negative vs. positive opinions expressed in the tweets. This is perhaps surprising; as there is a line of literature which argues that people mostly use Twitter (or social media in general) to vent out, to complain, and basically to be negative about urban issues (Resch et al., 2016). Our sentiment analysis, for both Parramatta Rd. and Five Dock, however shows a fair distribution of opinions. More interestingly, the less subjective the information shared via each tweet, the lower the spread or dispersion of the polarity. To the contrary, the higher the subjectivity of the information, the higher also the dispersion of the polarity. This shows that more subjective information has higher extremes of emotional expression of positivity or negativity in-built into it. It is also interesting to observe from Figures 1 and 2 that the overall distribution “shapes” for both the Parramatta Road and the Five Dock tweets are quite similar.

Regarding the content of the tweets, most of the positive tweets focused on good personal experiences, social events, or at times marketing related information. Most of the negative tweets focused on topics such as traffic and congestion, poor citizen or driver behaviors, or complaints against government or poor infrastructure (e.g. road conditions, telecommunication failure). For example, Table 3 provides a few examples of positively and negatively classified tweets for the Parramatta Road and Five Dock:

Table 3 Examples of positively and negatively classified tweets

Tweets	Parramatta Road	Five Dock
Positively classified	<p>"Best I've seen that stretch of Parramatta road look"</p> <p>"The joy of Parramatta Road this evening"</p> <p>"NOW is the perfect time to invest in Homebush and become part of a new growing community"</p>	<p>"Looking forward to #Ferragosto2017 today in #fivedock Come on #innerwesties it's a great day for food, sun and fun!"</p> <p>"Good morning #fivedock Happy Tuesday twitterverse! #happydays #lovinglife #canadabay #innerwestisbest"</p>
Negatively classified	<p>"There is a bad pothole round a manhole/access cover on #ParramattaRoad,westbound,ouside #VictoriaPark just b4 SydneyUniversity. Others closer"</p> <p>"That's so very terrible, @davidtickle_. I've always found Parramatta Road to be a traffic funnel, not good for business or people!"</p>	<p>"Hey @Telstra. Is there something wrong with the broadband service in Five Dock 2046? The service has been slow for 3 days."</p> <p>"#innerwest #sydney be careful of your children! Kidnapping attempt Belfield burwood Five Dock Drummoyne Haberfield"</p>

Figures 3 and 4 show the results of the cluster analysis for Parramatta Road and Five Dock. The size of the word corresponds to the highest frequency words of each cluster. Figure 3 shows word clouds for the top 3 topic clusters identified for Parramatta Road. The clusters can be broadly classified as: (a) Delayed traffic, (b) Accidents and breakdowns, and (c) Planning and government related tweets. Figure 4 shows word clouds for the top 3 topic clusters identified for Five Dock. The clusters can be broadly classified as (a) Five Dock popular culture, (b) Games and sports events, and (c) Traffic delays and congestions.



Figure 3 Cluster analysis for the Parramatta Road Tweets (a) Delayed traffic, (b) Accidents and break downs, and (c) Planning and government related tweets.



Figure 4 Cluster Analysis for the Five Dock Tweets (a) Five Dock popular culture, (b) Games and sports events, and (c) Traffic delays and congestion.

In terms of the content, each cluster identified is rich and meaningful as everyday citizens share their observations, frustration, and happy moments. For instance, a broad range of topic areas are discussed with direct relevance to local government decision making as part of the planning and government related tweets (cluster (c) for Parramatta Rd.): including but not limited to street parking, new constructions' noise pollution, public transport, and housing. Tweet examples follow:

*What's wrong with people? This is Parramatta Road, not a quiet Annandale back street!! They should address the parking issues*

*Somethings needs to be done to deal with noise emanating from the building sites in Parramatta, but sheesh... if you can't build there, where can you build?*

*Councils across the country are spending more than 1bn putting people in temporary accommodation because we don't have enough houses and I'm sure there's nothing better we could spend that money on.*

*The worst part of Sydney is definitely the overabundance of 413 and 431 buses. I'm just trying to get down Parramatta road*

*Very cool that a 40 min bus ride can take me between two European capital cities, while it takes 40 mins just to get down f\*\*\*\* Parramatta road*

There is a broader diversity of topic discussed in the Parramatta Road tweets in comparison to the patterns observed in the Five Dock tweets. This is not unexpected, and relates to the intensity and complexity of issues experienced in Parramatta Road versus Five Dock which is literally a low-profile local project. Having said, there is still specific and detailed information captured among Five Dock tweets that could be valuable – especially if presented and responded to in ‘real-time’ or ‘near-real-time’ basis. Below is an example, which reports a potential break down in the road system:

*Some buses travelling through Five Dock and Haberfield are delayed up to 20 minutes due to heavy traffic on Parramatta Rd and Ramsay Rd!!*

In sum, the preliminary findings show great potential for further investigations of topic areas discussed by citizens in their tweets and to better understand the topics of concern that require responses from government. Especially real-time analysis of tweets has the potential to inform the government on the burning issues in need of immediate action. Moreover, we also see potential for longitudinal analysis as it may reveal more information on the triggers of positive or negative reactions from citizens, or explain how public opinions shift over time about a certain urban project or issue.

## **5. Conclusion: What We Learned and Where to Go from Here**

To date we have used machine learning methods to extract overall sentiments on the urban projects at the core of our study. While sentiment analysis is able to provide an overall idea of positive or negative opinions on the projects, a deeper look at the data for its content was required. Thus, we used a second set of machine learning methods (sentiment analysis and cluster analysis) to extract primary latent topics in the data. These reveal, along with the positive and negative sentiments, the areas of primary concern for the public.

The analysis reveals that the rate of participation is low, but meaningful. A very small portion of population have so far participated in the online conversations on the urban projects at the core of our study. But those who do participate often leave meaningful observations that have the capacity to inform the decision-making process. Our future steps for the study are three folded:

First, we are in the process of advancing our data analytics. The next step is to re-apply sentiment analysis to the tweets classified by topics. The aim is to unravel specific positive and negative sentiments on different dimensions of the projects. This next analysis step will also enhance our understanding of the specific topic areas of concerns for the citizens which need immediate response from the government.



Second, we are in the process of a dashboard design to feed back our analysis of citizen voices and concerns, and at time suggestions to the local government to inform decision making processes and outcomes. The proposed interactive dashboard will visually present the 'real time' or 'near real time' data to citizens and local government. Indeed, the next steps of the research project funded by the Australian Government, includes consultations with the local government partners as part of the dashboard design process. The proposed interactive dashboards will provide further opportunities to test the reliability and quality of social media data; and to explore the role that it can play as a representative data source for capturing public opinions on urban projects in 'real time' or 'near-real time'.

Last but definitely not least, we are hoping to expand our study to a larger network of local governments, including a wider diversity of urban projects in different contexts. If anything, our preliminary findings have presented an exciting potential for passive crowdsourcing via social media platform to enhance our understanding of what matters to citizens in terms of each urban project. Building a larger network of local governments will enable responsive urban decision making based on an informed understanding of citizens' concerns and priorities. This will then enable participatory planning which is socially responsible and respectful to the diversity of citizen voices captured online.

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**RESILIENT CITY**



# THE INFLUENCE OF LANDSCAPE ARCHITECTURE ON LANDSCAPE CONSTRUCTION HEALTH AND SAFETY

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## Summary

The influence of design on construction H&S is well documented in literature, as the concept and practice of 'designing for construction H&S'. However, there is a paucity of literature relative to landscape construction H&S and none relative to the influence of landscape architecture on landscape construction H&S. Furthermore, no research has been conducted relative to this subject area, despite landscape construction entailing exposure to numerous hazards and risks. Given the status quo, a quantitative study was conducted among members of the Institute of Landscape Architects South Africa (ILASA), the objectives of the study being to determine, among other, perceptions, and practices of landscape architects relative to landscape construction H&S. The salient findings include: site handover, site meetings, and site inspections / discussions predominate in terms of the frequency landscape construction H&S is considered / referred to on various occasions; method of fixing predominates in terms of the frequency construction H&S is considered / referred to relative to design related aspects; position of components predominates in terms of the extent design related aspects impact on landscape construction H&S; tertiary landscape architecture education addresses landscape construction H&S to a minor extent; respondents rate their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills as poor, and experience predominates in terms of respondents' acquisition of knowledge of landscape construction H&S. Conclusions include: respondents are committed to landscape construction H&S, however they are lacking in knowledge; the extent to which respondents perceive landscape architecture impacts on landscape construction H&S indicates inadequate knowledge; the ratio of action in terms of consideration of / reference to landscape construction H&S as a percentage of perceived impact of landscape design thereon indicates that there is potential to enhance such consideration / reference; respondents appreciate the potential of interventions to improve landscape construction H&S, and the extent to which landscape architectural programmes address landscape construction H&S reflects inadequate commitment thereto on the part of the related stakeholders. Recommendations include: tertiary education landscape architectural programmes should include appropriate 'designing for landscape construction H&S' modules as a component of a subject – probably design. The ILASA should develop practice notes relative to landscape construction H&S, and the South African Council for the Landscape Architectural Profession (SACLAP) should include construction H&S in their six work stages as per the identity of work (IoW) in a more comprehensive manner.

Keywords: construction, health and safety, influence, landscape architects

## 1. Introduction

The definition of 'designer' in the South African Construction Regulations (Republic of South Africa, 2014) includes, *inter alia*, a landscape architect. The Construction Regulations require designers to, *inter alia*, modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S, and consider hazards relating to subsequent maintenance of the structure and make provision in the design for that work to be performed to minimise the risk. This alludes to the term 'designing for safety', which Behm (2006) defines as "The consideration of construction site safety in the preparation of plans and specifications for construction projects." Thorpe (2006) in turn contends that design is an important stage of projects, as it is at this stage that conceptual ideas are ideally converted into constructable realities. Thorpe (2006) further states that designing for safety is one of a range of considerations that need to be balanced simultaneously during design.

However, there is a paucity of literature pertaining to landscape construction H&S, and the role of landscape architecture in landscape construction H&S. Given this paucity, a study was undertaken, the objectives being to determine the:

- frequency at which landscape architectural practices consider landscape construction H&S on various occasions, and relative to various design related aspects;
- extent to which various design related aspects impact on landscape construction H&S;
- potential of various interventions to contribute to an improvement in landscape construction H&S;
- means by which landscape construction H&S knowledge is gained, and
- landscape architects' rating of their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills.

## 2. Review of the Literature

### 2.1. Health and Safety legislation and recommendations pertaining to designers

In terms of the South African Construction Regulations (Republic of South Africa, 2014), clients and designers have responsibilities with respect to construction H&S.

Clients are required to, *inter alia*, prepare an H&S specification based on their baseline risk assessment (BRA), which is then provided to designers. They must then ensure that the designer takes the H&S specification into account during design, and that the designers carry out their duties in terms of Regulation 6 'Duties of designers'. Thereafter, clients must include the H&S specification in the tender documentation, which in theory should have been revised to include any relevant H&S information included in the designer report as discussed below.

Designers in turn are required to, *inter alia*: consider the H&S specification; submit a report to the client before tender stage that includes all the relevant H&S information about the design that may affect the pricing of the work, the geotechnical-science aspects, and the loading that the structure is designed to withstand; inform the client of any known or anticipated dangers or hazards relating to the construction work, and make available all relevant information required for the safe execution of the work upon being designed or when the design is changed; modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S, and consider hazards relating to subsequent maintenance of the structure and make provision in the design for that work to be performed to minimize the risk. To mitigate design originated hazards, requires hazard identification and risk assessment (HIRA) and appropriate responses, which process should be structured and documented.

Despite the requirements of H&S legislation relative to clients and designers, in general, the related statutory councils' respective identities of work (IoW) record limited H&S deliverables (Deacon, 2016). The point with respect to the respective IoW is that in general, the deliverables inform with respect to the competencies of practitioners and graduates. In the case of the South African Council for the Landscape Architectural Professions (SACLAP) (2011), the reference to H&S is as follows: Stage 1 'Project Initiation and Briefing' - nil; Stage 2 'Concept and Feasibility' - advise the client regarding the appointment of an H&S consultant where necessary; Stage 3 'Design and Development'; Stage 4 'Tender Documentation and Procurement' – nil; Stage 5 'Construction Documentation and Management' - where the compliance of landscape contractors could be monitored in accordance with the requirements of the H&S consultant, and Stage 6 'Project Close Out' – nil.

Furthermore, the International Labour Office (ILO) (1992) recommends that designers should: receive training in H&S; integrate the H&S of construction workers into the design and planning process, and not include anything in a design which would necessitate the use of dangerous structural or other procedures or hazardous materials which could be avoided by design modifications or by substitute materials.

## 2.2. Landscape Construction H&S

The Occupational Safety and Health Administration (OSHA) in the United States of America (USA) identified landscape and horticultural services, which include, inter alia, landscape construction, as one of the most hazardous industries in the USA. Potential hazards include: motor vehicle and other equipment accidents; ergonomic injuries such as back strains; exposure to noise, heat, cold, chemicals, and insects; amputations; slips, trips and falls; eye injuries, and electrocutions (Integrity Insurance, 2013).

## 2.3. Statistics

Table 1 provides an overview of landscape gardening injury statistics for the years 2008 to 2014 (Federated Employers Mutual, 2015). The mean accident frequency rate of 1.71 indicates that 1.71 per 100 workers experience a disabling injury, which results in a loss of a shift or more after the day of the injury. The highest is 2.04 relative to 2010. The mean for all classes is 3.13, the highest being 3.86 relative to 2008. Then, the fatality rate for the year 2010 equates to 25.8 per 100 000 workers  $[(100\ 000 / 7\ 755) \times 2]$ , which is high.

*Table 1 Landscape gardening injury statistics for the years 2008 to 2014*

Year	Accident frequency rate	Employees (No.)	Accidents (No.)	Fatal accidents (No.)
2008	1.83	8 898	163	0
2009	1.80	9 025	162	2
2010	2.04	7 755	158	2
2011	1.57	8 010	126	0
2012	1.66	8 749	145	0
2013	1.61	8 466	136	2
2014	1.44	8 430	121	0
Mean	1.71			

## 3. Research Method

A previous study conducted among engineers in South Africa to determine their perceptions and practices with respect to construction H&S investigated the: frequency at which construction H&S

is considered on various occasions, and relative to various design related aspects; extent to which various design related aspects impact on construction H&S; sources of H&S knowledge, and the potential of various aspects to contribute to an improvement in construction H&S (Smallwood, 2004). The study reported on constitutes a replication of this prior study, which study in turn constitutes the origin of the occasions, aspects, and sources. Given that it is landscape oriented, some amendments were necessary.

The questionnaire consisted of primarily closed end five-point Likert scale type questions – 10 / 13 questions were closed end. The questionnaire, accompanied by a covering letter explaining the rationale for the study, was forwarded per e-mail to 139 members of the ILASA. 21 Responses were included in the analysis of the data, which equates to a net response rate of 15.1%. A follow up e-mail was sent after a few weeks in an endeavour to enhance the response rate, but with limited success. Possible reasons for the response rate include the subject relative to the practice of landscape architectural design, namely landscape construction H&S.

Descriptive statistics in the form of frequencies and a measure of central tendency in the form of a mean score (MS) were computed to present the findings of the empirical study. The MS is based upon a weighting of the responses to the five-point Likert scale type questions, and ranges from a minimum of 1.00 to a maximum of 5.00. The MS thus enables the range of percentage responses to be interpreted, and parameters, occasions, aspects, and interventions to be ranked. Due to the number of responses, inferential statistical analysis was not possible.

#### 4. Research Findings

Table 2 presents the importance of eleven project parameters to respondents in terms of percentage responses to a range of 1 (not) to 5 (very), and a MS ranging between 1.00 and 5.00. It is notable that all eleven MSs are above the midpoint of 3.00, which indicates the parameters are more than important, as opposed to less than important.

It is notable that 6 / 11 (54.6%) parameters' MSs are  $> 4.20 \leq 5.00$  – between near major to major / major importance. The environment (natural) ranked third, and public H&S ranked fifth are within this range. The remaining 5 / 11 (45.4%) MSs are  $> 3.40 \leq 4.20$  – between important to more than important / more than important. Project H&S ranked eighth is in this range. It is notable that the MS of public H&S is 4.45, and for project H&S 3.90 – an absolute difference of 0.55, and the former is 19% more important than the latter.

*Table 2 Importance of project parameters to respondents*

Parameter	Response (%)						MS	Rank
	Un sure	Not ..... Very						
		1	2	3	4	5		
Client satisfaction	0.0	0.0	0.0	4.8	9.5	85.7	4.81	1
Project quality	0.0	0.0	0.0	0.0	23.8	76.2	4.76	2
Environment (natural)	0.0	0.0	0.0	5.0	20.0	75.0	4.70	3
Designer satisfaction	0.0	0.0	0.0	4.8	38.1	57.1	4.52	4
Public H&S	0.0	0.0	0.0	5.0	45.0	50.0	4.45	5
Project cost	4.8	0.0	0.0	4.8	38.1	52.4	4.29	6
Project schedule	0.0	0.0	4.8	28.6	28.6	38.1	4.00	7
Project H&S	0.0	0.0	4.8	28.6	38.1	28.6	3.90	8
Contractor satisfaction	0.0	0.0	5.0	25.0	60.0	10.0	3.75	9
Worker satisfaction	4.8	4.8	4.8	28.6	47.6	9.5	3.55	10
Labour productivity	4.8	4.8	0.0	33.3	42.9	14.3	3.48	11



Table 3 presents the frequency at which landscape architects consider / refer to landscape construction H&S relative to fourteen occasions, in terms of a frequency range, never to always, and a MS ranging between 1.00 and 5.00. It is notable that 9 / 14 (64.3%) MSs are above the midpoint of 3.00, which indicates consideration of / reference to landscape construction H&S relative to these occasions can be deemed to occur.

It is notable that no occasions are  $> 4.20 \leq 5.00$  – between often to always / always, however, 5 / 14 (35.7%) are  $> 3.40 \leq 4.20$  – between sometimes to often / often. It is notable that the top three ranked occasions are downstream during Stage 5, namely site handover, site meetings, and site inspections / discussions. Then fourth ranked preparing project documentation, and pre-tender meeting are Stage 4 occasions. Those occasions ranked sixth to twelfth (50%) have MSs  $> 2.60 \leq 3.40$  – between rarely to sometimes / sometimes. Evaluating tenders, and pre-qualifying contractors are Stage 4 occasions, whereas constructability reviews, detailed design, working drawings, client meetings, and design coordination meetings are Stage 3 occasions. Client meetings also occur during Stage 1 and 2. Deliberating project duration and concept (design) have MSs  $> 1.80 \leq 2.60$ , and thus the frequency is between never to rarely / rarely. The former occurs during Stages 1, 2, 3 and 4. The latter is a Stage 2 occasion.

*Table 3 Frequency of consideration / reference to landscape construction H&S on various occasions*

Occasion	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Site handover	9.5	0.0	9.5	9.5	28.6	42.9	4.16	1
Site meetings	4.8	0.0	4.8	14.3	38.1	38.1	4.15	2
Site inspections / discussions	0.0	0.0	4.8	14.3	42.9	38.1	4.14	3
Preparing project documentation	0.0	9.5	0.0	23.8	38.1	28.6	3.76	4
Pre-tender meeting	4.8	0.0	23.8	19.0	23.8	28.6	3.60	5
Evaluating tenders	9.5	4.8	14.3	33.3	23.8	14.3	3.32	6
Constructability reviews	9.5	4.8	23.8	23.8	28.6	9.5	3.16	7
Pre-qualifying contractors	4.8	9.5	23.8	23.8	23.8	14.3	3.10	8
Detailed design	0.0	14.3	14.3	33.3	28.6	9.5	3.05	9
Working drawings	0.0	19.0	14.3	38.1	14.3	14.3	2.90	10
Client meetings	0.0	0.0	52.4	19.0	19.0	9.5	2.86	11
Design coordination meetings	0.0	9.5	23.8	52.4	9.5	4.8	2.76	12
Deliberating project duration	4.8	23.8	23.8	28.6	14.3	4.8	2.50	13
Concept (design)	0.0	9.5	57.1	14.3	19.0	0.0	2.43	14

Table 4 provides a comparison of the frequency at which landscape architects consider / refer to landscape construction H&S relative to design related aspects and the impact of the aspects on landscape construction H&S in terms of MSs, ranks, and the ratio of consider (Con.) to impact (Imp.). The table reflects action as a percentage of perceived impact. The 'impact' MSs are greater than the 'consider' MSs in 12 / 19 (63.2%) cases, and lower in 7 / 19 (36.8%) of cases. In terms of the lowest ratio, the greatest difference is relative to content of material (0.84) and design (general) (0.84), followed by position of components (0.89). In terms of the highest ratio, the greatest extent is relative to surface area of materials (1.55), followed by mass of vegetation / features (1.33), and edge of materials (1.21).

Table 5 presents the potential of interventions to contribute to an improvement in landscape construction H&S in terms of percentage responses to a range of 1 (minor) to 5 (major), and a

MS ranging between 1.00 and 5.00. It is notable that 11 / 13 (84.6%) MSs are above the midpoint of 3.00, which indicates the interventions have major as opposed to minor potential to contribute to an improvement. 'D' denotes design, and 'C' construction.

It is notable that only 2 / 13 (15.4%) interventions' MSs are  $4.20 \leq 5.00$  – between near major to major / major potential – awareness (D & C), and safe work procedures (SWPs) (C). 4 / 13 (30.8%) MSs are  $3.40 \leq 4.20$  – between potential to near major / near major potential - contractor planning (C), design of equipment (construction) (C), constructability

*Table 4 Comparison of the frequency at which landscape architects consider / refer to landscape construction H&S relative to design related aspects and the impact of the aspects on landscape construction H&S*

Design related aspect	Consider		Impact		Con. / Imp.
	MS	Rank	MS	Rank	
Position of components	3.33	3	3.62	1	0.89
Method of fixing	3.55	1	3.24	2	1.14
Content of material	2.88	9	3.24	3	0.84
Specifications e.g. hard surfaces	3.29	4	3.19	4	1.05
Details	2.95	7	3.10	5	0.93
Edge of materials	3.35	2	2.95	6	1.21
Position of vegetation / features	2.95	6	2.86	7	1.05
Design (general)	2.55	13	2.85	8	0.84
Finishes	2.95	8	2.70	9	1.15
Mass of materials	2.82	10	2.67	10	1.09
Plan layout	2.48	16	2.58	11	0.94
Elevations	2.38	18	2.53	12	0.90
Method of planting	2.60	12	2.50	13	1.07
Schedule	2.50	15	2.47	14	1.02
Texture of materials	2.50	14	2.45	15	1.03
Surface area of materials	3.19	5	2.41	16	1.55
Mass of vegetation / features	2.80	11	2.35	17	1.33
Texture of vegetation / features	2.26	19	2.28	18	0.98
Content of vegetation	2.47	17	2.21	19	1.21

In summary: one 'D&C' and one 'C' have between near major to major / major potential; two 'C' and two 'D' have between potential to near major / near major potential, and two 'C', two 'D & C', and three 'D' have between near minor potential to potential / potential.

In theory and practice, all the interventions have the potential to contribute to an improvement in landscape construction H&S.

*Table 5 Potential of interventions to contribute to an improvement in landscape construction H&S*

Intervention	Response (%)						MS	Rank
	Un-sure	Minor ..... Major						
		1	2	3	4	5		
Awareness (D & C)	0.0	0.0	0.0	9.5	47.6	42.9	4.33	1
Safe working procedures (C)	0.0	0.0	4.8	14.3	28.6	52.4	4.29	2
Contractor planning (C)	0.0	4.8	4.8	19.0	38.1	33.3	3.90	3
Design of equipment (construction) (C)	23.8	4.8	4.8	14.3	28.6	23.8	3.81	4
Constructability (general) (D)	0.0	4.8	9.5	28.6	33.3	23.8	3.62	5
Specification (D)	0.0	0.0	14.3	33.3	38.1	14.3	3.52	6
Workshop facilities on site (C)	9.5	9.5	9.5	28.6	28.6	14.3	3.32	7
Design of tools (C)	19.0	14.3	0.0	23.8	33.3	9.5	3.29	8
Mechanisation (D & C)	14.3	9.5	9.5	28.6	23.8	14.3	3.28	9
Reengineering (D & C)	23.8	4.8	9.5	38.1	9.5	14.3	3.25	10
Details (D)	0.0	9.5	9.5	38.1	38.1	4.8	3.19	11
General design (D)	0.0	14.3	23.8	33.3	19.0	9.5	2.86	12
Prefabrication (D)	9.5	14.3	9.5	47.6	14.3	4.8	2.84	13

(general) (D), and specification (D). The remaining 7 / 13 (53.9%) interventions have MSs  $> 2.60 \leq 3.40$  – between near minor potential to potential / potential. 5 / 7 MSs are in the upper half of this range - workshop facilities on site (C), design of tools (C), mechanisation (D & C), reengineering (D & C), and details (D).

Respondents were required to rate their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills in terms of percentage responses to a scale of 1 (limited) to 5 (extensive). The MS of 3.00 indicates the rating is between near limited to average / average as the MS is  $> 2.60 \leq 3.40$ .

Respondents were required to indicate the extent tertiary landscape architecture education addresses landscape construction H&S in terms of percentage responses to a scale of 1 (minor) to 5 (major). The resultant MS of 2.15 indicates the extent is between a minor extent to near minor / near minor extent, as the MS is  $> 1.80 \leq 2.60$ .

It is notable that 42.9% of respondents identified 'A subject construction H&S', and 23.8% each of 'Included in a range of subjects', and 'Included in the subject design' (Table 6).

*Table 6 Form in which landscape construction H&S should be addressed in landscape architecture programmes*

Form	Yes (%)
A subject 'construction H&S'	42.9
Included in a range of subjects	23.8
Included in the subject 'design'	23.8
Unsure	9.5
Not at all	0.0

In terms of respondents' source of landscape construction H&S knowledge, 95.2% identified experience, followed by magazine articles (38.1%), and tertiary education (23.8%) (Table 7). The seven other sources were identified by less than 20% of the respondents.

*Table 7 Respondents' source of landscape construction H&S knowledge*

Means	Yes (%)
Experience	95.2
Magazine articles	38.1
Tertiary education	23.8
Workshops	19.0
Practice notes	14.3
Postgraduate qualifications	14.3
CPD Seminars	9.5
Other: H&S Act	4.8
Journal papers	4.8
Conference papers	4.8

## 5. Conclusions

The traditional project parameters of cost, quality, and time are more important than project H&S, which indicates that landscape architects' perceptions reflect those of built environment designers, and other stakeholders. However, public H&S is substantially more important than project H&S, which reflects an awareness of the impact of the landscaped environment on the users in the form of the public.

Landscape construction H&S is considered / referred to on various occasions mostly to a major as opposed to a minor extent, and relative to design related aspects mostly to a minor as opposed to a major degree, which indicates a degree of commitment to landscape construction H&S, and inadequate knowledge. There is minor as opposed to major appreciation in terms of the extent design related aspects impact on landscape construction H&S, which indicates inadequate knowledge. Then, the ratio of action in terms of consideration of / reference to landscape construction H&S as a percentage of perceived impact of landscape design thereon indicates that there is potential to enhance such consideration / reference.

There is major as opposed to a minor degree of appreciation of the potential of interventions to contribute to an improvement in landscape construction H&S.

Landscape architectural programmes address landscape construction H&S to a limited extent, which indicates that: the presenters of such programmes are likely not committed thereto; ILASA and SACLAP are not engendering the inclusion thereof in such programmes; ILASA and SACLAP are not interrogating the degree to which it addressed in such programmes during accreditation panel visits, and ILASA and SACLAP are likely not commitment thereto.

Respondents' self-rating of their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills, and the level of acknowledgment relative to experience as the source of landscape construction H&S knowledge further confirms that landscape architectural programmes address landscape construction H&S to a limited extent.

## 6. Recommendations

Recommendations include tertiary education landscape architectural programmes should include appropriate 'designing for landscape construction H&S' modules as a component of a subject - ideally design. The ILASA should develop practice notes relative to landscape construction H&S, and the SACLAP should make more comprehensive reference to construction H&S in their six work stages of their IOW. Furthermore, SACLAP accreditation reviews of tertiary education landscape

architectural programmes should interrogate the extent to which landscape construction H&S is addressed, or rather embedded in such programmes. Both ILASA and SACLAP should actively promote landscape construction H&S-related continuing professional development (CPD).

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# TOWARDS A CIRCULAR ECONOMY IN THE BUILT ENVIRONMENT: AN INTEGRAL DESIGN FRAMEWORK FOR CIRCULAR BUILDING COMPONENTS

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## Summary

The building sector consumes 40% of resources globally, produces 40% of global waste and 33% of emissions. The Circular Economy (CE) proposes an alternative to the current linear economy by decoupling economic growth from resource consumption. In a circular built environment resource depletion and waste generation are minimised, and materials are circulated at their highest utility and value. Buildings consist of many components such as kitchens and facades which could be replaced by 'circular components' during maintenance and renovation, thus allowing a bottom-up implementation of the CE within the built environment. To support industry in the development of such components an integral design framework is needed, including technical, supply chain and business specifications. Current frameworks do not suffice, as they are either fragmented (addressing only the business model or technical design) or are not developed for the building sector. In this paper, we present a framework to support industry in the integral design of circular components. The framework was developed in three stages. First, through a literature review, existing circular design frameworks were identified. Second, by combining and specifying these frameworks, the Circular Building Components Generator (CBC-Generator) was developed. Finally, the CBC-generator was tested in the development of an exemplary component: The Circular Kitchen (CIK). The CBC-Generator is a three-tiered design tool, consisting of a technical, industrial and business model generator. The generators are 'parameter based': consisting of a design template and option-matrix. By filling the templates through systematically 'mixing and matching' the options of each parameter, different variants for circular components can be formed. Employing the CBC-generator, TU Delft, AMS-institute, housing associations and industry partners developed the CIK. The CIK consists of a dockingstation in which kitchen modules can be plugged in and out. The modules consist of a frame to which 'function modules' (appliances) and 'style packages' (front, countertop) can be easily attached, using click-on connections. The professional side of the business model applies a purchase with take-back model including circular KPI's and service subscriptions. A dealer offers extra kitchen modules and style packages to tenants through a variety of financial arrangements that motivate returning the product after use, including lease and sale-with-deposit options. After use, the kitchen producer and dealer 're-loop' the dockingstation, kitchen modules, parts and materials in a 'Return factory' and local 'Return streets'. The CBC-generator successfully supports the integral design of circular components: (1) it provides all the design parameters which should be considered; (2) it gives various design options per parameter; (3) the generator supports systematic synthesis of design options to a cohesive and comprehensive circular design. Further development can contribute to establishing causal links between 'parameter-options', and identification of 'the most circular variant' in terms of both environmental burden and Total Costs of Ownership/Use.

Keywords: circular economy, design framework, building components, circular kitchen

## 1. Introduction

The building sector consumes 40% of natural resources globally, produces 40% of global waste and 33% of emissions (Ness & Xing, 2017) the pursuit of sustainable buildings is dominated by a focus on carbon neutrality and green, often overlooking resource consumption and its contribution to greenhouse gas emissions and planetary degradation. Accordingly, this article seeks to highlight the importance of a resource-efficient built environment, which enables required functions to be delivered with less assets, and to put forward an approach toward this objective. In this regard, the circular economy (CE). Due to its high impacts, the transition to a circular built environment is pivotal to achieve a resource 'effective' and sustainable society. The Circular Economy (CE) proposes an alternative model to the current linear '*take-make-use-dispose*' economic model. The CE can be summarised in the following three principles (Ellen MacArthur Foundation, 2012): (1) preserving and enhancing natural capital by controlling finite stocks and balancing renewable resource flows; (2) optimizing resource yields by circulating products, components, and materials at their highest utility and value at all times in both technical and biological loops and (3) fostering system effectiveness by revealing and designing out negative externalities.

Looking at current practice in the building sector, the emphasis is still very much on how to deal with waste, or 'recycling', which is the outer loop of the CE. However, a main principle of CE is to first make optimal use of the inner loops such as 'maintain', 'reuse', and 'remanufacture', and thus to prevent waste. Looking at the built environment, maintenance and renovation of buildings is then by definition a way to make use of the inner loops of the CE. However, maintenance and renovation currently does not contribute to making the housing stock itself (e.g. components and material) more circular. Buildings consist of many components such as climate installations, kitchens, bathrooms and facades, which could be replaced by 'circular building components' during the natural maintenance and renovation moments. This would create an opportunity for a bottom-up implementation of circularity in the built environment without needing a complete overhaul of the system.

The theory of circularity in the built environment is still developing and circular design frameworks applicable for the built environment are a paucity. To facilitate development, and subsequently the implementation of circular components in the built environment, professionals (e.g., architects, manufacturers, contractors) would benefit from a specific framework which can support choices concerning for example material use, composition of the supply chain and financial engineering. Many researchers in the field agree that such a framework would require a systemic and integral approach to ensure the designed component is (used) circular along and beyond their life cycle (Bocken, et al., 2016; Geldermans, 2016; Mendoza, et al., 2017; Mestre & Cooper, 2017; Saidani, et al., 2017). In an integral design a technical model, business model, and industrial model should be developed in cohesion with each other (Bocken et al., 2016). This paper presents a design framework to support the integral development of circular building components, including design of the following: (1) technical model (referring to aspects such as shape, construction and materialisation); (2) industrial model (referring to the composition of the supply chain); (3) business model (referring to aspects such as finance and economic feasibility).

## 2. Method

The framework has been developed in three stages.

The research stage, presented in section 3.1, consisted of an analysis of existing circular design frameworks. The review considered peer-reviewed, conference as well as professional circular design frameworks. The articles were identified through Web of Science and Google Search engines using the following keywords: 'circular economy' and 'design' and 'framework', 'method' or 'tool'. From the search results, only articles that are concerned with a framework which supports the design of a circular technical, industrial and/or business model of an artefact and/or service and/or organisation, and (specifically) offers support in the synthesis of a design proposal were included. De Koeijer, Wever & Henseler (2017) summarise two main types of circular design

tools and models: generative and evaluative, based on the tools' applicability in the front-end or back-end of the product development process, respectively (Bocken, et al., 2014; Bovea & Pérez-Belis, 2012; de Koeijer et al., 2017; Fitzgerald, et al., 2005; Telenko, et al., 2008). Both generative and evaluative design frameworks are important to fully support circular design. Yet, generative tools offer the initial support in synthesis of design variant(s) and, therefore, are the focus of this paper.

An aspect analysis was performed on the selected frameworks to identify gaps and employable elements for the development of the circular design framework. Three aspects were analysed: (I) scale on which the model can be applied. The CE can be applied at the macro (country, region, municipalities and urban agglomerates), meso (network, eco-parks and buildings) and micro (company, product and building components) level (Geng, et al., 2012; Pomponi & Moncaster, 2017). (II) The type of design support offered in the model, distinguishing: (1) guidelines, (2) design criteria, (3) checklists, (4) step-by-step guide, (5) design canvas, (6) archetypes, (7) strategies, (8) parameters, (9) options and (10) examples. (III) The type of model for which the framework offers design support: business model, technical model or industrial model.

In the second stage, the identified employable elements from analysed design frameworks were adapted, built upon and specified using additional data from scientific, secondary literature and brainstorming to propose a design framework for supporting the integral development of circular building components (section 3.2). In the third stage (section 3.3), the proposed design framework was tested through application in the development of an exemplary building component: The Circular Kitchen. In section 4, we reflect upon the resulting framework and the conclusions are summarised in section 5.

### 3. Results

#### 3.1. Literature Review

Using the selected keywords and the developed selection criteria, 30 of the found frameworks were regarded admissible. For the results of the aspect analysis, see table 1.

*Table 1 Results aspect analysis circular design frameworks*

Source	Name framework	Scale			Type of support										Discipline		
		MA	ME	MI	1	2	3	4	5	6	7	8	9	10	TM	IM	BM
(Achterberg, Hinfelaar, & Bocken, 2016)	The value hill			x				x					x				x
(Antikainen & Valkokari, 2016)	Framework for sustainable business model innovation			x					x			x			~	~	x
(Bakker, et al., 2014)	Products that last - framework			x						x	x			x	x		x
(Bocken et al., 2016)	Circular design framework			x						x	x			x	x		x
(Ellen MacArthur Foundation & IDEO, 2017)	Circular design guide			x				x	x	~	~			x	x		x
(Ellen MacArthur Foundation, 2015)	ReSOLVE framework			x							x		~	x	x		x
(Ellen MacArthur Foundation, 2013)	New framework on circular design			x								~		~		~	x
(Evans & Bocken, 2014)	Circular economy toolkit			x							x			x	x		x
(Fischer & Achterberg, 2016)	10 steps to create a circular business model			x				x				x					x

Legend: x (yes), ~ (in part)

Source	Name framework	Scale			Type of support										Discipline		
		MA	ME	MI	1	2	3	4	5	6	7	8	9	10	TM	IM	BM
(Forum for the Future & Novelis, n.d.)	Design for demand			x				x	x	x	~				x		x
(Forum for the Future & Unilever, n.d.)	Circular business model toolkit			x						x				x	~		x
(Geldermans, 2016)	Circular building matrix and new-stepped strategy		x	x				x	x						x		
(Gerritsen, 2015)	Circular design checklist			x		x	x						x		x		
(Gispen, n.d.)	Design framework			x			x					x	~		x	x	
(Goldsworthy, 2017)	Speedcycle			x						x		x			x		
(Joustra, de Jong, & Engelaer, 2013)	Guided choices towards a circular business model			x				x			~	x	~	x	~		x
(Leising, et.al, 2018)	Collaboration tool for CE in the building sector		x		x			x							x	x	x
(Lewandowski, 2016)	Circular business model canvas			x					x			x					x
(Mentink, 2014)	Business cycle canvas			x					x			x				~	x
(Mestre & Cooper, 2017)	Multiple loop life-cycle design frame			x					x		x				x		
(Mendoza et al., 2017) and (Heyes, et al., 2018)	BECE framework			x			x	x	x						x	x	x
(Moreno, et al., 2016)	Circular design framework			x	x					x	x				x		x
(Nußholz, 2017)	Circular strategies embedded in the business model canvas			x					x			x					x
(Poppelaars, 2014)	Design framework			x	x			x					x		x		
(Van Dam, et al., 2017)	Circular Pathfinder			x							x			x	x		
(Scheepens, et al., 2016)	Circular transition framework for business model innovation towards a CE	x	x	x					x			x			x	x	x
(Sempels, 2014)	Sustainable business model canvas			x					x			x					x
(The Great Recovery & RSA, 2013)	Design tools for a circular economy			x						x					x		x
(van den Berg & Bakker, 2015)	Circular design framework			x							x		x		x		
(WIITHAA, n.d.)	Circulab board			x				x	x			x					x

Legend: x (yes), ~ (in part)

## Gaps and employable elements

From the analysis, several gaps are identified. Firstly, there is a paucity of frameworks which are developed for the 'meso' scale or buildings. The exceptions are the design frameworks developed by Geldermans (2016) and Leising et al. (2018). Secondly, although all of the frameworks recognise the need for a systemic and/or interdisciplinary approach, very few offer a convincing integrated framework; only Bakker, et al. (2014), Bocken, et al. (2016), Mendoza, et al. (2017), Monero, et al. (2016) and Scheepens, et al. (2016). Thirdly, there is a missing link between more comprehensive yet 'abstract' frameworks (e.g., Bakker et al., 2014; Bocken et al., 2016; Leising, et al., 2016; Scheepens, et al., 2017) and frameworks which offer (comprehensive) concrete design options. Finally, the business model and industrial model are often integrated as some parameters of these models overlap. Yet, in an integrated model the industrial side of these parameters is insufficiently considered (e.g., mode of transport, and location of activities are omitted).

Although none of the analysed frameworks provide complete integral design support for circular building components, they contain useful elements. First, the Circular Building Matrix by Geldermans (2016) contains a strong link between the meso and micro scale through the inventory matrix. It facilitates the unravelling of the building into elements of a system-tree, distinguishing the building, component, part and material level. It also facilitates the exploration of the circular potential of each element. Second, the majority of the analysed circular business model frameworks build on adapted versions of the business model canvas (Osterwalder & Pigneur, 2010), providing an employable set of design parameters. Third, the design framework as developed by Bocken, et al. (2016) contains the taxonomy of 'narrowing, slowing and closing loops', which offers a clear umbrella for circular design strategies. The integrated frameworks by Bakker, et al. (2014) and Bocken, et al. (2016) offer insight in how the technical, industrial and business model can be linked. Finally, the frameworks of Poppelaars (2014), van den Berg & Bakker (2015), and Gerritsen (2015) provide valuable concrete design options. Together, these elements have been employed in the development of the circular design framework.

### **3.2. Development of the Circular Design Framework: The CBC-Generator**

In this section, we present the design framework, building on elements of frameworks discussed in section 3.1: 'the Circular Building Components (CBC) Generator'.

The CBC-Generator is a three-tiered design tool, consisting of a technical, industrial and business model generator, which together support the integral design of circular building components. The three generators are based on the developmental parameters of the technical, industrial and business model for a circular component. For each parameter, different possible design options are provided, which can serve as the 'building blocks' to create the design. For each generator, the parameters and options are listed in a matrix. The matrix is complemented with a template to support the synthesis of design options. The design framework should be easy to use, to offer a true support for practice. For designers, utilising a visual language runs parallel to the process of using words, when synthesising a design (Van Dooren, et al., 2014). Hence, the generators were designed – and can be applied – using both textual and visual language. The tool is applicable in the different stages of a design process. A design process is characterised by an exponential information growth curve (Ullman, 2010, p.19). A tool meant to support the synthesis of a first design idea should not require detailed information of the designer. To ensure the tool supports synthesis in different design stages it includes three *modi operandi*.

#### **Modi operandi: from first idea to detailed circular design proposal**

The tool has three operational pathways: (1) 'ideate', (2) 'generate' and (3) 'refine', each supporting synthesis in a different stage of the design process. The *modi operandi* are organised in the design templates; each surpassing *modus operandi* requires the designer(s) to fill in more parts of the template and with a higher level of detail.

The first operational pathway, 'ideate', supports the development of first idea(s) for a circular building component design. The 'design template' is filled in by systematically 'mixing and matching' the design options of different parameters listed in the matrix. The outcome can be understood as a logical combination of technical, industrial and business model options which could be applied in a design (for an example see section 3.3). The design team is free to start from the technical, industrial or business model generator, based on their preference. However, it is encouraged to always use the generators in parallel to achieve an integral circular design.

The second operational pathway, 'generate', supports the generation of circular building component concept designs. The combination of design options, as selected in the ideation stage, are applied as building blocks and translated to a concept design. Additional design options can be selected from the matrices. Parts of the template which



are not yet relevant can be left blank, allowing a quick synthesis of design variants.

The third operational pathway, 'refine', supports the refinement of a circular building component design. The concept design is further detailed and refined to a comprehensive circular design proposal by completing and detailing all parts of the templates. The matrices can be consulted for additional options, and alternative options for parts of the design which were considered unfeasible or undesirable.

### The parameter-option matrices

The matrices include the parameters relevant for designing a circular technical, industrial and business model (see attachments B-D). The parameters were selected from the analysed design frameworks. For each parameter, various design options were specified.

The technical model matrix, employs elements (amongst all) from: Bakker, et al. (2014), Bocken, et al. (2016), van den Berg & Bakker (2015), Gerritsen (2015), Geldermans (2016) and Poppelaars (2014), and includes the following parameters: (1) *systemics* of the technical design. Referring to the unravelling of the building into elements (from building to component, to part to material). (2) The *material* used. (3) The *energy* used. (4) The *applied circular design strategy*. (5) The *expected lifespan* of a system element. (6) The *amount* of a system element measured in [pieces or m<sup>3</sup>].

Parameters which influence circularity of the industrial model were identified in the business model canvas (Osterwalder & Pigneur, 2010), and were complemented with industrial parameters used in an LCA assessment of products (Scheepens et al., 2016) and is capable to analyse circular systems, Product Service Systems, and systems for recycling. However LCA falls short of analysis of the added value of business models. Since new sustainable business models are part of the transition towards a circular economy, there is a need for combined analyses of value and eco-burden. This paper applies the LCA-based Eco-costs Value Ratio (EVR). The following parameters are included in the matrix: (1) The *key partners* in the supply chain. (2) *Activities* carried out by the partners, including their (re-)production processes. (3) *Key resources* needed in the supply chain. This includes the facility in which the activity takes place and the system elements (e.g., components, parts) which move through the supply chain. (4) Mode of *transport* in the supply chain. (5) Type of *process energy* used.

Parameters which influence circularity of the business models were found in the business model canvas (Osterwalder & Pigneur, 2010), and the circular business model frameworks by Mentink (2014), Lewandowski (2016) and Nußholz (2017). The following parameters are included in the matrix: (1) *Key partners* in the business model. (2) *Customer segments* in the business model (3) The *supply chain relations* between partners. (3) The *cost structure* per partner. (4) The *revenue streams* per product or service offered, including the financial arrangement (lease, sale, etc.). (5) The *value proposition* which specifies: the product or service proposition offered to the customer, the value delivery and capturing per partner. Value delivery clarifies how the product brings value to customers and value capturing how the business model brings value to a partner. Both are needed to align incentives within the supply chain, and it is this alignment that is crucial for the feasibility of the business model. (6) The *channels* used to reach the customer. (7) The *take-back systems* applied to ensure the return of *key resources* for re-looping (Lewandowski, 2016). (8) The *adoption factors* which determine how the business model can be implemented within the organisation of a partner, regulations and society (Lewandowski, 2016).

### The design templates

The matrices are complemented with a design template (see figure 1). How elaborate these templates need to be filled in is prescribed by the operational pathways 'ideate', 'generate' and 'refine'. The template consists of a table, whose use is twofold. First, it forms the frame in which options are systematically combined - applying them as building blocks - to form logical combinations for a design.

For these purposes the horizontal axis of this table lists several categories in which the selected options can be organised, according to how they contribute to achieving circularity. The categories apply the taxonomy of the circular design framework developed by Bocken, et al (2016): 'narrowing, slowing or closing resource loops'. Designing to 'narrow resource loops' aims to reduce resource use, or achieve resource efficiency. Designing to 'slow resource loops' aims to slow down the flow of resources through extension or intensification of the utilization period of the designed artefact. When a design is made to 'close resource loops', it is designed so all used materials are recycled at the end of life. This categorisation is further nuanced with the 9R model - (0) Refuse, (1) Rethink, (2) Reduce, (3) Re-use, (4) Repair, (5) Refurbish, (6) Remanufacture, (7) Repurpose, (8) Recycle and (9) Recover – as developed by Potting, et al. (2017) and van Buren, et al. (2016) this alone will not bring the circular economy to market or scale. In order for a circular economy to materialize, an integrated approach that focuses on a long-term system change or transition is required. To set the change process in motion, many (public and private). The vertical axis of the design table is used to list the technical, industrial or business model design, depending on the operational pathway, from its entirety to more and more specified per parameters.

IDEATE					NARROWING LOOPS			SLOWING LOOPS				CLOSING LOOPS		
	FILL IN NAME VARIANT HERE				REFUSE	RETHINK	REDUCE	RE-USE	REPAIR	REFURBISH	REMAN.	REPURPOSE	RECYCLE	RECOVER
	GOAL (✓ CHECK APPLICABLE GOAL)													
	CLARIFY THE CHOSEN OPTIONS HERE:			OPTIONS TO APPLY										
GENERATE + REFINE					NARROWING LOOPS			SLOWING LOOPS				CLOSING LOOPS		
	CATEGORY	#	ITEM(S)		REFUSE	RETHINK	REDUCE	RE-USE	REPAIR	REFURBISH	REMAN.	REPURPOSE	RECYCLE	RECOVER
	COMPONENT	1	FILL IN NAME HERE	APPLIED NARROWING LOOP OPTION										
	SUB-COMPONENT	1.1	FILL IN NAME HERE	APPLIED SLOWING LOOP OPTION										

Figure 1 Design template for the technical model generator

### 3.3. Testing the CBC-Generator: The Development of the Circular Kitchen

The CBC-Generator has been tested through application in the development of an exemplary building component: The Circular Kitchen (CIK), following the modi operandi ‘ideate’ (3.3.1), ‘generate’ (3.3.2) and ‘refine’ (3.3.3).

## **From a blank page to the first ideas: ideating a circular building component**

Applying the CBC-generator's operational pathway 'ideate' several ideas for circular kitchen design variants were developed. To illustrate how we have used the CBC-generator, we elaborate on the development of one of these ideas: 'The plug-and-play kitchen'.

The ideation process started by conceiving an inspirational direction (e.g., requirement, guiding theme, example) for the design variant. In this case, we started from the idea to make a kitchen which has a long life, can be recycled and, subsequently, saves resources. The parameter-option matrices were consulted by systematically looking at each parameter. Design options which helped to achieve the inspirational direction were selected. The technical model matrix was consulted first. Various design strategies to prolong the lifespan through re-use, repair, refurbishment, remanufacturing and recycling were selected. Subsequently, we turned to the accompanying business model, which needed to make the long-life design interesting to the manufacturer. From

the business model matrix, the options: ‘the manufacturer as owner’ and ‘revenue stream generated through service and updates’ were selected. Then, for the industrial model, options were selected for the various ‘re-loop’ activities, initiated by the manufacturer. The options were organised in the design template, creating a cohesive set of technical, industrial and business model options (see figure 2).





















IDEATE			NARROWING LOOPS			SLOWING LOOPS					CLOSING LOOPS	
	PLUG-AND-PLAY KITCHEN		REFUSE	RETHINK	REDUCE	RE-USE	REPAIR	REFURBISH	REMAN.	REPURPOSE	RECYCLE	RECOVER
	GOAL (Check applicable goal)		✓						✓ TECHNICAL LOOP			
	TECHNICAL MODEL	The technical design facilitates re-use, repair, refurbishment and remanufacturing through a modular design, separation of the components in support and risk, standardisation, updates and easy de- and re-assembly parts. Recycling is facilitated through separation of parts in biological or technological materials.	OPTIONS TO APPLY	       								
	INDUSTRIAL MODEL	The manufacturer, as owner of the kitchen throughout the life-cycle, initiates the various technical re-loops.	OPTIONS TO APPLY	   								
BUSINESS MODEL	The business model makes the long-life design interesting to the manufacturer, by placing the ownership of the kitchen with the manufacturer and by generating a revenue stream through service and updates.	OPTIONS TO APPLY	       									

Figure 2 Ideation design template for the technical, industrial and business model.

### Generating a concept design for the CIK

The combination of options for ‘the plug-and-play kitchen’ – as selected during ideation – were the starting point to ‘generate’ the CIK concept design. The selected options were applied as building blocks to develop an initial design for the CIK. Then, all the *system elements* (the component, sub-components, parts, and materials) of this initial design were placed on the vertical axis of the technical model design template, and the *key partners* of the initial design on the industrial and business model design templates. Per *system element* and *key partner*, the matrices were consulted. The options for each parameter were reviewed and additional design options were selected. The selected options were placed in the design templates, exploring how they could ‘narrow, slow or close the loops’ for each of the *system elements*, *key partners* and for the design as a whole (see figure 3). The ‘generate’ process was highly iterative: the exploration of circular potential would feed the design and, ultimately, help create a cohesive and comprehensive concept design for the CIK.

The synthesised CIK design facilitates various re-loops by separating parts based on *lifespan*. The kitchen consists of a docking station in which modules can be easily plugged in and out, allowing for future changes in lay-out. The kitchen modules themselves are also divided in a long-life frame to which ‘module infill’ (e.g., appliances) and ‘style packages’ (e.g., front, countertop, handles) can be easily attached using click-on connections. The high level of modularity and customisability of this design, allowed for additional opportunities in the business model, such as: diversification of *revenue streams* and enlargement of the targeted *customer segments*. The business model parameter-option matrix was reviewed and additional options were selected and applied in the design. In the business model, the kitchen manufacturer sells the docking station and base modules directly to the housing associations, with a take-back guarantee, maintenance subscription and circular KPI’s. This arrangement offers a clear incentive for the manufacturer to realise a kitchen which is easy to repair and to give a second life, or more. The extra modules and style packages are made available to users through financial arrangement such as lease and sale-with-deposit, that motivate returning the product at the end of their use cycle. The industrial model was aligned with the technical and business model. As the repair, re-use, refurbishment, and remanufacturing possibilities increased, the *mode of transport* and/or *location* of these re-loop processes became increasingly important to define. As the selected *transport* option relies on fossil fuels, options were selected from the matrix which reduce the distance between the user and the location where frequent re-loop activities take place. A local ‘Return-Street’ is introduced in which collected products are sorted to be traded, resold, lightly refurbished or sent back to the

kitchen manufacturer. Products that come back to the manufacturer are sorted in their national 'Return-Factory' to be refurbished, remanufactured or recycled.

GENERATE	PLUG-AND-PLAY KITCHEN			NARROWING LOOPS			SLOWING LOOPS					CLOSING LOOPS	
	CATEGORY	#	ITEM(S)	REFUSE	RETHINK	REDUCE	RE-USE	REPAIR	REFURBISH	REMAN.	REPURPOSE	RECYCLE	RECOVER
	COMPONENT	1	PLUG-AND-PLAY KITCHEN	Applied systems	Design for long life	1. The kitchen's lifespan is increased several times (>100 years) through facilitating re-use, repair, refurbishment, remanufacturing, by only replacing parts when needed the amount of material used (compared to a kitchen with a 20-year life-cycle) is reduced.	Design modular	Separate "support" and "soft"	1. The kitchen is a modular design consisting of kitchen modules (infit) which can be plugged in and out in a docking station (support), increasing flexibility in function and layout and so extending the kitchen's lifespan.				
	SUB COMPONENTS	1.1	DOCKINGSTATION	Applied systems			Company component standardisation	Industry measurement standardisation	Separate based on lifespan	Plan for standardisation for layout change	Allow customising for outfit		
				Re-use verification			1. Dockingstation can be easily re-used in another home due to standardisation of the dockingstation or added to accommodate change in the kitchen layout. 2. The dockingstation consists of 3 sub-subcomponents which are separated on lifespan: (1) constructive frame, (2) backplash style package and (3) flexible infrastructure. Sub-subcomponents with a shorter lifespan can be replaced during repair, refurbishment and remanufacturing preventing premature obsolescence.						
		1.2	KITCHEN MODULES	Applied systems			Company component standardisation	Industry measurement standardisation	Separate based on lifespan	Allow customising for outfit	Plan for standardisation for layout change		
				Re-use verification			1. Kitchen modules consists of 3 sub-subcomponents which are separated on lifespan: (1) module frame, (2) module infit, (3) the style package. Infit elements with a shorter lifespan can be replaced during purchase and can be replaced during repair, refurbishment and remanufacturing preventing premature obsolescence. 2. The modules are standardised allowing kitchen modules to be re-used (in other homes), or added to change the kitchen layout.						

Figure 3 Part of the technical model design template as filled in during 'generation'.

## Refining the CIK

The concept design of the plug-and-play kitchen was refined to a full design proposal. The design templates were completed and further detailed (see figure 4). In this process the design option matrices were reviewed to select additional options to complete parts of the templates which were previously left underdeveloped. Options, which were dismissed by the group, were reviewed with the parameter-option matrix and alternative options were selected. For example, to increase longevity, *the material* of the kitchen module frames was initially metal. For reasons of feasibility and poor environmental performance this material was dismissed. Alternative options were reviewed in the matrix and a (technical looped) wood was selected. For an image of the refined CIK, see attachment A.

REFINE	PLUG-AND-PLAY KITCHEN			NARROWING LOOPS			SLOWING LOOPS					CLOSING LOOPS	
	CATEGORY	#	ITEM(S)	REFUSE	RETHINK	REDUCE	RE-USE	REPAIR	REFURBISH	REMAN.	REPURPOSE	RECYCLE	RECOVER
	SUB-SUB-COMPONENT	1.2.3	STYLE PACKAGE	Applied systems	NO THRESHOLD	Optimise disassembly	Use materials efficient	Design for long life	Design for repair	Design for refurbishment	Design for remanufacturing	Design for recycling	Design for recovery
				Re-use verification	Make parts digital to reduce material	Use materials efficient	Design for long life	Design for repair	Design for refurbishment	Design for remanufacturing	Design for recycling	Design for recovery	
				Re-use verification	The frame and sides of the style package are designed to be easy to disassemble and reassemble. Material thickness can be reduced, reducing the total amount of material used.	The frame and sides of the style package are designed to be easy to disassemble and reassemble. Material thickness can be reduced, reducing the total amount of material used.	The style package can be reused. As parts are designed to be easy to disassemble and reassemble, they can be reused in other projects or as raw material for other products.	The style package can be reused. As parts are designed to be easy to disassemble and reassemble, they can be reused in other projects or as raw material for other products.	The style package can be reused. As parts are designed to be easy to disassemble and reassemble, they can be reused in other projects or as raw material for other products.	The style package can be reused. As parts are designed to be easy to disassemble and reassemble, they can be reused in other projects or as raw material for other products.	The style package can be reused. As parts are designed to be easy to disassemble and reassemble, they can be reused in other projects or as raw material for other products.	The style package can be reused. As parts are designed to be easy to disassemble and reassemble, they can be reused in other projects or as raw material for other products.	

Figure 4 Part of the technical model design template filled in during 'refinement'

## 4. Discussion

The example of the CIK shows that the CBC-generator can support integral synthesis of circular building components in different stages of the design. It supports designers as follows: (1) it provides designers all the design parameters which should be considered when making a circular design; (2) it gives designers an extensive list of circular design options for each parameter; (3) through the design templates, in which selected design options can be systematically mixed and matched, the CBC-generator supports the synthesis of a cohesive and comprehensive circular design. Yet, several limitations should be noted. Firstly, the framework analysis focused on frameworks explicitly related to the circular economy. The literature of circular economy precedents' design frameworks – such as eco design tools – were considered to a far lesser extent. Secondly, no systemic literature review was performed to identify a complete list of all possible design options. Therefore, the options included in the matrices could benefit from further



specification. Furthermore, the CBC-generator does not show any causal link yet between different options nor between the technical, industrial, and business models. For example, if for the parameter *transport energy*, the option fossil fuel is selected, then the parameter *distance* should not offer any long(er) distance options such as global, continental, and national. The long transport with fossil fuels would likely have such a negative impact on the environmental performance that the process had better be performed locally, or not at all. The lack of advice on what makes 'logical combinations' of options makes the CBC-generator less suitable for use without assistance of a CE expert. The frameworks as developed by Bakker, et al. (2014) and Monero, et al. (2016) did manage to develop such a correlation by linking technical model strategies to business model archetypes, but the 'design freedom' to investigate alternative options is strongly reduced. This does raise the question to what extent the CBC-generator enables a skilled and unskilled design team to develop a more circular design. Additional testing of the CBC-generator, through a comparative analysis, could create a better understanding of how to improve the tool for both skilled and unskilled designers. Additionally, the design template allows to systematically mix design options, but does not support the translation of options to a design. The canvasses of Mentink (2014) and Scheepens, et al. (2016) do support translation and could be integrated in further development of the CBC-generator. Finally, the CBC-generator only provides support in the synthesis and not in the assessment of the most circular design. For example, when it is more 'circular' to facilitate upgrading of a product or when to choose for recycling does not become evident in the framework. Scheepens, Vogtländer, & Brezet (2016), propose that the environmental assessment of circularity should include quantitative assessment of material consumption, environmental impact and the value of the designed artefact. Bradley, Jawahir, Badurdeen & Rouch (2018) suggest that the financial assessment of circularity could consist of an analysis of the 'Total Cost of Ownership (TCO)'. Further research can contribute to develop complementary circular assessment tool(s).

## 5. Conclusion

This article has sought to develop an integral design framework to support the design synthesis of circular building components. Through analysis of previous developed circular design frameworks, gaps and employable elements were identified. By combining, adapting and specifying the employable elements of the design frameworks, an integral design framework for circular building components: The Circular Building Components (CBC) Generator has been proposed. The CBC-Generator is a three-tiered design tool, consisting of a technical, industrial and business model generator. The generators are 'parameter based', consisting of a design template and parameter-option matrix. By filling the templates through systematically 'mixing and matching' the options, applying them as building blocks, design variants for circular building components can be synthesised. The application of the CBC-generator in the development of the Circular Kitchen shows that it can successfully be applied in the integral development of circular building components, and makes an important step towards supporting the building industry in developing and implementing such components in the built environment. Further development can contribute to adding design options, supporting translation of options to a circular design proposal, establishing causal links between design options and identification of 'the most circular variant', improving user-friendliness for industry.

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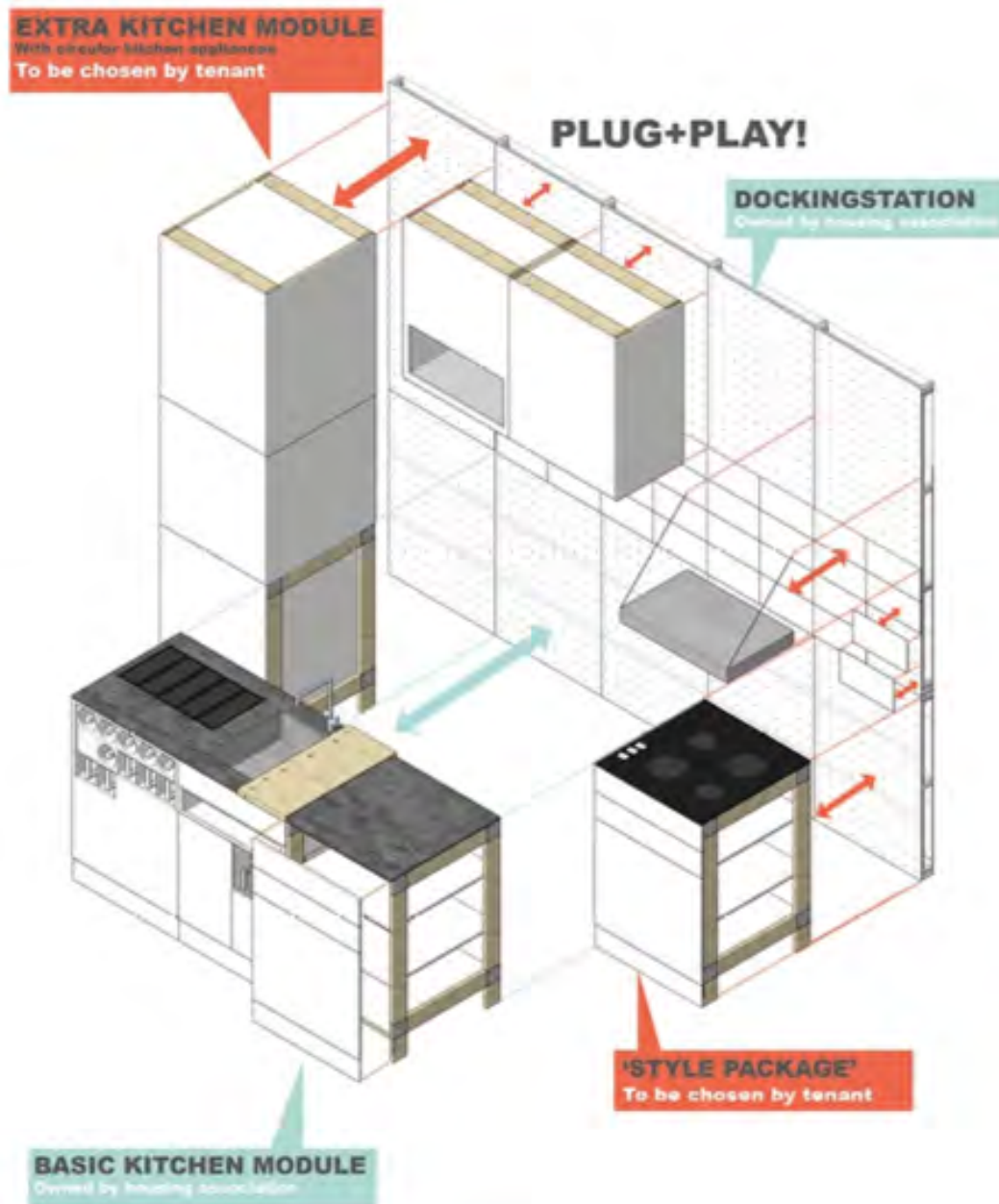
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



























































































































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## Appendix A. Example case: Design proposal for the CIK





## Appendix B. Parameter-Option Matrix of the Technical Model Generator

Parameter	Sub-Parameter	Options
 <b>Materials</b>	Biological material use	 Bio-degradable  Non-toxic  Bio-based
	Technical material use	 Durable "virgin" materials  Durable "virgin + non-virgin mix" materials  Durable "non-virgin" materials
 <b>Energy</b>	Component energy	 Natural Gas  Grid power  Bio gas  Bio Fuel  Hydrogen  Green alternating electricity  Green direct electricity  Heat from thermal storage  On-site pre-heating  City heating  Block heating
 <b>Circular design strategy</b>	 Narrowing loops [2]	 Light weighting component / parts  Minimize the component / parts  Make (part) digital  Light weighting component / distribution packaging  Minimize component / distribution packaging  Find industrial symbiosis for materials  Minimize material use in use phase  Scarce materials only for short cycle use
		 Minimize energy use  Insulate  Optimize efficiency  Recover + exchange energy  Use passive energy over active
	 Slowing loops [2]	 Design for attachment [1,3]  Design for easy use  Add surplus quality [6]  Consider obsolescence + growth alternative [6]  Design for user trust [8,17]  Design for long emotional desirability [8,17]  Make a timeless (base) design
		 Design for long life [1,3]  Direction for unintended use [8,14,17]  Design out moving parts [14,17]  Only include electric parts consciously [14,17]  Over-dimension critical parts [14,17]  Design for resistance to wear [8,16,17]  Reduce coated, painted or plated materials [14,17]  Prevent discoloration of materials [17]  Use compatible fasteners to base materials [11,14,17]  Use compatible materials preventing aging + corrosion [13,17]  Anticipate new regulations in the design [17]  Decomplexify the use of (sub) component (part) [6]  Make well-aging design [6]
		 Design for standardisation + compatibility [1,3]  Company part standardisation [11,17]  Industry part standardisation [11,17]  Company sub-component standardisation [6]  Industry sub-component standardisation [8,12]  Company component standardisation [6]  Industry component standardisation [8,12]  Company measurement standardisation [12]  Industry measurement standardisation [2,12,15,17]  Company joint standardisation [2,12,15,17]  Industry joint standardisation [2,12,15,17]  Company tool standardisation [11,17]  Industry tool standardisation [6]  Performance test (adapters) [11,17]  Joint pieces (adapters) [6]  Interface standardisation [6]
		 Design for easy maintenance + repair [1,3]  Easy + opening plane [2,8,13,16,17]  Easy (included) maintenance + repair components / parts [2,11,12,13,16,17]  Optimize sequence for test + repair [8,11,12,17]  Keep cleaning + repair intensive parts accessible [11,12,15,16,17]  Design to allow on-site maintenance cleaning process [11,17]  Use materials that can stand maintenance cleaning process [11,17]  Make an uncomplicated design [8,11,17]  Design modular [8,11,12,13,17]  Separate based on lifespan [2,8,17]  Standardise design fit + sequence [11,17]  Include a component-part passport [4]  (Live) monitoring of performance [6]  Offer spare components / parts [6]
		 Design for upgrades + adjustments [1,3]  Separate "support" and "infill" [8,7]  Design the "support" for long life  Over-dimension the support  Design a future proof "support" [12,17]  Leave room for upgrades  Allow customising (of infill) [6]  Plan for scenarios for (infill) change [6]
		 Design for Dis-, and re-assembly [1,3]  Easy (enclosed) dis-assembly instructions [2,8,11,13,17]  Minimize number of components / parts [2,8,11,13,17]  Optimize sequence for dis-assembly [2,8,17]  Prefer (grasp fit) click connections [2,16,12,17]  Easy + idiot proof + fast [8,11,12,13,17]  Avoid wet joints / construction like wet-laid + poured (in) concrete [11,12,17]  Avoid (non-soluble) adhesives [11,17]  Easy tools + limited number [2,17]  Allow easy access to connections [2,8,11,13,16,17]  Limit the number of different connections [2,8,11,13,16,17]  Limit the number of connections [2,8,11,13,16,17]  Keep one surface for Apply a loose fit to ease re-assembly [8,15,17]  Apply a loose fit to ease re-assembly
		 Design for recycling [1,3]  Use appropriate biological or parts at material technical materials (no composite) [12]  Separate parts at material technical materials (mono-material) [8,12]  Include a material passport [4]  Limit number of (incompatible) materials in industry [2,8,16,13,17]  Increase common materials in industry [2,8,17]  Break-lines for (destructive) disassembly [2,16,17]  Use recycle compatible materials for fasteners + base [16,17]  Keep toxic materials grouped together [2,8,13,17]  Keep critical, valuable, re-usable parts/materials grouped [2,8,12,17]  Prevent secondary paint/coating [2,8,10,12,13,17]  Make components/ parts suitable to ease re-loops [8,17]  Minimize product volume to ease re-loops [8,17]  Make disassembly easy or not needed for proper recycling [8,17]
 <b>Lifespan</b>	Expected lifespan	 Very Short (0-5 years)  Short (5-10 years)  Medium (10-20 years)  Long (20-50 years)  Very Long (50-100 years)  Very Very Long (>100 years)
 <b>Amount</b>	Amount of material	 Number of pieces  Amount of material in m3
 <b>Systemics</b>	System element	 Built Environment  Building  Component  Sub-component  Sub-sub-component  Part  Material  Resources
<b>Sources</b>		<ol style="list-style-type: none"> <li>Bakker, C., den Hollander, M., van Hinte, E., &amp; Zijlstra, Y. (2014). Products that last. Delft: TU Delft Library &amp; Marosi den Hollander IDRC.</li> <li>Balkenende, R., Aarts, M., Ochoconski, V., &amp; van Meemel, W. (2011). Design-for-Recycling rule set. GreenElec.</li> <li>Bocken, N. M. P., de Pauw, I., Bakker, C., &amp; van der Grift, B. (2016). Product design and business model strategies for a circular economy. <i>Journal of Industrial and Production Engineering</i>, 33(5), 308–320.</li> <li>Detacker, W., Manafshoev, S., Peters, M., Ribeiro, A., &amp; De Weert, Y. (2017). Circular economy and design for change within the built environment: preparing the transition. <i>International HSE Conference on Advances in Recycling and Management of Construction and Demolition Waste</i>, (June), 116–117.</li> <li>Desai, A., &amp; Mittal, A. (2003). Incorporating work factors in design for disassembly in product design. <i>Journal of Manufacturing Technology Management</i>, 16(7), 712–737.</li> <li>Geldemans, R. J. (2014). <i>Circular Bouwen in De Gavalindustrie</i>. Delft: TU Delft.</li> <li>Geldemans, R. J. (2016). Design for change and circularity: Accommodating circular material &amp; product flows in construction. <i>Energy Procedia</i>, 96, 301–311.</li> <li>Gertsen, M. (2015). Circular design checklist. The Netherlands: Reversed Concepts.</li> <li>Hata, T., Kato, S., &amp; Kimura, F. (2001). Design of Product Modularity for Life Cycle Management. In <i>IEEE</i>. Tokyo.</li> <li>Hultgren, N. (2012). Guidelines and Design Strategies for Improved Product Recyclability. Chalmers University of Technology.</li> <li>Jonah, W., McMahon, C., Hammond, G., &amp; Newman, S. (2010). Development of robust design-for-remanufacturing guidelines to further the aims of sustainable development. <i>International Journal of Production Research</i>, 48(16–18), 4513–4536.</li> <li>Kubinger, B., &amp; Wilson, D. (2016). Design for Disassembly. <i>Netherlands: Nederlandse Organisatie voor Wetenschappelijk Onderzoek</i>.</li> <li>Mittal, A., Desai, A., Subramanian, A., &amp; Mittal, A. (2008). Designing For Assembly And Disassembly. In <i>Product Development</i> (pp. 35–177). Burlington: Butterworth-Heinemann.</li> <li>Muller, W., Bakker, R., Jeurgens, B., Blok, J., Hoekstra, S., &amp; Kokkeler, F. (2014). Supporting industrial equipment development through a set of design-for-maintenance guidelines. In <i>13th International Design Conference</i>. Dubrovnik, Croatia.</li> <li>Peters, J., Vanegas, P., Dey, W., &amp; Duffalo, J. (2012). Design for demanufacturing: a life cycle approach. In <i>ISUP2012</i>. Leuven.</li> <li>Sundin, E. (2004). <i>Product and Process Design for Successful Remanufacturing</i>. Linköping University.</li> <li>van den Berg, M. R., &amp; Bakker, C. A. (2015). A product design framework for a circular economy. In <i>PLATE Product Lifetimes And The Environment 2015</i> (pp. 365–376). Nottingham: Nottingham Trent University.</li> </ol>



## Appendix C. Parameter-Option Matrix of the Industrial Model Generator

Parameter	Sub-Parameter	Options
<b>Key partners</b> [1,2,3,4]	Partners in supply chain / value network	Building owner            Third party financier            Material / sub-component / part supplier            Component manufacturer            Transporter            Specialised dealer            Service provider            Contractor            User            Maintenance specialist            Second hand reseller            Specialised refurbisher            Specialised remanufacturer            Specialised recycler
	Activities	Financing component            Supply materials + parts            Manufacturing            Transporting            'Sale'            Installation
<b>Key activities</b> [1,2,3,4]	Reloop activities	Financing component            De + re-installation            Re-transport            Sorting components            Refurbishing            Remanufacturing            Re-selling            Dis + re-assembly            Recycling            Biodegrading            Monitoring
	(Re-)production process per activity	(Re)casting            Imaging + (re)coating            (Re)moulding            (Re)forming            Machining - milling            Machining - sawing            Machining - drilling            Joining - welding            (De + re) joining - fastening            Joining - adhesive bonding            Additive man. 3-D printing
<b>Key resources</b> [1,2,3,4]	Facilities for activities	Mine            Factory            Warehouse            Distribution centre            Shop            Digital platform            (Re)makers space            Home (of user)            (Re)sorting centre            Second hand shop            Repair cafe / shop            Return street            Re-factory            (Re)print shop            Recycling facility            Urban mine Redistributor centre
	System elements [2]	Built Environment            Building            Building component            Sub-component            Sub-sub-component            Part            Material            Resources
<b>Transport</b> [5,6]	Mode of transport	Truck            Van            Car            Freight ship            Bike            Bulky transport (non dense)            Dense transport (flat-pack)
	Distance	At home (0km from user)            Local (city)            Regional            National            Continental            EU            Global
<b>Process energy</b>	Process energy source	Petrol            Diesel            Natural Gas            Gray grid power            Bio gas            Bio Fuel            Hydrogen            Green alternating electricity            Green direct electricity            Heat from thermal storage            On-site pre-heating            Industrial symbiosis
Sources		<ol style="list-style-type: none"> <li>1. Lewandowski, M. (2016) Designing the business models for circular economy - Towards the conceptual framework. <i>Sustainability</i>, 8(43), 1-26.</li> <li>2. Merilä, B. (2014) <i>Circular Business Model Innovation: A process framework and a tool for business model innovation in a circular economy</i>. Master thesis, Delft University of Technology &amp; Leiden University.</li> <li>3. Nützholz, J. L. K. (2017) Circular business models: Defining a concept and framing an emerging research field. <i>Sustainability</i>, 9(1810), 2-16.</li> <li>4. Osterevelter, A., &amp; Pignatari, Y. (2010). <i>Business model gameology: A handbook for visionaries, game changers, and challengers</i>. Hoboken, NJ: John Wiley and Sons.</li> <li>5. Schreyögg, A. E., Voglländer, J. G., &amp; Brezet, J. C. (2016). Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems: Case: making water tourism more sustainable. <i>Journal of Cleaner Production</i>, 114, 257-268.</li> <li>6. Voglländer, J. G. (2019). <i>A practical guide to LCA for students, designers and business managers</i>.</li> </ol>

## Appendix D. Parameter-Option Matrix of the Business Model Generator

Parameter	Sub-parameter	Options
<b>Key partners</b> [4,5,6,7]	Partners in supply chain / value network	Building owner Third-party financier Material / sub-component / part supplier Component manufacturer Transporter Specialised dealer Service provider Contractor User Maintenance specialist Second hand reseller Specialised refurbisher Specialised remanufacturer Specialised recycler
<b>Customer Segments</b> [4,5,6,7]	Customer	Building owner as customer User as customer Building owner and user as customer
	Owner	Building owner as owner Manufacturer as owner User as owner Specialised dealer as owner Service provider as owner Contractor as owner
<b>Chain relations</b> [4,5,6,7]	Primary contact customer	Building owner as contact User as contact
	Primary contact chain	Building owner as primary contact Manufacturer as primary contact Specialised dealer as primary contact Service provider as primary contact Contractor as primary contact
<b>-€ Cost structure</b> [4,5,6,7]	TCO proposition	Cost driven (low manufacturer / high residual + installation costs) Value driven (high residual value) Low operational costs driven
	(up front) financier	Building owner as financier Manufacturer as financier User as financier Specialised dealer as financier Service provider as financier Contractor as financier Third party financier (financial institution / bank)
<b>+€ Revenue streams</b> [4,5,6,7]	Financial arrangement	Product oriented [9] Sale Sale + take-back guarantee Sale + buy-back guarantee Sale + deposit Use oriented [9] Product lease Pay per use Use subscription Rent Pooling Trading fee Performance lease [9] Pay per service [9] Service subscription [9]
	Service level included	Including installation [9] Including maintenance [9] Including repairs [9] Including de-installation [9] Including upgrades [9] Including replacements [9] Including performance (set through KPIs) [9] Including energy use [9] Including consumables [9] Including use advice (consultancy) [9]
	Income source	Product as income source (Repair) sub-components as income source (Repair) parts as income source Adaptors as income source Consumables as income source Service as income source Connecting as income source Advice (consultancy) as income source
	Income division [1]	Income division per company Income division in "mini" coalitions Income division over the value chain [1]
<b>Value propositions</b> [2,3,5,6,7,8]	Value delivery [2,3]	Value through service Value through lower TCO Value through better products Value through better LCA / climate performance Value through lower initial investment Value through risk reduction Value through customisation options Value through technological upgrades Value through off-balance investment Value through on-balance end-value
	Value capture [2,3]	Value through stable revenue stream Value through chain interest alignment Value through long-term client relations Value through lower material costs Value through climate performance Higher profit margins (through service)
<b>Key resources</b> [5,6,7,8]	Product / service proposition [2,3,4,5,6]	Building Building components Sub-components Sub-sub-components Parts (repair part / updates / connectors) Materials Resources Service Consumables Component use energy
	Key resources per chain partner	Physical resources (materials / production plant) Intellectual resources (patents / IP / brand) Human resources (skilled / unskilled employees) Financial resources (cash / finance capacity)
<b>Channels</b> [4,5,6,7]	(Re)sale channels [4,5,6,7]	Online (re)store Online (2nd hand) marketplace (Re)store On phone sale Sales advisors (social) media advertisement (social) media sellers
<b>Take back system</b> [2,4]	Facilities for take-back [2,4]	Nation-wide collection points At home pick-up In store drop-off Post return
<b>Adoption factors</b> [4]	Circular business model Adoption factors [5]	Circular Leadership present [5] CE concept acceptance / motivation [5] Chain collaboration possible [5] Chain alignment / demand [5] Customer acceptance + demand [5] Customer behaviour [5] Political system [5] Legislation [5] Resource availability [5] Technical ability [5]
<b>Sources</b>	<ol style="list-style-type: none"> <li>Bakker, C., den Hollander, M., van Hinte, E., &amp; Zijlstra, Y. (2014). Products that last. Delft: TU Delft Library &amp; Marcel den Hollander IDRC.</li> <li>Bocken, N. M. P., de Pauw, I., Bakker, C., &amp; van der Grinten, B. (2016). Product design and business model strategies for a circular economy. <i>Journal of Industrial and Production Engineering</i>, 33(5), 308-320.</li> <li>Bocken, N. M. P., &amp; Short, S. W. (2018). Towards a sufficiency-driven business model: Experiences and opportunities. <i>Environmental Innovation and Society Transitions</i>, 18, 41-61.</li> <li>Leuning, E., Quins, J., &amp; Bocken, N. (2018). Circular economy in the building sector: Three cases and a collaboration tool. <i>Journal of Cleaner Production</i>, 176, 979-989.</li> <li>Lewandowski, M. (2016). Designing the business models for circular economy - Towards the conceptual framework. <i>Sustainability</i>, 8(43), 1-28.</li> <li>Martens, B. (2014). Circular Business Model Innovation: A process framework and a tool for business model innovation in a circular economy. <i>Master thesis</i>. Delft University of Technology &amp; Leiden University.</li> <li>Nahat, J. L. K. (2017). Circular business models: Defining a concept and framing an emerging research field. <i>Sustainability</i>, 9(181), 2-16.</li> <li>Christenfelder, A., &amp; Pigneur, Y. (2010). Business model generation: A handbook for visionaries, game changers, and challengers. Hoboken, NJ: John Wiley and Sons.</li> <li>Tukker, A. (2004). Eight Types of Product Service Systems. <i>Business Strategy and the Environment</i>, 13, 248-260.</li> </ol>	

# RESILIENT SPATIAL PLANNING FOR DROUGHT-FLOOD COEXISTENCE (“DFC”): OUTLOOK TOWARDS SMART CITIES

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## Summary

The challenges of booming urbanisation are multi-faceted. There have been many different concepts being raised concerning the urban puzzle during the past few decades. The most recent concern among them relates to ‘smart cities’, in which cities embrace available technology to make them “smart”. Many studies show that advanced technologies have been used extensively in managing cities. But from an environmental point of view, the studies have not been able to explain how a city may become smart while being environmentally resilient and sustainable. As the concept of ‘smart cities’ evolves after being introduced at the beginning of 21st century, the notions of resilience – urban resilience and resilient city – have attracted great attentions and interests, in both academia and urban governance, then gradually been adopted in planning practice over recent years. With the help of technologies such as remote sensing and GIS, architects and planning authorities are able to effectively govern policies which can make cities more and more resilient and sustainable. The more available data GIS can offer, the more effective the task of planning will be.

The scope of this paper is to explore how a city with drought-flood coexistence (“DCF”) can become resilient through spatial planning, which will be presented in three sections. The first section examines the relationship between smart and resilient cities. The next section focuses on a research which attempts to turn smart cities into resilient cities by applying (OR UTILIZING) remote sensing technique and GIS to manage natural hazards in urban planning. Last but not least, the case of Ninh Thuan province located in the South-Central part of Vietnam Coastal region will be discussed in the last section together with several key findings from its own context of natural conditions resulting in the current DFC. A number of focal principles will be proposed, based on local context and the new technology of remote sensing and GIS, as tools for resilient spatial planning in the case of DFC. The proposed principles not only regulate the water resource management, but also mitigate drought severity for the province, and could become drivers for both future planning implementation and policy.

The study will conclude with discussions on the critical role of spatial planning in making cities smart and resilient, with respect to their environment, particularly when remote sensing and GIS are considered.

Key words: smart city, resilient city, resilient spatial planning, remote sensing and GIS, sustainability, extreme weather events, drought-flood coexistence.

## **1. Introduction**

The very fast industrialization and booming population since the industrial stage in the urban areas have become a globally problematic challenge. The extended urbanization requires smart and innovative approaches to manage the complexity of the urban ecosystems: over population, energy consumption, resources management and environmental protection, etc. This matter is a real puzzle to not only authorities, but to the professionals, particularly architects and urban planners as well.

According to the results from the 2015 Revision by United Nations, the world population reached 7.2 billion by mid-2015, implying that the world has added approximately one billion people in the span of the prior twelve years, of which, more than 50% of the global population currently lives in the urban areas (Debnath et al., 2014). And between 2015 and 2050, the world population will increase by 32%, i.e. from 7.2 to 9.7 billion inhabitants, while the urban population will increase by 63%, from 3.9 to 6.3 billion inhabitants. The current estimations suggest that until 2030, over 60% of the world population will live in the cities, and the significant growth will be in the developing countries in Africa, Asia and Latin America (Eremia, Toma and Sanduleac, 2017). The most important point is that although the cities occupy only 2% of the planet's surface, they accommodate about 50% of the world population, consume 75% of the total generated energy, and are responsible for 80% of the greenhouse effect (Eremia, Toma and Sanduleac, 2017).

Under such increasing environmental pressures on urban areas, how to administrate a city sustainably has been considered and studied in a very long history. From the first intention in ancient time, later in 1898 with "Garden city of To-morrow" proposed by the British urban planner Ebenezer Howard, with the purpose of transforming the slums into neighbourhoods capable of providing human's life-cycle opportunities and comfort, so on and so forth. The trend afterward was about transforming the cities into green, sustainable, resilient, intelligent, etc., and the emerging one is smart cities. However, the term only focuses on managing cities to be technologically smart and ignores making cities environmentally sustainable and resilient.

Resilience and resilient cities are the ecological-based concept to develop a smart city, where a city is basically considered as a complexity of Social-Ecological System (SES) (S.T.A Pickett, M.L. Cadenasso, 2013). Coincidentally, resilient spatial planning needs to be studied to meet the natural services' challenging demand (Lu and Stead, 2013). In addition to the current already complexity of urban development, urban data sets have become ever more and more complicated with more data added to the system. Remote sensing and Geographical Information System (GIS) are the most effective tools for approaching cities information at the moment (Jhawar, Tyagi and Dasgupta, 2012) (Verma, Kumari and Tiwary, 2009).

This paper will explore in depth how these theoretical concepts and contemporary techniques could help establish a system of resilient spatial planning principles for DFC: (i) the connection of smart cities and resilient cities, with the focus will be on resilient spatial planning for DFC, (ii) remote sensing and GIS in urban planning and methodology, and (iii) the case of Ninh Thuan generalities and key principles of resilient spatial planning for DFC.

## **2. The Relationship between Smart Cities and Resilient Cities**

### **2.1. Smart Cities**

Sustainable development of the urban areas has been a major concern since early 19th century for both architects and authorities. One of the first modern concepts is discussed in the book "Garden Cities of Tomorrow", and further elaborated in "...The cities of Tomorrow will be more readily susceptible to transformation and adornment than the Cities of Yesterday" (Eremia, Toma and Sanduleac, 2017).

The characteristics of future cities have been adopted over the years. From the interwar period, the key purpose is to alleviate shortcomings caused by the industrialization and to create green cities. Among these concepts, the ideas from “The City of Tomorrow and its planning” (1929) by Le Corbusier, and later from “The City: its growth, its decay, its future” (1943) by Gottlieb Eliel Saarien, have influenced on the cities’ features in Europe and Northern America. Professional urban planners later focused on how to make a city smarter in the future.

M. Eremia et al (Eremia, Toma and Sanduleac, 2017) reviewed various definitions from specialists from different domains and summed up that a city is smart when it is:

using information and communications technology (ICT) to enhance livability, walkability, and sustainability (Smart cities council 2014);

monitoring and integrating conditions of all critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, that can optimize its resources, reduce maintenance, and monitor security aspects while maximizing services to its citizens; and

being a geographical space, being able to manage all resources (natural, human, building and infrastructure), wastes generated by lifestyle sustainable unharmed to the environment.

Irrespective of the differentiating names and meanings, the future cities must adapt to all changes of societies and natural environment.

## **2.2. Resilient Cities**

### **Resilience**

The notion of resilience has passed through a long history. It is originally used to refer to systems and their ability to cope with external shocks and disturbance (Lance, Gunderson and Holling, 2002). Simpler understanding of resilience is the ability to absorb outside disturbance while remaining former structures and functions (Holling, 1973)(Holling, 2001)(Eraydin et al., 2013). Later, various scholars consider resilience in terms of the adaptive cycle (Folke, 2006)(Holling and Gunderson, 2002)(Walker and Salt, 2006), which focuses on the dynamics of systems (e.g., ecosystems, societies, and economies) that do not have a stable or equilibrium condition but repeatedly pass through four characteristic phases: growth and exploitation; conservation; collapse or release; and renewal and reorganization.

### **Urban Resilience and Resilient Cities**

Although originally resilience was discussed the first time in 1973 (Holling, 1973), it only got the attention of urban planning a little bit later in 1990s (Mileti and Henry, 1999). Resilience in planning has often put the emphasis on preparation and mitigation actions, especially at the local scale.

A city is an ecosystem, technically termed Socio-Ecological System (“SES”), which is supported by ecosystem services, including: (i) provisioning services such as food and water; (ii) regulating services such as regulation of floods, drought, and disease; (iii) supporting services such as soil formation and nutrient cycling; and (iv) cultural services such as recreational, spiritual, religious and other nonmaterial benefits (S.T.A Pickett, M.L. Cadenasso, 2013). Therefore, an ecosystem (Pickett, 2012) (Ahern, Cilliers and Niemelä, 2014) is a complex adaptive system which consists of four basic environments: 1) biological, 2) social, 3) physical, and 4) built components (Grove, 2009). They cannot be separated from one another (Pickett and Grove, 2009).



S. Meerow's reviewed and defined *"Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change and to quickly transform systems that limit current or future adaptive capacity"* (Meerow, Newell and Stults, 2016).

Based on the literature of resilience and urban resilience, several definitions of resilient cities have been further developed. Among them, the most adapted definition is in Sendai Framework (Cities, 2018) (Framework and Reduction, 2015): "The ability of a city exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions", United Nations Office for Disaster Risk Reduction ("UNISDR"), "2009 UNISDR Terminology on Disaster Risk Reduction", Geneva, May 2009.

A number of recent studies (Davoudi and Strange, 2009)(Fleischhauer and Fleischhauer, 2008) acknowledge that spatial planning plays an important role in promoting urban resilience to cope with climate change through the spatial configuration of cities (by way of land-use management). Particularly, Mark Fleischhauer mentioned on his research that urban structures in spatial planning can mitigate multi-hazards (Fleischhauer and Fleischhauer, 2008), where he introduced several indicators used to assess the resilience of spatial planning, such as keeping areas free of development (under the threats of climate change; differentiated decisions on land use), accepting land use development according to the intensity and frequency of hazards, recommendations in legally binding land use or zoning plans, and contributing on reducing the potential hazards.

With regards to spatial planning for DFC, the nature's regulating service (particularly water cycle) becomes the most critical one, whilst others become supporting factors. The natural land such as forest, grassland, wetland, etc. being destroyed for agriculture and urban development could make the region vulnerable to the potential hazardous events of both droughts and floods. To prepare for urban resilience, these land stock must be spatially planned, and be strictly protected by authorities and urban planners.

Smart and resilient cities are quite similar in term of promoting a city develop and sustain in the future, one is smart, while the other is resilient. Both are going toward to sustainability.

### **3. Remote Sensing and GIS in Urban Planning**

#### **3.1. Remote Sensing and GIS for Urban Planning and Natural Hazards Management**

The applications of remote sensing and GIS has become an integrated, well developed and successful tool in urban and environmental studies (Bahaa and Al, no date)(Verma, Kumari and Tiwary, 2009)(Vân, 2011). Indeed, "Urban greenbelt (or open space) mapping, urban encroachment, growth of slums on vacant lands, urban housing, urban utilities and infrastructure, solid waste management, urban transportation and traffic planning, urban hydrology, urban cadastral and real estate, urban ecological hazards, and urban census data all can be mapped, monitored, and analyzed using remote sensing" (Rahman, 2007). They are also useful for disaster risk management (Westen, 2012)(Voroventii, 2011)(Thenkabail, Gamage and Smakhtin, 2009) (Vinh, 2014).

The modern technology of remote sensing allows us to collect lot of physical data rather easily, quickly and on repetitive basis, and together with GIS help us analyze the data spatially, offering possibilities of generating various options, thereby optimizing the whole planning process. These information systems also offer interpretation of physical (spatial) data with other socio-economic data, and thereby providing an important linkage in the total planning process and making it more effective and meaningful.

### 3.2. Applications of Remote Sensing and GIS for Studies of Urban, Drought and Flood

Remote sensing offers cost-effective solutions to city planners' data needs for both macro and micro level analysis of the land use planning leading to urban environment management. GIS is best utilized for integration of various data sets which helps in identifying the problem areas and suggests conservation measures. The remote sensing technology along with GIS is an ideal tool to identify, locate and map various types of lands associated with different landform units. That is quite helpful for an immediate perspective planning of cities.

Currently, drought monitoring management exists in most countries based on site-based information on drought related parameters such as rainfall, weather, crop condition and water availability, etc. However, the limitation in some regions is available of data sets: often related to inaccurate and out-of-date information. The remote sensing and GIS technology significantly contribute in all the three phases of drought disaster management: preparedness, monitoring and relief. Similar with flood and flash flood, all sorts of information related to flood prone/risk zone identification data could be extracted from remote sensing images with quite accurate information.

## 4. Case of Ninh Thuan Province

### 4.1. Location and Natural Conditions



Figure 1 The location of Ninh Thuan province in Vietnam. (Source: authors)

Ninh Thuan is the coastal province of Vietnam center, located at the co-ordinate of: 11°18'14" to 12°09'15" Northern latitude, 108°09'08" to 109°14'25" Eastern longitude. It is adjacent to Khanh Hoa province in the North, to Binh Thuan province in the South, to Lam Dong province in the West, and to East sea in the East.

Ninh Thuan belongs to the common characteristics of Vietnam central parts, which is divided into 4 ecosystems, from the mountains to the sea, such as: (i) high mountainous area, (ii) hilly area, (iii) plain area, and coastal sandy area (Sâm, Lân and Vượng, 2008)

The geological location of the province has created its natural conditions. They are as followed:

- Hydrology: total area of rivers basin is 3.092 km<sup>2</sup>, including 46 rivers, main streams and four main aquifers, of which Cai river basin takes major area of 3.000 km<sup>2</sup>, others take 92 km<sup>2</sup>. Cai river is 120km long, includes branches: Dinh, Me Lam, Sat, and Ong rivers. Water flow is of 10 l/s/km<sup>2</sup> during rainy season, and of 0.5 l/s/km<sup>2</sup> during dry season. Main geographical character is non-existence of surface water, only of mid-low underground water (Sâm, Lân and Vượng, 2008).
- Meteorology: dry (75-77%) and hot (26-27°C), strong wind (2.3-5m/s, the strongest is of 25m/s) and high vaporization. Average rainfall is of 700-800mm in Phan Rang city, and it is increased to 1.100mm mountainous areas.
- Geology: bedrock topography types in the Ninh Thuan are divided into 2 types: “partial downwarping” and “constant slope to the sea”. The first type has better water retention ability, however, water is always lack in the dry season, due to its capacity is not enough for uses (Khuyển, 2011).
- Extreme events: Flash flood often follows immediately after storm upstream, and typically occurs to areas with harsh topography, meteorology and hydrology. Flash flood and landslide happen during rainy season in riverine and mountainous areas and have significant impacts on the population.

#### 4.2. Extreme Events in Ninh Thuan: Droughts, Floods

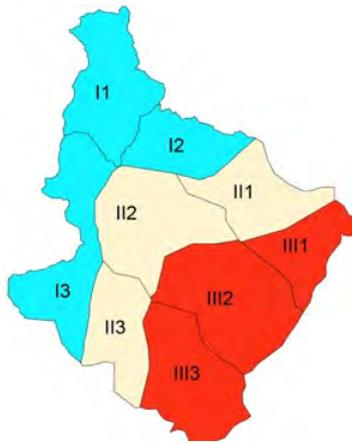


Figure 2: The three regions of sensitive drought and relevant rainfall (Source: authors)

##### Droughts

Ninh Thuan is the hottest province in Vietnam with the average temperature of 27°C. The highest temperature recorded was 40.5°C at Nha Ho station in 1937.

The province is divided into three sub-regions of climate. The coastal area (region III) has the worst droughts with the average rainfall of around 500-700 mm per year. This area receives the strong wind from the East Sea with hot temperature almost throughout the year. The plain area (region II) also suffers drought with the rainfall allocation from 750-1,200 mm per year, and the mountainous area (region I) has a rainfall allocation from 1,000 – 1,700 mm per year (Sam and Vuong, 2008).

##### Floods and flash floods

Weather conditions are alternating from droughts to floods in Ninh Thuan province. There have been severe floods since the 1960s that have caused negative impacts on the societies: 1964, 1998, 1999, 2000, 2003, 2005, 2009, 2010, and 2011. But since 1978, flash floods happen

regularly on most of the provincial catchments, and seem to increase (Viện Hàn Lâm Khoa học và Công Nghệ Việt nam, 2016) (Sâm, Lân and Vượng, 2008).

### 4.3. Resilient Spatial Planning for DFC: Study Methodology and Methods

Methodology: flood and flash flood could be regulated through resilient spatial planning based on local natural conditions. Drought will be mitigated accordingly, based on regulated flood and storm water during rainy season across scales.

Methods: remote sensing and GIS. Images related to the three studied elements at different periodic times for analyzing their transformations and inter-relationships: (i) urban settlements in 4 period of times, based on urbanization statistics, (ii) on topography, NDVI, soil types; and (iii) peak times of drought, based on drought history.

The process of mapping flash flood potential acquires raster (gridded) datasets representing the type of physio - graphic characteristics influencing the hydrologic response and flash flood potential. A relative flash flood potential index will be assigned to each data layer based on the layer attributes associated with the hydrologic response.

FFPI: Flash Flood Potential Index.

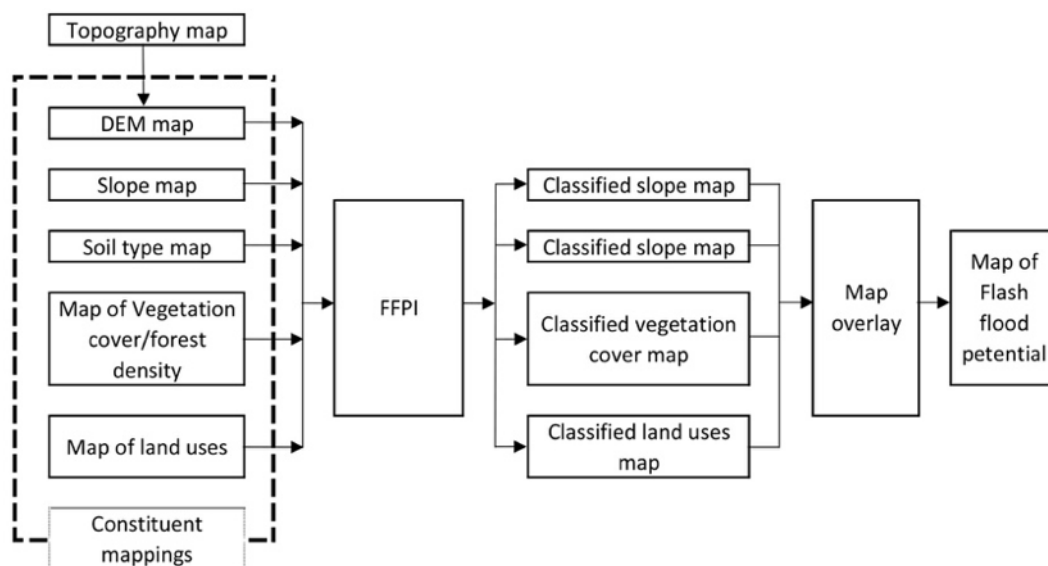


Figure 3 Procedure of mapping flash flood potentials (Source: authors)

Mapping sensitive drought will be carried in 3 steps:

1. Identifying inputs to evaluate sensitive drought. Based on drought impacts, integrating with meteorology conditions of the study area, 9 indexes are selected as input criteria,
2. Standardizing the indexes,
3. Overlaying these maps in GIS to set up sensitive drought map.

These indexes are created utilizing GIS to overlay four physical elements, as indicated on the Fig.3, that relate to precipitation runoff. These elements were each scaled to create an overall indexed value that forecasters could use to locate basins that may respond more quickly than expected. A smallest index value indicates a minimum flash flood threat and the largest value indicates a maximum flash flood threat.

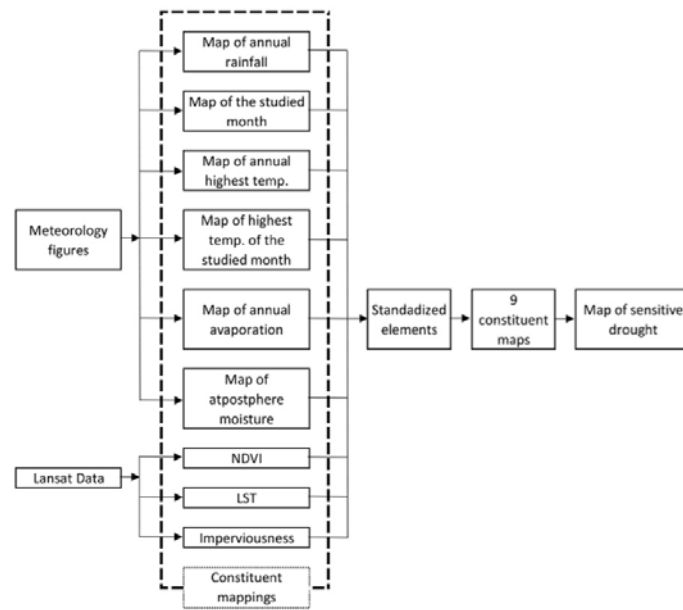


Figure 4: Procedure of mapping sensitive drought. (Source: authors)

To identify appropriate spaces in the study area for resilient spatial planning for DFC, besides maps of sensitive drought and flash flood potential, remote sensing images of timing urban transformation will be collected for tracking and evaluating. Three periods to be selected are:

1. Before 1996, time recorded as a starting point of first urbanization
2. After 2000, when the master plan of the city approved
3. The current time.

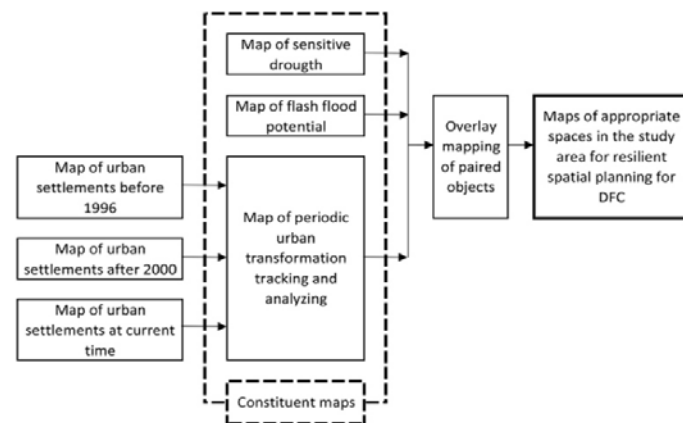


Figure 5: Procedure of mapping spaces in resilient planning (Source: authors)

All these images of urban settlements will be investigated, supported by ENVI software, with drought sensitiveness, especially land surface temperature, flood potentials respectively. The results will be overlaid and integrated into GIS, to analyze in different models with different assumptions. That will finally help identify causes and effects and define appropriate areas for spatial planning.



#### 4.4. General Principles of Resilient Spatial Planning for DFC

Based on the new technology of remote sensing and GIS, the proposed general principles of resilient spatial planning for DFC must follow across scales:

1. at regional scale: respect the ecology and the natural environment by fully understanding of nature's services, particularly the service of regulating droughts and floods in accordance with water cycle, adapt and mitigate for both, and together with strictly saving and protecting land for natural conservation;
2. at city scale: to be basically determined (on land use) by social and environmental considerations, not by land value (or potential land value) alone, to combine the natural water bodies into a city's networked system of green and blue infrastructures; and
3. at site scale: to be reasonably planned urban functions, especially green spaces, to technically design buildings that could maximizing recycled used water.

These expected key principles are resulted from the study's methodology and methods. Systematized principles will be further studied on the next steps of the research, including concrete indicators of resilient spatial planning for DFC.

#### 5. Conclusion

Urban transformation is ubiquitous over the last decades. However, this extraordinary alteration has no set endpoint. Cities, as complex adaptive systems, are not only dynamic but also self-organizing and actively adjusting to cope with all predictable and unforeseen disturbances. This concept, in contrast with traditional equilibrium paradigm, is heterogeneity, non-linearity, hierarchy, and multiple stable states. That is emphasized in theory of ecological resilience, which is effectively to manage SES, including spatial planning and urban design. Spatial planning can play a critical role in the progression of cities. How spatial planning leads to a smart and resilient urban, however, depends on resilient planning principles that are increasingly influenced by ecological theory.

Beside the traditional methods, this paper introduces remote sensing and GIS as an integrated, already proved to be effective, method for the case of Ninth Thuan province to make it a smart and resilient urban. This methodology first extracts data from remote sensing images of three main objects and their inter-relationships, such as data on urban settlements, droughts and floods, and then analyses. Second, initial results are integrated into GIS to identify appropriate areas for spatial planning. Key principles of resilient spatial planning for DFC, based on ecological theory, are initially raised and will be furtherly studied in the next steps of the study. These principles can become drivers and a useful tool for both policy and implementation for not only Ninh Thuan, but also regions facing similar challenges. It is an outlook towards smart cities.

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# ANALYZING THE POTENTIAL OF LAND USE TRANSFORMATION IN THE URBAN STRUCTURING AND TRANSFORMATION AXES IN SÃO PAULO: A CASE STUDY IN THE BELENZINHO NEIGHBOURHOOD

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## Summary

Traffic congestion, low-quality public transportation, long distances and the time spent are problems for thousand Brazilians. The city of São Paulo brings together services, employment, among others activities, attracting a thousand of people. The transit-oriented development (TOD) strategies integrated to Sao Paulo urban regulations from 2014 to 2016, redirect the urban planning strategies to the construction and retrofit of compact and high density neighbourhoods. The strategies are based on land use, population diversity and compactness while they aim to promote the improvement and the increased use of public spaces. The aim of this work is to analyze the requirements for the implementation of TOD strategies correlated to the land use potential of transformation, in the selected neighbourhood of Belenzinho, which is the region of influence of the Belem Metro Station. In São Paulo, the Urban Transformation Structuring Axis (UTSA) indicate the areas in the city where it is desired to intensify the land use transformation, and that are directed accessed from the high and medium capacity transport network. The case study area of Belenzinho forms a mixed urban fabric among sheds and residential buildings. Possible developing areas were identified and classified into 5 categories: i) very low transformation potential; (ii) low transformation power; iii.) high power transformation; iv) potential for requalification; and v.) in transformation. Results showed 78% of the lots registered are likely to be transformed according to TOD strategies. However, this percentage decreases to 47% when it comes to the available area of these lots. There are many small lots with underutilized occupations, but with potential for transformation. Although the region is well located and represents potential for transformation, its location close to public transport should encourage investment and new real estate developments. Although the Master Plan guidelines promote solutions associated with the TOD, it is necessary to evaluate the possibilities of transformation of each urban area, the number of lots and their available areas for transformation. In addition, it was noted that an improvement in infrastructure is necessary to attract investors aligned with the Masterplan guidelines, and new constructions must attend the diverse social groups to avoid the dispersion of low income people to the periphery. Finally, the challenge of integrating humanized public area to the private constructions remains.

Keywords: TOD. urban planning, urban transformations, land use.

## **1. Introduction**

Gomide (2006) and Gouveia (2017) point that traffic congestion, low quality public transport, long distances travelled, and time spent to displacement are common problems faced by millions of Brazilians living in urban centres. São Paulo boasts services, jobs, universities, entertainment and cultural attractions. It brings a populational contingent every day to central areas, moving millions of people, further worsening the externalities associated with urban mobility.

According to IPEA (2012), the Urban Mobility National Policy (PNMU) is an important milestone in the management of public policies in Brazilian cities, promoting prioritization instruments on nonmotorized and public means of transportation rather than individual ones.

In this context, the Transit-Oriented Development (TOD) propose redirect planning strategies and urban design, through the development of high density compact neighborhoods which offer diversity of uses, services and safe and active public spaces, favoring social interaction.

The aim of this work is to analyze the requirements for the implementation of TOD strategies correlated to the land use potential of transformation, in the selected neighbourhood of Belenzinho, which is the region of influence of the Belem Metro Station. The question is what is requirements needed in urban areas to, in fact, implementing development urban strategies aimed to transport.

## **2. TOD Urban Parameters**

TOD strategies lead to creation of urban sustainable communities where the territory, land uses, infrastructure and services networks are planned in a integrated manner. Therefore, distances between people and their places of destination and main activities are shorted, promoting sustainable mobility and reducing daily travel time.

As pointed out by Hidalgo (2015) and Young (2015), transport-oriented planning strategies favor community development, economic improvement and revitalization of the neighborhood because of the results of the actions

Strategies are outlined by the high-density regional growth organization, in the corridors of the high capacity transport system and in the main centrality nodes. In stations surroundings, large sidewalks are predicted to favor paths by foot and the elaboration of more diverse uses, buildings that provide the first floors to commercial activities and services and upper floors available to housing as pointed by Hidalgo (2015).

One of the ideas is that buildings that provide the first floors for commercial activities and services and upper floors available for housing, contribute to a better distribution of activities in the city, and revitalize certain areas.

Almost all principles guiding the design and implementation of TOD zones directly influence land use, circulation, urban form and overall performance of a place. Creative mix of uses within proximity is vital to attract riders and community in general (Dittmar, Belzer & Autler, 2004).

Lively mix of uses strengthens the link between transit and development, Having a dense mix of uses near transit is important to creating a center. The process of Selecting transit hubs to be developed as TOD zones hinges on the existing as well as proposed urban development schemes (Jacobson, Justin, & Ann Forsyth, 2008)

The potential of a successful selection depends to a great extent on the particular characteristics of the transit station's immediate and surrounding area, and experience from numerous cities demonstrates that implementing TOD can result in significant benefits to individuals, communities and entire regions by improving the quality of life for people of all ages and abilities to live, work, shop, learn and play (Carlton, 2009).

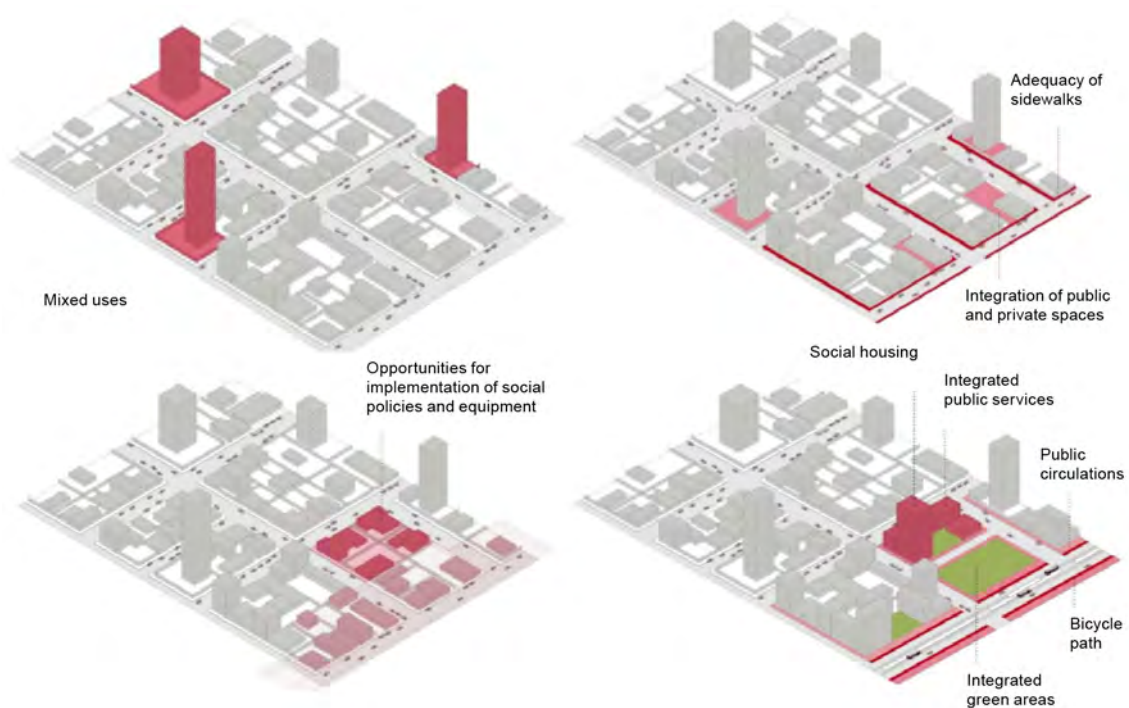


### 3. Strategies adopted in the revision of the São Paulo strategic master plan

São Paulo Strategic Master's Plan, approved in 2014, orients the rebalancing city growth by shortening the distances between housing and work, facing, consequently, socio-territorial inequalities and diminishing displacement daily flows. For this purpose, would be necessary substantial urban transformation, balanced and planned by municipality, based on guidelines, goals and referencing principles (YAMAGUTI et al, 2017).

The Urban Transformation Structuring Axis (UTSA) are fractions of territory destined to promote residential and non-residential uses, with demographic and constructive high densities and promote landscape qualification of public spaces, items articulated with public collective transport system (GESTÃO URBANA, 2016), according to figure 1, avoiding dispersed verticalization, reducing free and fragmented areas, developing opportunities to implementation of social policies.

For this transformation, was defined Urban Structuring and Transformation Network, that network connects city areas where the intensification of the soil use process, oriented by the densification of the population and building, are desired to urban public spaces qualification. One important point of these structuring elements is the collective high-capacity public transport.



*Figure 1 Strategic opportunities adopted in São Paulo*

TOD planning, incorporates multi-objective, which includes not only the economic efficiency aspect of transit ridership, but also the living environment aspect of service facilities, and the social equity aspect of inequalities in land development, between planned areas and other areas

TOD is a fast-growing development strategy and is becoming more popular among city planners, land developers, and government officials, and São Paulo adopted strategies in this way to advance to the next decades.

One of the premises of the Strategic Master Plan is to guide the growth of the city around the axes of public transportation, such as subway stations and bus corridors. Therefore, it is necessary to transform the use and occupation of the soil near these axes, so this work sought in a preliminary way to evaluate the transformation potential of the region.

#### 4. Evaluation of the opportunities in the Belem Neighbourhood in São Paulo

The work characterized as field research, consisted of visits to the study area, with characterization of the lots and systematization of the data on a georeferenced basis. The urban area of study is located near Belém Metro station. The region was marked in the last century by industrial occupations and workers' villages, recently it forms a mixed urban fabric, between industrial sheds, horizontal towns and real estate ventures

In addition to the subway station, there is the Radial Leste, an important avenue that connects the most populous region of the city, and the bus corridor, according to figure 2. It is interesting to analyze the process of development of the region around these axes, which behave as physical divisors. On both the north and south sides, the dichotomy between large verticalized buildings and horizontal buildings mixed with an urban mosaic with various nonresidential uses is striking.

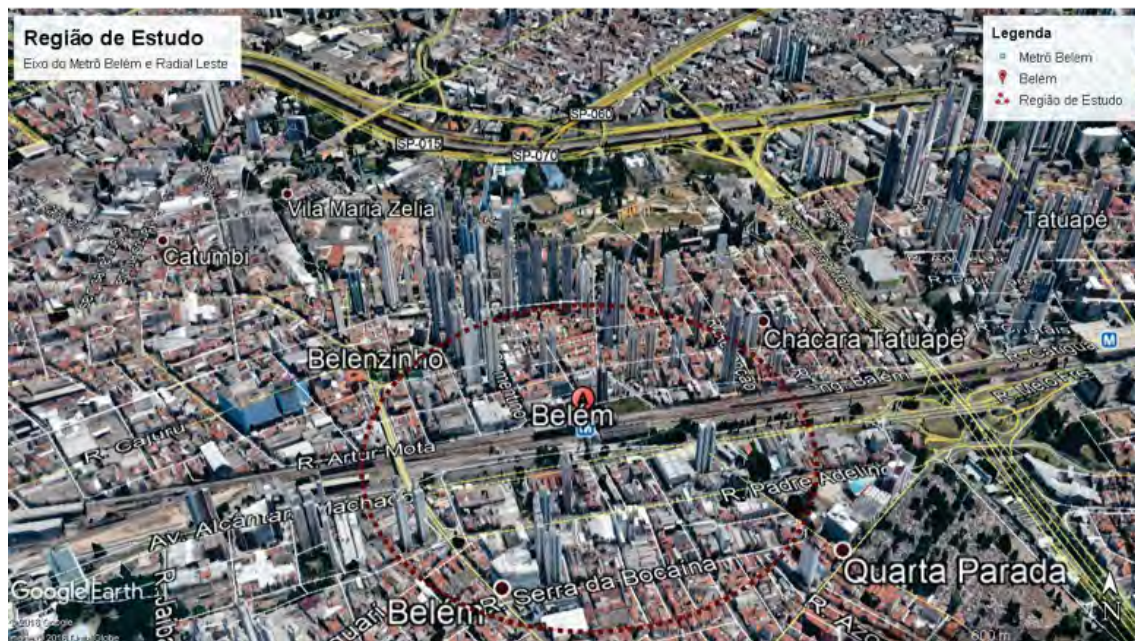
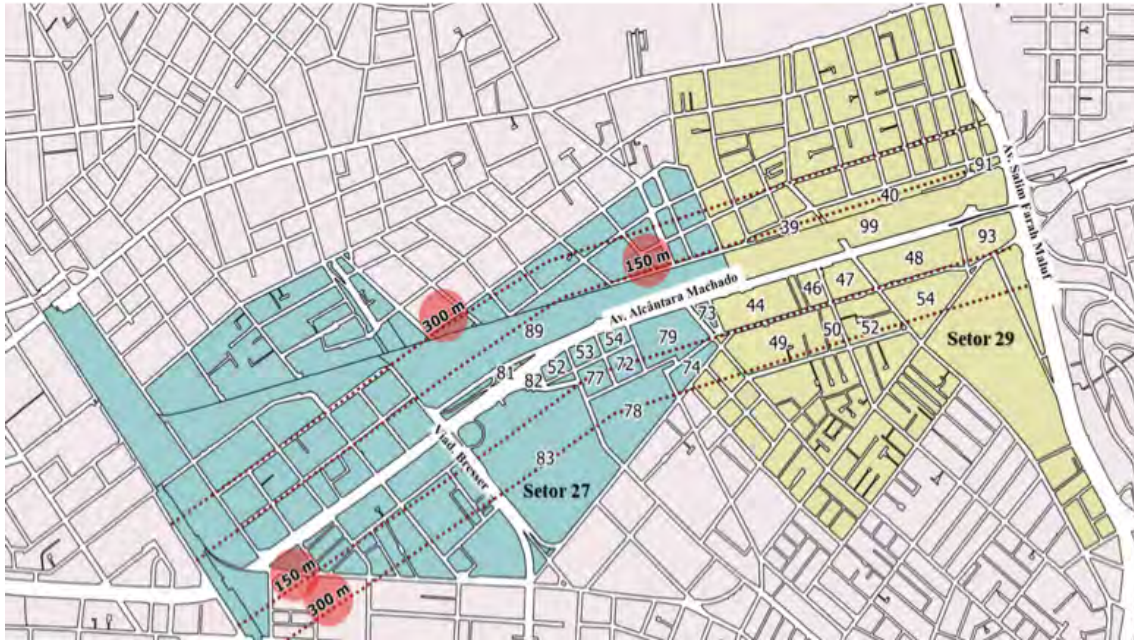


Figure 2 Study area

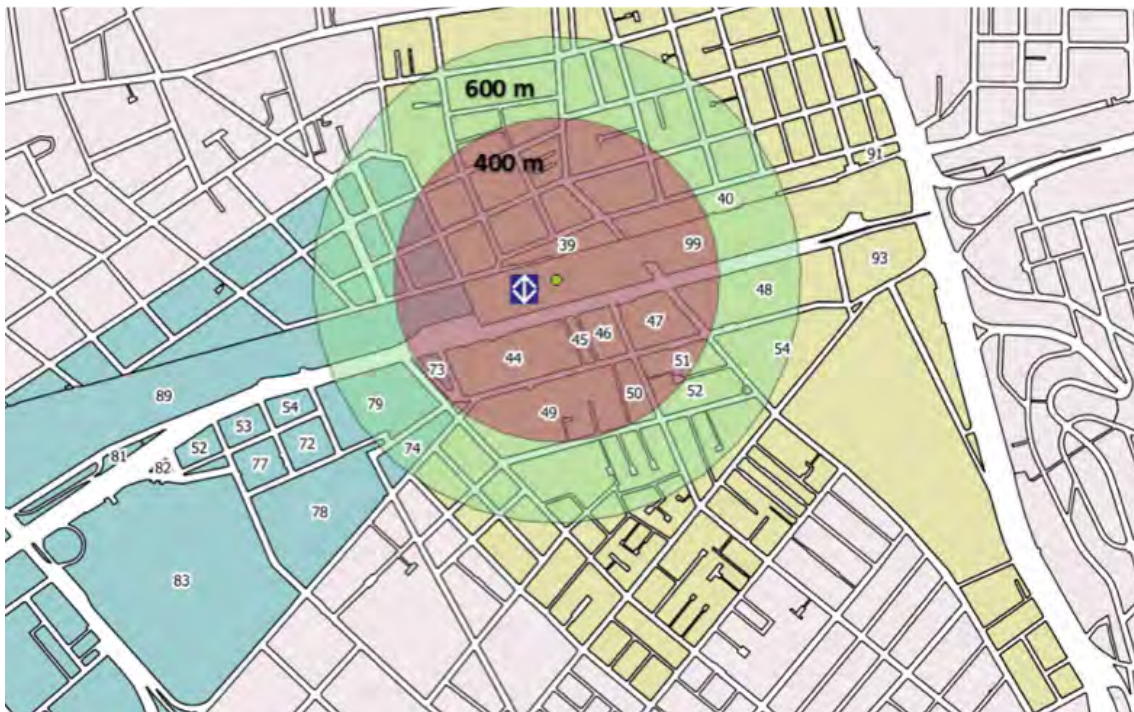
Therefore, it is necessary to transform the use and occupation of the soil near these axes, so this work sought in a preliminary way to evaluate the transformation potential of the region. The adjacent blocks of the transport axes comprise sectors 27(blue) and 29 (yellow), respectively in Figures 3 and 4.





*Figure 3 Delimitation of the area of influence of the Radial Leste Avenue axis.*

These sectors were chosen, since they are within the area of influence of the axis comprised by the delimited Radial East, by dashed lines at 150 meters and 300 meters. These sectors were also delimited by Salim Farah Maluf Avenue and Bresser Viaduct, in order to maintain a study area occupied by blocks with similar profiles, and around the block where the subway station is located, at a distance of 400 and 600 meters of the same stroke the range radius of the axis.



*Figure 4 Area of influence of the subway station Belem.*

The blocks were obtained from the GeoSampa portal of the City of São Paulo. From these can be identified their respective batches, to classify the transformation potential of batches

with grades 1 to 5, in which: 1 - Reduced transformation potential: in general, public spaces or consolidated private spaces, which transformations is difficult due to their characteristics and form of occupation; 2 - Low transformation potential and high requalification potential: lots with greater difficulties of expropriation, in general, small and medium-sized buildings, with several lots in the same land, and therefore, more than one owner. In this way, a change in its use is considered, to qualify it; 3 - High potential for transformation: the lots are subject to expropriation and their constructions are demolished, being replaced by new developments; 4 - Lot in transformation: lots that have projects under execution; 5 - Municipal areas: in general, public squares.

The region is divided by the subway line, in two lanes, one to the north and one to the south. The results of this work concentrate on the analysis of the lots located in the strip to the south.

The results of the classification were imported into the digital map of the city of São Paulo through and can be seen in figure 5.

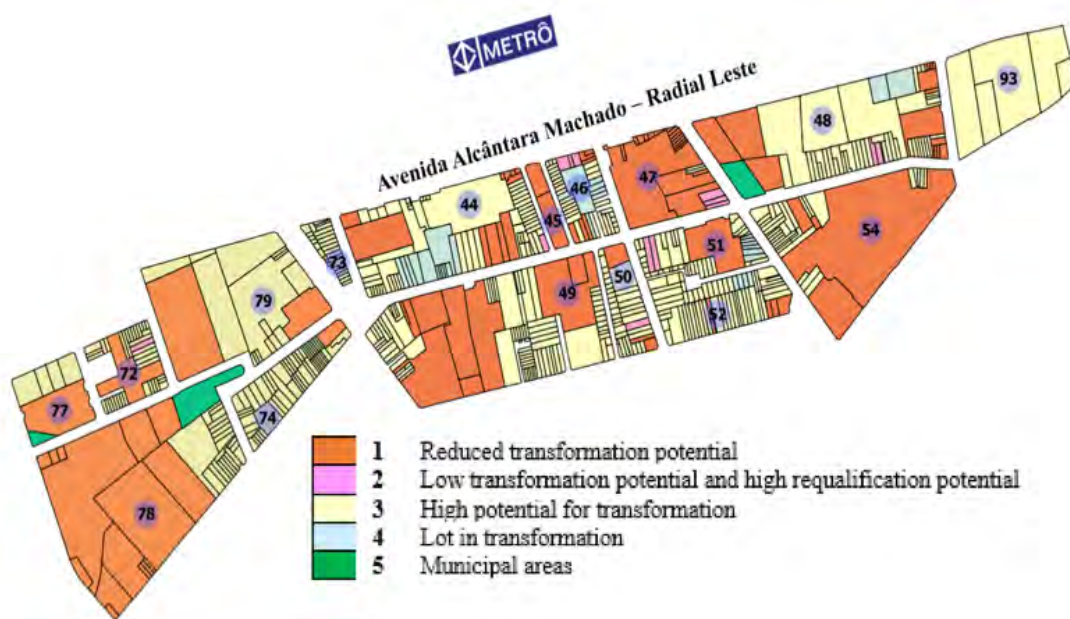


Figure 5 Map of Classification of lots in relation to processing potential.

## 5. Results the potential of land use transformation in in the Belem Neighborhood in São Paulo

Areas with a low processing potential (14.2% in lots and 2.3% in land area) are characterized by residential buildings, hospitals, hotels, a shopping club, educational establishments, churches, gas stations, a municipal deposit, an energy transformation and distribution station, a graphic, among others. Due to its characteristics, as different owner in the case of buildings and the type of use and occupation of the soil its transformation and requalification is greatly impaired.

The lots already under transformation (4.6% in lots and 6.4% in land area) are mostly residential or commercial buildings and a new private hospital under construction, which, probably due to the time of drafting the projects, do not follow the proposals given by the updated Master Plan.

Areas with reclassification potential (1.8% in lots and 2.3% in land area) are occupied by larger commercial establishments, small and medium office buildings, due to their characteristics, the land purchase process, demolition of the existing building and execution of a new one, is also impaired and therefore, it is recommended a re-qualification of its use, made possible, for



example, by the provision of part of the building area for public use, allowing a greater flow of people and activities and diversifying their occupation.

The results indicate that approximately 78% of the lots and 75% of the area allow an urban transformation in this area, but when analyzed in more depth, the lots in this category, representing an opportunity for transformation, are small. The largest lots have already gone through a construction process. This can be seen in visual analysis in figure 6.

However, although there is considerable scope for transformation, it is necessary to reconcile the interest of the various segments of society: municipal management, the population that inhabits and uses the region, potential investors in future ventures, the real estate market, developers and builders.

The classification of lots for each sector was organized according to their quantity and area of land, by number of lots, and area in Table 1.

*Table 1 Classification in relation to the quantity of lots and area*

Classify potential	Sector 27 e Sector 29		Sector 27 e Sector 29	
	Number of lots	%	Land Area (m <sup>2</sup> )	%
1	93	14.2%	189,048	15.5%
2	12	1.8%	3,823	2.3%
3	515	78.9%	188,989	75.6%
4	30	4.6%	12,832	6.4%
5	3	0.5%	6,332	0.2%
<b>Total</b>	<b>653</b>	<b>100%</b>	<b>472</b>	<b>100%</b>

In addition, most of the new developments in the region follow the old planning guidelines, and do not adopt the measures proposed by the TOD. This table indicates, therefore, that the new strategies will be developed and executed in the long term, nevertheless there is a great territorial space available for its implantation.

Authors such as Ye (2013) point out that these transformations can considerably increase the population density of the affected regions, may favor an increase in GDP per capita in Chinese cities.

Handayani (2014) points out that this development occurs in an evolutionary way around the centers of the axes, and that a strategy of zoning that favors the progressive occupation of the lots is favorable the transformation in the case of the Indonesian cities.

In the case of China, Indonesia, and now in São Paulo (Brazil), it is a consensus among the authors that plans, and standards alone are not sufficient if there is no joint effort, it is stressed that these transformations take time and require support and legitimacy.

In addition, most of the new developments in the region follow the old planning guidelines, and do not adopt the measures proposed by the TOD. This table indicates, therefore, that the new strategies will be developed and executed in the long term, nevertheless there is a great territorial space available for its implantation.

Authors such as Ye (2013) point out that these transformations can considerably increase the population density of the affected regions, may favor an increase in GDP per capita in Chinese cities.



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In the case of China, Indonesia, and now in São Paulo (Brazil), it is a consensus among the authors that plans, and standards alone are not sufficient if there is no joint effort, it is stressed that these transformations take time and require support and legitimacy.

## **6. Analysis of the results from the literature perspective**

Rufino (2016) and Marques & Bichir (2001) argue that in areas where traditionally real estate market production is more intense, there is a transformation of the more attractive lots, that is the larger lots and closer of points of interest. To urban planners there is the challenge of transforming the territory, integrating to the lots that will not be transformed an infrastructure of urban equipment, trades and services that possibly will be created with the new transformations.

Probably the purchase price of the lot, can be a factor regulated by the urbanistic instruments. Because lots with differentiated formats (narrower and elongated, or with irregular shapes), have greater difficulty of transformation, and thus influence the expected result of the built environment resulting from the proposal by the TOD. This behavior is difficult to preview, according to Crane (2000), because there are several variables linked to the urban form to design neighborhoods.

In this context, urban regulation that encourages transport-oriented development strategies isn't enough. Systematic integration should take place, including the remodeling of the streets system, the occupation and use of the lots and a distribution of the transformation opportunities in the territory. In this way, it is possible for a city that combines transportation and cheaper and affordable housing, a city where residents can access employment opportunities, a city that takes place synergy of public services and economic nuclei, among other transformations, as point by Salat & Ollivier (2017).

## **7. Conclusions**

Preliminary results point out that, although the guidelines propose interesting solutions, what is observed in practice is that the need to diagnose the potential areas of transformation, either by the number of plots available or by the existing supply areas, is an important condition in the making decisions of the urban transformation strategies that will be adopted for each case.

It is observed that real estate higher stand enterprises are in larger distances from the subway station axis and a important avenue which connects the most populous region of the city. This fact, in a preliminary way, shows the real state sector choice in occupying residential areas not affected by intense traffic, noise and air pollution, characteristics of the blocks nearby axis, which tend to have occupation marked by vulnerability and marginalization. This interpretation deserves a deeper and better diagnose to be exploited in future works, since it is an initial researcher's perception.

Therefore, in a preliminary way, for the study area, it is perceived that the necessary requirements in urban areas to implement transport-oriented urban development strategies are associated with the availability of lots, as well as the availability of the area they own potential for transformation.

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The background of the page is an abstract composition of organic, flowing shapes in various shades of blue, teal, and light purple. These shapes are layered and overlap, creating a sense of depth and movement. Overlaid on these shapes are numerous small, diagonal lines forming a halftone or dot pattern, which adds a textured, almost woven appearance to the overall design. The colors are muted and pastel-like, contributing to a calm and modern aesthetic.

**URBANITY**



# EVALUATING FACTORS INFLUENCING THE UNCONTROLLED GROWTH OF URBAN-RURAL BELT – A CASE STUDY OF DELHI, INDIA

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## Summary

The unprecedented growth of cities in the last few decades gave rise to a new kind of peri-urban area, which is neither urban nor rural in a real sense. The complexity of these spaces has given them various names in different parts of the world such as peri-urban, urban-rural zone, exurbia, transition zone, urban-rural belt etc. These hybrid spaces have a unique socio-spatial dynamic of their own which defy the principles of sustainable development and fail to enjoy the benefits of urban and the subsidised welfares of rural. The transition from agriculture to a new mixed and diversified economic base is one of the significant characteristics of the urban-rural belt.

Delhi, the capital territory of India, is not immune to the uncontrolled growth of urban-rural belt. Often referred to as the “policy void zones”, these spaces display an extraordinary “order in chaos”. However, uncontrolled growth of urban rural belt is pertinent in many cities of India but Delhi is the only megacity where this transformation has been enormous in the last few decades and provides a model for the study in Indian context. The massive in-migration and rampant development are threatening the growth of the city on one side and unique characteristics of rural on the other. The people in the urban-rural belt face enormous challenges concerning essential infrastructure services, safety and security, which affect the standard of living. Often regarded as the provider for urban areas, the belt has failed to sustain its own growth, repeatedly, in spite of numerous interventions.

This paper investigates the factors influencing the uncontrolled growth of urban-rural belt through a settlement’s perspective in Delhi, India. The methodology is based on the exploratory literature review to understand the growth of urban rural belt. The study briefly outlines the concept of urban rural belt and presents the impact of urbanisation in its proliferation. The temporal change in Delhi’s land use is presented to show the massive extent of transformation in the urban rural belt in the region. A small town is selected in the urban rural belt of Delhi to explain the morphology of settlements and demographic change in the wake of urbanisation. The multifunctional nature of urban rural belt is analysed through land use map of the settlement and socio-economic profile through census of India data. With the help of this case study the paper analyses the urban and rural development policies, which resulted in imbalance in the urban rural integration. The outcomes aid to comprehend the rooted interest of people and institutions in the belt, as well as, bias towards its recognition as zone of unique characteristics. The study concludes by providing recommendations and calling for sustainable development of the belt.

Keywords: urban rural belt, urban fringe, urban governance, urban growth



## 1. Introduction

The urban-rural belt (URB) has emerged as a dominant spatial form in the last few decades. It is often regarded as part of the greater peri urban zone but with distinct characteristics, which neither resemble urban nor rural. Often fragmented or clustered in nature, these settlements sprout on the contested and valuable land of the urban-rural belt. A hybrid zone, pertinent around sprawling megacities of developing countries and growing at massive rate. These zones are not only struggling for their spatial identity in the urban and rural landscape but also face massive challenges in terms of social, economic and environmental vulnerabilities. In the post industrial nations peri-urban zone is a symbol of suburbanisation, socio-economic change and spatial restructuring whereas in developing countries it is a zone of chaotic urbanisation, haphazard development (Ravetz, Fertner & Nielsen 2013). It is important to understand the growth and dynamics of urban-rural for the equitable development of the region (Eppler, Fritsche & Laaks 2015). Figure 1 below shows the author's vision of urban rural belt with respect to city centre, peri urban and rural.

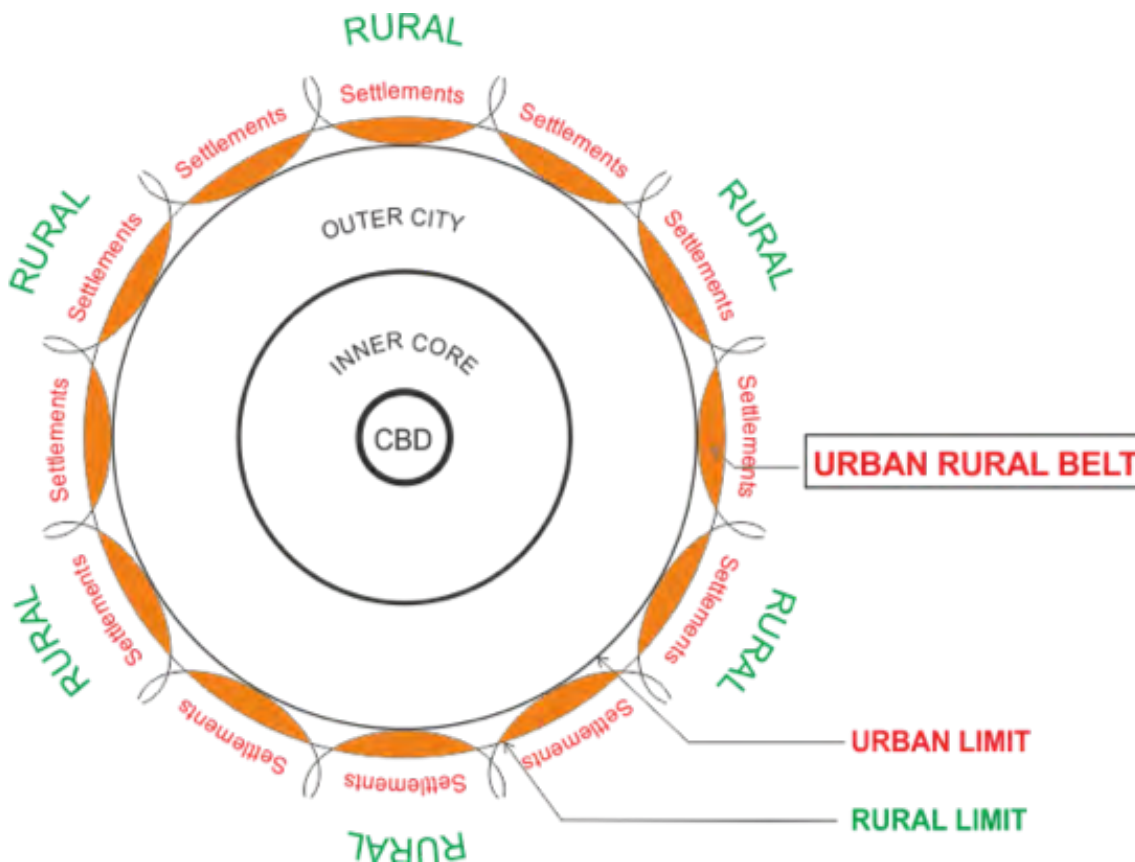


Figure 1: Concept of Urban Rural Belt. (Drawn by Author)

There is no consensus among the social scientists for the definition of URB (Allen 2003) and it has been called different names throughout the world. "Complex transition zone" (Pryor 1968), "rural-nonfarm" (Smith 1937), "acre lot" and "amphibian farming" (Tylor 1933) based on its multi-functional nature and "suburbs", "rural-urban fringe", "outlying adjacent zone", "extended fringe" and countless other terminologies based on its location and context. The confusion and diversity of concept diluted the study of fringe zones to certain extent. Kurtz & Eicher (1958, p. 32) points to three difficulties in precise categorisation of fringe areas in planning theory; i) inconsistency in the use of the term "fringe" in individual research studies, ii) difference in criteria used in determining fringe areas and iii) erroneous combination of fringe areas with other residential areas. Today, it

has emerged as a grey area in the planning and policy making especially for developing countries like India.

## 2. Methodology

The discussions in this paper is based on an exploratory literature review on India's growing urban rural belt. An overall view of urbanisation and its impact on the urban rural belt is presented in Indian context. The transformation of Delhi's land use in the last five decades is examined to understand the nature of urban growth in Indian megacities. Alipur, a small town in the urban-rural belt of Delhi is selected to analyse land use transformation, morphology and demographic variations at settlement level. OpenStreetMap data and ArcGIS software is used to prepare and analyse the land use map of Alipur to highlight the patterns of growth. This case study is conducted to understand the form-specific characteristics in the urban-rural belt. Census of India statistics is used as a primary data source to analyse the demographic profile of the settlement and comprehend the socio-economic profile of the resident population living in the belt. The outcome from this analysis is corroborated with national and state policies to investigate the existing imbalance in urban rural governance and to draw conclusions and recommendations.

## 3. Urbanisation in India

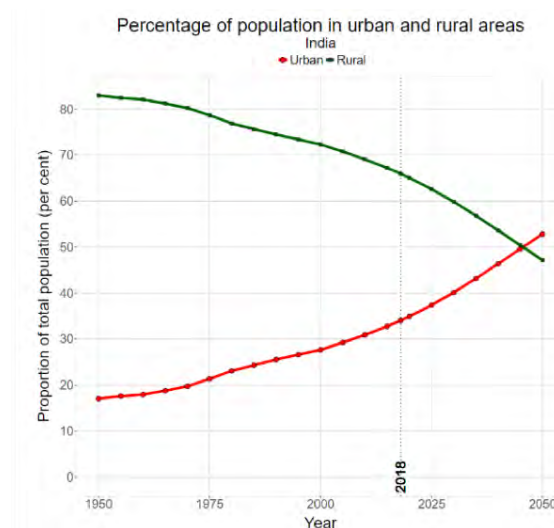


Figure 2: Percentage of urban rural distribution in India since 1950 (Source: UN Population Division (Revision 2018))

In developing countries like India, formation of urban rural belt is a direct consequence of rapid urbanisation and the sustenance of these zones is mostly due to the dysfunctional/disoriented socio-political system and urban governance. The level and process of urbanisation vary from region to region and time to time. Indian urbanisation can be attributed to the combination of rural push (Datta 2006) and urban pull due to declining agriculture benefits and rising industrial/service opportunities in urban centres. Whereas in most of the post industrial nation, it is a consequence of urban push (Jedwab, Christiaensen & Gindelsky 2017) where the culture of suburban living is high. The push and pull of the urban-rural dynamics are at its peak in the urban-rural belt, which experiences a constant flux in the demography and morphology of the settlements over time.

Indian cities play a major role in today's world urbanisation prospects. India's 34% urban population constitutes of 460 million people and is growing at an average rate of 1.02% annually since 1950 (United Nations 2018). To put this into global perspective, India's urban population exceeds the population of USA (326.7 million), Eastern Africa (433 million) and the entire continent of South America (428.2 million). Major share of urbanisation happened by in-migration in the existing

megacities and the growth of existing small towns and villages to Census town<sup>1</sup>. The number of urban areas increased from 5161 in 2001 to 7935 in 2011 (addition of 2532 Census Towns and 242 Statutory Towns<sup>2</sup>). Cities with more than a million-population increased from 35 in 2001 to 53 in 2011. Table 1 below shows the top five Indian cities by population in 2001 and 2011.

*Table 1 Top five Indian cities by population in 2001 and 2011 (Source: Census of India 2011)*

Rank	City	Population 2001 (Million)	Population 2011 (Million)
1	Greater Mumbai	16.37	18.41
2	Delhi	12.79	16.31
3	Kolkata	13.22	14.11
4	Chennai	6.42	8.7
5	Bangalore	5.69	8.5

### 3.1. Restructuring of Urban Rural Belt – In Delhi's Context

The overall growth of Delhi can be attributed to two major events. The first is after India's independence and partition in 1947, when large number of refugees from Pakistan (former India) in search of new home settled in and around Delhi. The population of Delhi during that decade (1941-1951) increased 106% (Dupont 2003), resulting in large number of informal settlements, slums and housing colonies. The second major transformation can be attributed to economic reforms over the years, which stemmed heavy industrialisation and commercialisation of fringe areas, reflecting the potential of urban fringe as new growth centre. Today, Delhi is the economic and political hub of the country and the second largest city after Mumbai and the second largest urban agglomeration in the world with 27 million people (UN 2018).

Available LULC (Land Use Land Cover) data shows that from 1977 to 2014 the city experienced 398.94% increase in its built up area (Jain et al. 2016) whereas the population increased from 3.6 million in 1971 to 16.7 million in 2011 (Census of India 1971 & 2011).

*Table 2 Land Use Land Cover change of Delhi in different years (Source: Jain et al. 2016)*

Land Use/ Land Cover categories	1977		1993		2006		2014	
	Area (km2)	Area (%)	Area (km2)	Area (%)	Area (km2)	Area (%)	Area (km2)	Area (%)
Dense forest	149.84	10.1	164.83	11.11	55.49	3.74	71.1	4.79
Open forest	107.11	7.22	110.77	7.47	99.51	6.71	112.52	7.59
Scrubs/ degraded forest	235.74	15.9	222.52	15	269.61	18.18	210.58	14.2
Plantations	73.89	4.98	38.24	2.58	40	2.7	63.45	4.28
Cultivable area	662.35	44.66	379.85	25.61	263.79	17.79	324.92	21.91
Built-up area	113.77	7.67	344.99	23.26	540.49	36.44	567.64	38.28
Road/rail network	43.42	2.93	38.72	2.61	57.18	3.86	79.17	5.34
River/waterbody	26.69	1.8	20.36	1.37	24.61	1.66	24.38	1.64
Waste land	70.22	4.73	162.75	10.97	132.35	8.92	29.27	1.97
<b>Total</b>	<b>1483.03</b>		<b>1483.03</b>		<b>1483.03</b>		<b>1483.03</b>	

1 Census Town: A minimum population of 5,000; At least 75 per cent of the male main workers engaged in non-agricultural pursuits; A density of population of at least 400 per sq. Km

2 All places with a municipality, corporation, cantonment board or notified town area committee, etc. known as Statutory Town

The major impact of this transformation was the loss of fertile cultivable land which was reduced from 44.66% in 1977 to just 21.91% in 2014 (see Table 2). The North West district of Delhi alone saw a reduction of agricultural land from 92.06% in 1972 to 64.71% by 2003 (Rahman et al. 2012).

#### 4. Case Study – Alipur, Delhi

Alipur is a census town located 20 km north of Delhi's CBD. It is part of the North West district, which is one of the largest districts of Delhi and experienced massive land use transformation in the last few decades. Alipur's selection as a case study for this research is based on its locational context, diverse socio-economic profile, massive change in land use and a typical settlement morphology, which is prevalent in the region. It demonstrates that this area has undergone a conversion from rural to urban at settlement level and acts as a transition zone to rural, which is a distinct feature of urban-rural belt in Indian context. In terms of size it fits more towards the smaller town size category with a population of 20,332 in 2011, whereas the average population of Delhi Census Towns is 47,628 (Census of India 2011). Figure 3 below shows the location of Alipur on Delhi's map.

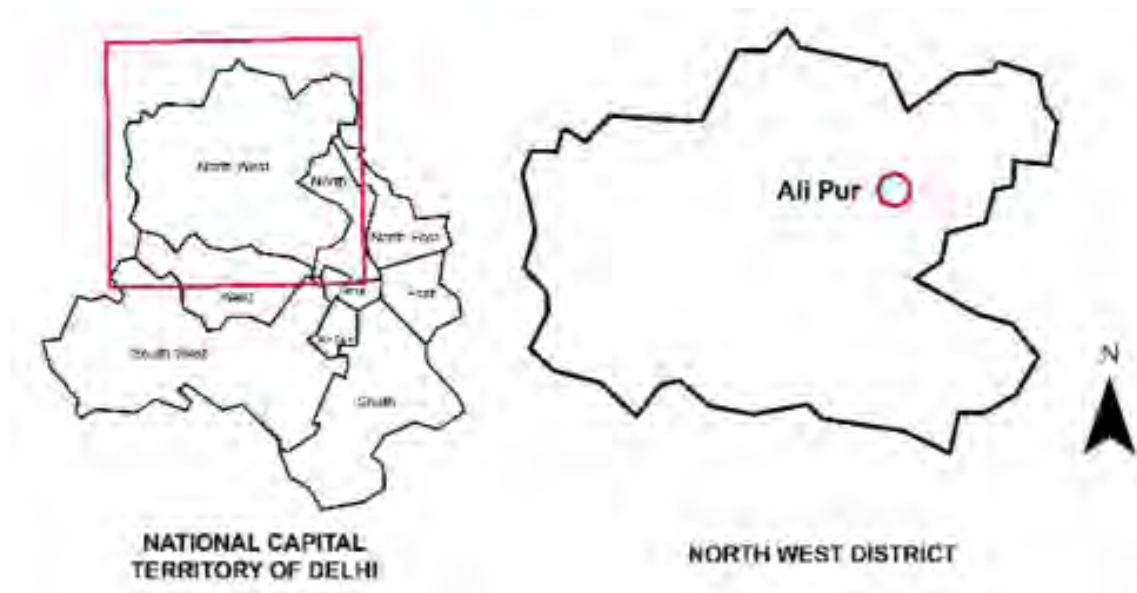
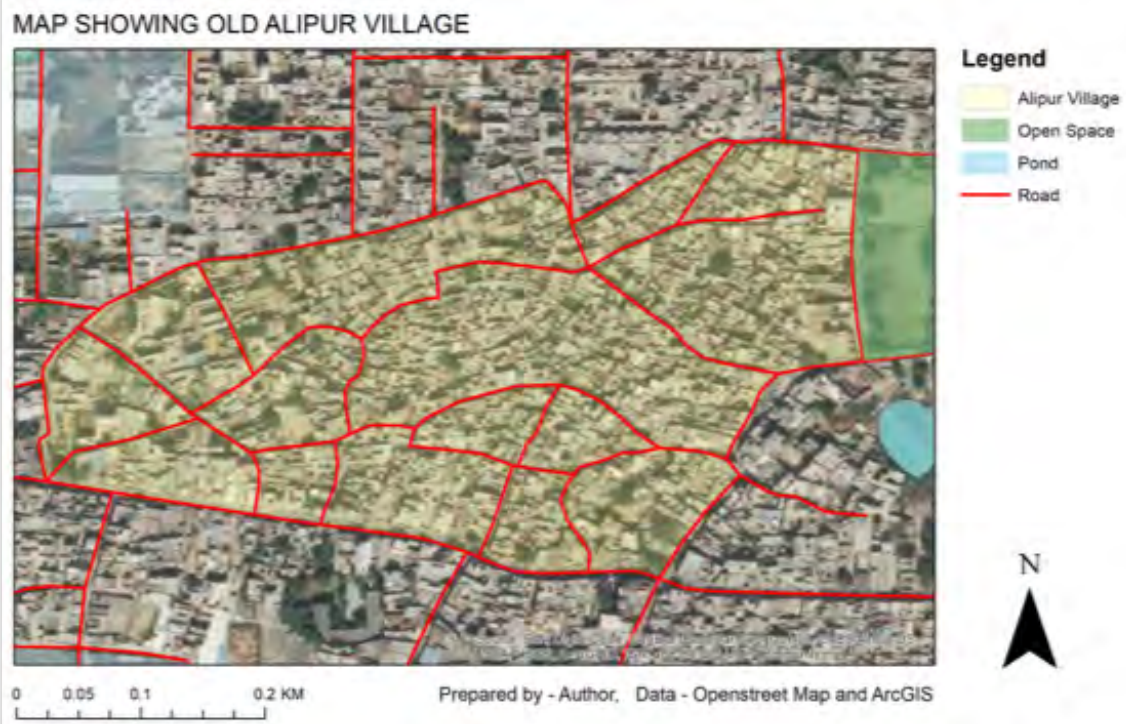


Figure 3 Location of Alipur town in the National Capital Territory of Delhi. Source: Author

##### 4.1. Morphology, Growth, Governance and its Impact

The core of Alipur town (previously Alipur village) shows an irregular pattern of growth, especially in terms of street layout and unit placement (Please see Figure 4 below). It shows a compact development with narrow lanes and close-knit houses, lacking open spaces and well defined zones to represent market, parks or gardens. Whereas, the periphery of the town which developed over the period shows more defined and oriented street and housing pattern. Alipur is a typical example of settlement which developed from a rural village to an urban centre and became part of the urban-rural belt.





*Figure 4 Morphology of Alipur village showing irregular planning and compact development. (Map drawn by the Author; Data source: OpenStreetMap and ArcGIS.*

In the words of Karan (1957, pg. 70), Indian towns acquired an uneven pattern during its long period of evolution with irregular street layout, complex aspect and functions. He also mentions the absence of clear cut functional zones but presence of central bazar in many towns. The morphological characteristics of Alipur matches Karan's description in many ways reflecting its natural growth from a rural settlement to town in the last few decades.

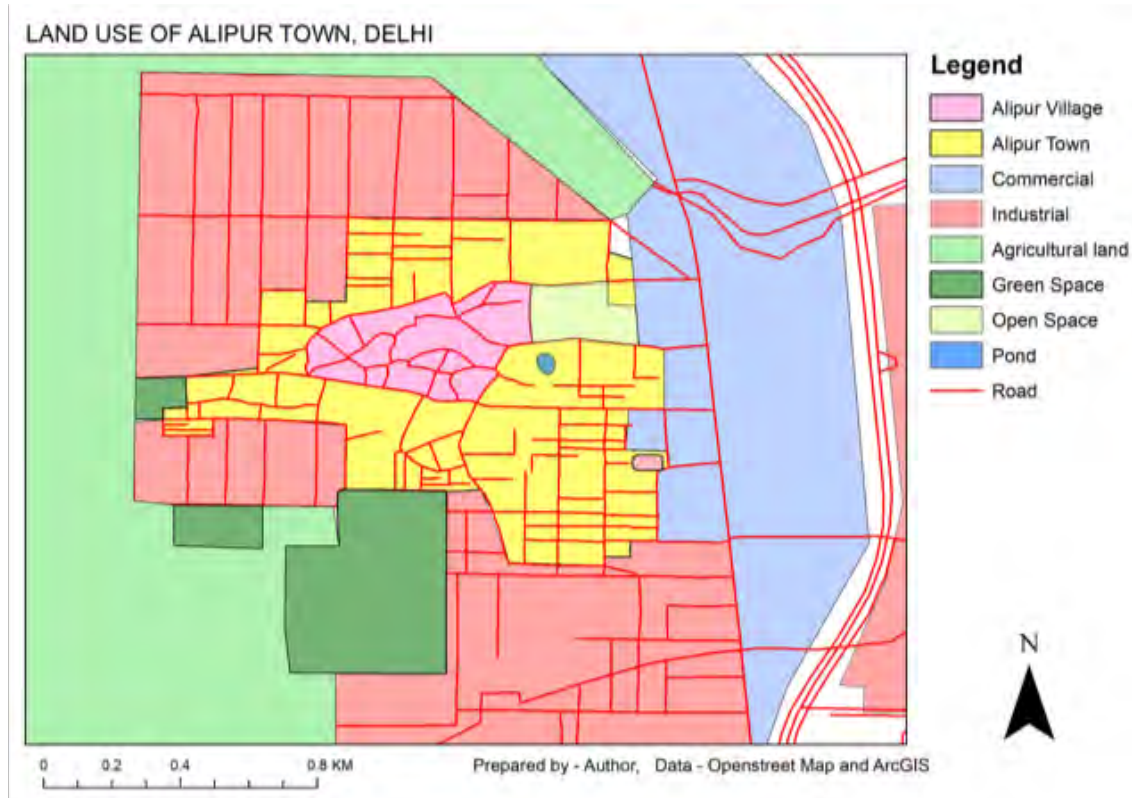
Alternatively, the emergence of this kind of haphazard and uncontrolled growth in contemporary urban-rural landscape reflects negligence and absence at national and state level policies towards rural spatial planning regulations. Even the 73rd Amendment Act of 1992 (Singh 1994), which empowered rural bodies (Gram Panchayats) to prepare socio-economic welfare plans, did not mention any spatial planning guidelines for the development of rural areas. At the same time, urban authorities created planning regulations to guide the development in areas under Urban Local Bodies (Nandi & Gamkhar 2013) but failed to identify sprawl towards the rural and recommend any strategic plan for integrated development. In 2017, a Rural Area Development Plan Formulation and Implementation (RADPFI 2017) guideline was proposed by Ministry of Panchayati Raj, India, for the spatial development of rural areas (Ministry of Panchayati Raj 2017) in the country. Though it would not have any legal enforcement until and unless the states incorporate this guideline in the Town and Country Planning Act.

#### **4.2. Land Use and Demographic Change**

The present land use plan of Alipur (see Figure 5 below) shows impact of urban policies and rooted interest of stakeholders at play. To give direction to the growth after the post-colonial era Delhi Development Authority (DDA) was formed in 1957 by the Planning Commission of India (replaced by NITI Aayog in 2015). The first master plan of Delhi in 1962 (first in the country) by DDA was instrumental to certain extent in creating restrictive land control, launching new housing programs, decongesting existing colonies, removal and resettlement of people in slums (Dupont



2003). This could be seen in the new areas of Alipur town, which shows more controlled growth compared to central village.



*Figure 5 Present Land Use distribution of around Alipur Census Town. (Map drawn by the author; Data source: OpenStreetMap and ArcGIS)*

The massive industrial land use around the town is a direct consequence of India's 1990s economic reforms which focussed on heavy industrialisation and commercialisation to boost the economic growth. The reforms resulted in substantial transformation of agricultural land and demographic growth (mostly through in-migration) in the region including Alipur where population grew by 79.7% from 1991 to 2001 (Census of India 2011). The significant growth of the cities took place mostly due to rural to urban migration, which was nearly 56% in 2001-2011, compared to the natural growth of 44% during the same period (Bhagat 2011). Most of the migrants unable to bear the cost of living in the urban core or inner-city land ended up in the urban rural belt, because of the availability of economical space, minimal cost of living and improved connectivity. The convenience of urban rural belt gives them better accessibility to work either in the rural farmlands, industries or as daily labourer/worker in the city.

The census data also shows that, out of 5904 main workers in Alipur, 5404 are involved in diverse economic fields (categorised as "other") and only 197 workers work as cultivators and agricultural labourers, showing the multifunctional nature of the belt. Most of the workers in the town are male, the women representation is just 11%, which shows drastic shift from pure rural areas where the percentage of women workers is much higher. Urban-rural belt also gained lot of attention from real estate developers in the last few decades due to availability of large patches of land at economical rate and better connectivity to cities. There has been huge increase in farm houses, housing societies and commercial establishment along highways in urban rural belt. Conversion of land use through lobbying and manipulation in the name of development is common in urban rural belt. Today, most of the industrial area around Alipur comprises of massive warehouses and small-scale industries. The commercial areas include marriage gardens, motels and restaurants mostly along the highway.

## 5. Recommendations and Conclusion

India's urban and rural governance is a gradual culmination of development policies at national, state and local levels. The major challenge comes in the form of institutional imbalance, which fails to see the development of urban and rural cohesively. On a larger scale, rural governance was mostly about agricultural development for self-sufficiency in food production and urban development was about economic growth and social inclusion. This notion created isolated institutional framework for each causing disparity in governance, which subsequently resulted in uneven and uncontrolled growth in the urban rural belt. Ahluwalia (2017, p. 1) points to three major hindrance for better urban governance in India, firstly, a federal framework that has not empowered the third tier despite amending the constitution in 1992 (74th Amendment Act which gives Urban Local Bodies autonomy for development). Secondly, a missing link between metropolitan planning and governance and thirdly, a system that is heavily biased towards the rural sector (Ahluwalia 2017, p. 1).

On one hand, the government is investing heavily in the development of smart cities (Paharaj, Han & Hawken 2018), but on the other hand, this development policies fail to recognise their linkages to surrounding rural belts. In the case of Delhi, the peripheral settlements especially small towns were allowed to develop naturally and when they reached certain population and fulfilled the criteria of "urban" in census book, they were converted to "census town" overnight. For example, the change in demographic and economic indicators by Census of India 2011 resulted in the conversion of 17 villages into urban areas in the north west district of Delhi (Census of India 2011). Whether they are treated as urban in terms of amenities and opportunities is a matter of concern. This represents a hasty approach of urbanisation, risking the sustainable growth of the urban rural belt.

This paper suggests two recommendations; first, the states should adopt a strict and practical development regulation guidelines with focus on the urban rural belt. This will help into orienting the growth and empowering rural settlements in the periphery to adopt to dynamics of the belt. Second, it is important to develop innovative policies, ideas and tools to preserve the existing rurality, which gets lost in the wake of uncontrolled urban sprawl. It is important for planners and policy makers to understand that the equitable growth of the region is not possible, if urban and rural are seen in isolation. The paper also calls to address the urban and rural bias in planning and policymaking and recognise the intricate relationship between the two.

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# IMPLEMENTING A NEW HUMAN SETTLEMENT THEORY: STRATEGIC PLANNING FOR A NETWORK OF CIRCULAR ECONOMY INNOVATION HUBS

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## Summary

Whilst the energy transition from fossil fuels to renewables offers significant environmental benefits, the other transition—from a centralised to a distributed energy system—underpins a disruptive model for planning cities, towns and villages. A local energy micro-grid can power a local water micro-grid, which in turn can irrigate a local food system, offering a community the opportunity to harvest, store and distribute food, water and energy within their immediate catchment. Designing the layout of the built environment in the form of a campus or resort—with smaller private spaces and a wide range of accessible shared spaces and facilities—would also minimise energy demand while simultaneously providing opportunities for social interaction and connection.

Creating places where local residents can collaborate to provide their basic needs is a form of Place-Making as well as an achievable alternative to the Universal Basic Income (UBI). The direct delivery of basic needs—consumed by the producing community—rather than the provision of money to pay for the purchase of these same needs, addresses the issue of wealth distribution but also re-imagines how wealth is created. It requires communities to take responsibility for their local environment, supporting infrastructure and others in their community.

Described by the author as a **Circular Economy** Innovation Hub, such a planning strategy adopts the principles of the Circular Economy—systems thinking, life-cycle planning and striving for zero waste. By integrating the water, energy, food and built systems, waste can be re-purposed and the overall efficiency of all component systems is significantly increased. The more efficient delivery of the identified natural needs then offers residents more free time for **innovation** and creativity. Finally, such places are not isolated villages but **hubs** or nodes in a network, connecting and collaborating with others in their bio-region and beyond.

With the planning theory stage completed, a number of further projects with research partners and local governments are now building a knowledge platform, including infrastructure modelling, planning policies, an architecture brief and financial strategies. These would enable this form of regenerative land development to be incorporated in Local Government planning policies, providing certainty for investors and enabling delivery by developers.

**Keywords:** Circular Economy, Energy Transition, Regenerative Development, Universal Basic Income, Healthy Built Environment

## 1. Introduction

Smart Cities, Liveable Cities, Green Cities, Biophilic Cities, EcoCities and Regenerative Cities. Add to the mix Eco-Villages, Intentional Communities and Place-Making and it seems everyone is talking about cities and what cities of the future could or should be like. Yet in all this conversation there is little or no discussion about what a city is. Before adding an adjective let's try to understand the noun we are trying to describe and change. What is a City?

Most commonly, the 'city' refers to 'urban settlements', where urban implies non-rural. Yet, while the United Nations' *World Urbanization Prospects (2014 Revision)* was widely quoted, reporting that 54percent of the world's population now lives in urban areas, the same report acknowledged that "there is no common global definition of what constitutes an urban settlement" and indeed "the urban definition employed by national statistical offices varies widely". In this paper it is argued that given clean energy technologies as well as the need to reconnect humans with the environment on which we live, the fundamental separation between urban and rural areas is inappropriate and that food systems should be integrated with the built environment.

For the purposes of this paper we will use the original Greek and Roman concept of the city as simply 'a community of citi-zens'. Taking this as a starting point, we ought to ask what do these citizens need? The natural needs are a good place to start; water, food, energy and shelter. Then, given advances in technology and knowledge more generally, as well as awareness of human impacts on ecosystems, how would we design a new city to provide these basic needs? How big would it be and how many citizens would it have? Recognising various options for tele-commuting and the future of electric vehicles and car sharing, how would this city connect with other cities? How might we design an energy system using renewable energy to generate, store and distribute energy in a micro-grid? Significant research in water sensitive urban design (WSUD) and cities as water supply catchments, suggest that it is also possible to re-imagine our systems for harvesting, storing and distributing water. Then, of course, water can generate energy and also store both potential energy and heat energy. There are substantial opportunities to increase efficiency by integrating the energy and water systems. What if we then include a food system—an expanded form of diverse urban agriculture—also using it to clean water, while saving the energy used for packaging and transport?

To implement a new human settlement theory, the question to ask is: If you were able to build a city from scratch, knowing what we now know and having access to the technology that is available to us today, how should we go about it? If we were to imagine ourselves as explorers, looking for new lands and wishing to build a new settlement, what characteristics of geography and climate would we look for? How would we determine the appropriateness of a locality so as to complement existing settlement patterns and restore degraded land? It is considered that this approach offers significant opportunities for rural and regional Councils who are seeking to attract people and investment to their localities. Land is less expensive, large parcels are available and farming communities are looking for options not only to attract investment and people but also to regenerate the land that has been so degraded by the chemical-based, large scale monoculture practices that have been imposed on them over the past 50 or so years.

The purpose of this paper is to describe what is considered possible if we were to re-imagine our approach to strategic planning in the manner described above and then, to briefly outline how this model could be implemented through the NSW planning framework.

**Section 2** provides a general overview of an evolving development model described as a **Circular Economy Innovation Hub**. This model adopts the principles of the Circular Economy—systems thinking, life-cycle planning and striving for zero waste. The concept of the Circular Economy allows us to think of cities as systems that efficiently provide residents with their basic needs. Rather than connecting detached houses to the energy and water grids, how do we integrate food, water, and energy into the built system? Can a local energy micro-grid power a local water micro-grid to, in turn, irrigate a local food system, offering a community the opportunity to harvest,



store and distribute food, water and energy within their immediate catchment? This section also explains why the term '**Circular Economy Innovation Hub**' is used.

**Section 3** offers a discussion about how the proposed innovation hub addresses a number of significant public debates. These include:

- the **future of work** due to technological change, including how the internet is creating opportunities for remote work, sometimes referred to as the **e-change**.
- the **future of work** and the consequent suggested need for a **universal basic income**,
- **affordability of housing** and cost of living pressures,
- **one planet living** and striving to live within the limits of our ecological systems,
- the characteristics of **healthy urban design** as developed by public health experts exploring the impacts of the built environment on health outcomes,
- the concept of **regenerative development** and its intersection with **regenerative agriculture**.

**Section 4** outlines how the Circular Economy Innovation Hub can be implemented through the NSW planning system. This identifies how specific strategies, policies and development plans would need to be created or amended to enable this form development. This is important to provide certainty for investors and future residents.

## 2. Overview of the development model

### 2.1. What's in a name?

The development model is referred to as a 'Circular Economy Innovation Hub'. The term has been carefully chosen to reflect its inherent characteristics and also to differentiate it from other 'alternative' approaches to land development.

The first characteristic implicit in the name is that the settlement is referred to as a 'Hub' rather than a village. The aim is to emphasise that the development should be imagined as a node within a broader network and not an isolated entity. The hub should not be imagined as a gated community but would remain connected with, and a part of, the broader society, complying with its laws and participating in the local, regional and global economy in an open and transparent manner. This model should essentially be viewed as an alternative to greenfield subdivisions. Rather than developers simply providing housing, they would provide housing integrated with shared spaces as well as food, water and energy systems. Also, the aim is not just to build a single hub but to create a replicable process that can be implemented by other land developers to eventually create a network of like hubs.

Secondly, the hub will be designed according to the principles of the Circular Economy. The proposed transition from a linear to a circular economy has gained significant momentum in recent years, receiving the support of the European Parliament (2016), European Investment Bank (2015) and numerous major banks and corporations. A useful definition of the Circular Economy is provided by the Ellen MacArthur Foundation, a leading European advocate of the Circular Economy:

*Looking beyond the current "take, make and dispose" extractive industrial model, the circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to design waste out, while minimising negative impacts. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural and social capital.*

From the above definition we can extract some of the key design principles of our proposed land development model such as life-cycle planning, systems thinking and striving for zero waste. The Circular Economy is underpinned by renewable energy so, taking a systems approach, an energy micro-grid will generate, store, monitor and distribute renewable energy on site. The energy

system will power a water system that will be cycled through the site, providing for residents, irrigating crops and watering animals. The living and work spaces will be passively designed to minimise energy demand and more generally, the energy, water, food and built systems will be integrated to maximise efficiency.

The development is referred to as an Innovation Hub to emphasise that it is not a dormitory suburb but will integrate living spaces with work spaces, incorporating a work hub that supports the transition from the work commute to tele-commuting. There will also be a significant amount of work available in the management and maintenance of the water, food and energy systems and the shared spaces and facilities.

It is also proposed to incorporate innovative product development and business models to advance the notion of the Circular Economy. This primarily involves the inclusion of waste to resource micro-factories as currently being developed by the Centre for Sustainable Materials Research and Technology (SMaRT) at the University of New South Wales. The SMaRT Centre refers to green materials as those that “are made entirely, or primarily, from the rubbish we throw away”.

The reference to innovation also includes the innovative systems approach to the design of the infrastructure so as to efficiently provide the basic needs of all residents. The efficient provision of necessities maximises the free time available for innovation, art, relaxation and social connection.

The idea of developing a network of hubs that provide residents and visitors with water, food, energy and shelter aligns with the indigenous view of the landscape as a network of waterholes connected by song-lines. Watson (2015), in describing indigenous law refers to a distributed system, with obligations for people in each place to renew the land. The relationship with the natural world involves a way of being that is cyclical—aligning with natural cycles—rather than our current linear world-view.

## **2.2. Life Cycle Planning**

Designing at the village scale also allows for more efficient delivery of living and work spaces, allowing for shared spaces to be used for multiple purposes and enabling residents to move to different parts of the hub as their housing needs change through different life stages. Current failure to plan for different household sizes, coupled with significant transaction costs involved in moving house, have resulted in a significant misalignment between housing structures and household occupancy rates as illustrated in **Figures 1 and 2**. This has been exacerbated by demographic changes in the Australian population over the last half century—an ageing population, increasing age for getting married, reduced housing affordability and increasing divorce rates. These have all resulted in a falling number of occupants per household. Currently in NSW, 56 percent of households have only one or two occupants, while 67 percent of houses are detached dwellings, essentially designed for families.

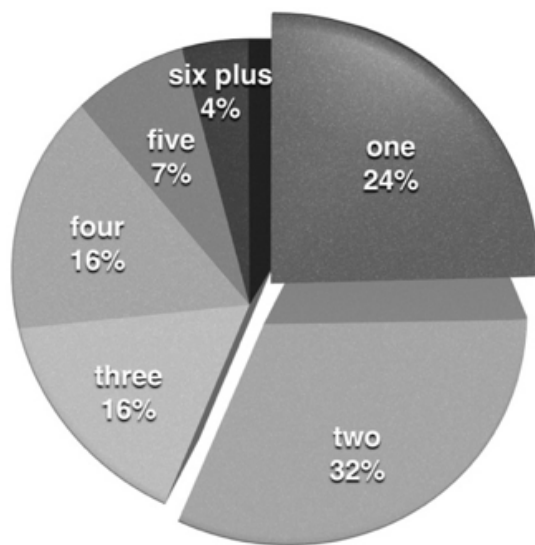


Figure 1 Occupants per occupied dwellings in NSW (ABS Census 2016, table G31)

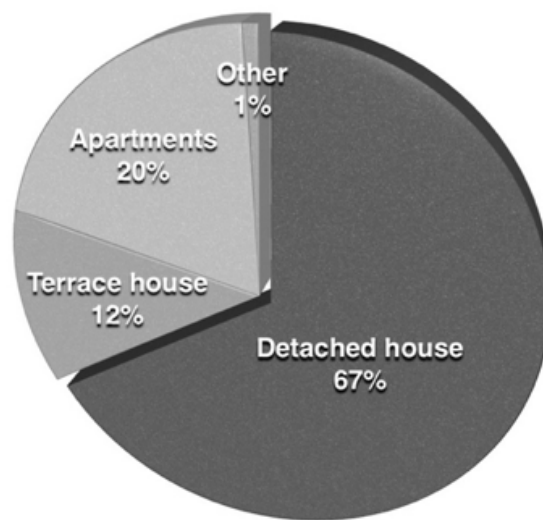


Figure 2 Dwelling Structure in NSW of occupied dwellings (ABS Census 2016, table G32)

The proposed Circular Economy Innovation Hub would design for a microcosm of the NSW age demographic and household size demographic, providing smaller private spaces, with access to wide range of shared spaces. These ideas are already being developed through **flexible house designs** and in **co-housing developments**.

### 3. Responding to Public Debates

#### 3.1. The Future of Work and the E-Change

Modelling included in a 2015 report by the Committee for the Economic Development of Australia (CEDA) suggested that “around 40 per cent of the [Australian] workforce face the high probability of being replaced by computers in the next 10 to 15 years”. It is difficult to comprehend the transformative effect that the Information Revolution is likely to have on our society. The only comparison we have is the massive changes caused by the Industrial Revolution when technological advancement resulted in the restructuring of society and the consequent reorganisation of cities. According to Grigg (1987:93), “In the early eighteenth century farmers and farm workers made up three-quarters or more of the labour force in nearly every country.” Yet by the late 20th century this had fallen to as low as two percent of the workforce in Sweden, Switzerland, the UK and the US, while in Europe it employs about 8 percent (Grigg 1987:95).

From a widely distributed population mostly involved in agriculture, the Industrial Revolution created a centralising force, resulting in high population concentrations in urban centres. From the late Nineteenth Century, various solutions have been proposed to address the issues arising from congestion in large cities. Ebenezer Howard (1898) expressed concern that “the people should continue to stream into the already over-crowded cities, and should thus further deplete the country districts”. Howard argued for the need to draw people out of large cities and into rural areas by designing places that provide a better balance between town and country life. He referred to these as ‘Garden Cities’. Despite the significant role of the Garden Cities Movement in town planning in the UK, plans and policies in Australia to encourage people to leave the cities have been largely non-existent or ineffective. The proposed innovation hub can be imagined as a type of garden city in which the gardens are diverse, integrated food systems rather than simply pleasant open spaces or rural landscapes.

Over recent decades, much of the migration from the cities to rural and regional areas has been attributed to individuals seeking a more relaxed lifestyle, that is, a sea-change (to coastal towns) or a tree change (to rural or farming areas).

Demographer and Business Analyst Bernard Salt argued in a report for NBN Co. (2016) that access to the internet is adding another dimension to this shift:

*"We are witnessing a quiet lifestyle revolution in suburban Australia. The fusion of a relaxed lifestyle in tree-change and sea-change locations combined with super connectivity provided by the NBN network, is giving people even greater scope to take greater control of where they live and how they work."*

*"I predict a cultural shift or 'e-change movement' which could see the rise of new silicon suburbs or beaches in regional hubs as universal access to fast broadband drives a culture of entrepreneurialism and innovation outside our capital cities."*

Embracing this e-change represents an important economic development strategy for rural and regional councils. The Circular Economy Innovation Hub development model, with internet co-working spaces and waste to resource micro-factories, can be imagined as a futuristic 'garden city' that provides the co-working spaces as well as a low-cost platform (see 3.3 Housing Affordability) for innovators and entrepreneurs willing to relocate to a rural or regional area as part of an e-change movement.

### **3.2. The Future of Work and Universal Basic Income**

The study of city planning over the last century or so, evolved to address the problems of congestion and pollution caused by this agglomeration of manufacturing and factory workers in cities. Whilst these urban problems are important, the urban environment as we know it was created by changes in the agricultural system. The production of the food needed to sustain urban populations is entirely missing from the planning of cities. The Circular Economy Innovation Hub is a system that provides for the needs of the citizens by incorporating food as an essential part of that system.

It is no longer appropriate for the planning of cities and towns to be based on the consequences of agglomeration and centralisation, ignoring food production and the possibilities for decentralisation offered by the internet. Planning should extrapolate the future from the world as it is today, rather than from the world of the Industrial Revolution. As technology continues to advance, making many traditional jobs obsolete, it is important to start creating resilient places where people can work to directly satisfy their basic needs, relying less on jobs that provide an income to satisfy these same basic needs.

There is growing interest in the concept of a Universal Basic Income (UBI) as a means of addressing the likelihood of future job losses as well as a means of addressing inequality in wealth distribution. Rather than debating how to fund a basic income in monetary terms, a far more effective and efficient strategy would be to create places that provide peoples' basic needs directly.

This also addresses a significant gap in the UBI debate, which aims to address the inequality in the distribution of wealth but does not address how that wealth is created. Regenerative land development complements the UBI debate as it aims to increase our natural capital through restoration and maintenance of land and water, and also plant and animal life, while minimising waste and other negative impacts.

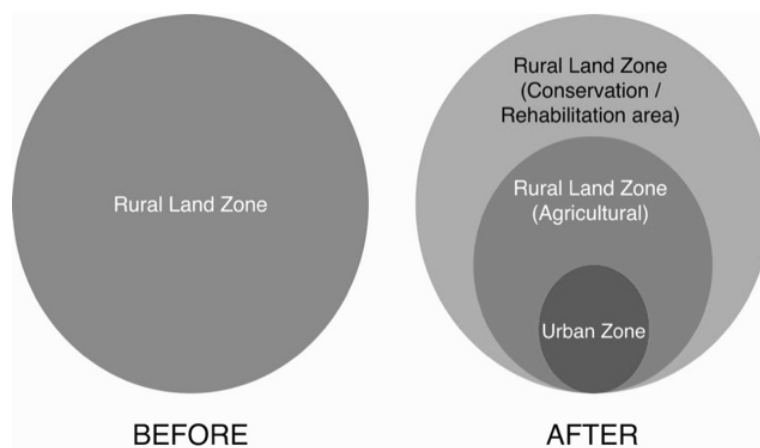
### 3.3. Housing Affordability

The housing affordability crisis is a symptom of much broader structural issues. Housing affordability is not just about house prices, it is also about access to and availability of work, transport costs and other costs of living. These issues can no longer be addressed in isolation but need to be tackled holistically and systemically. This has been our approach in the design of the Circular Economy Innovation Hub.

With respect to the **cost of living**, the hub would be designed to provide food, water and energy for a discrete population. Having a known and fixed population, allows for the design process to provide for an abundance of these basic necessities. An over-supply of food, water and energy—the demand for which doesn't vary significantly with price—drives their price towards zero. Whilst work is still necessary and so a fair system for allocating responsibility for this work will be required, food, water and energy—having zero marginal cost—would not be market exchange commodities. The passive architectural design of the built environment also reduces energy demand and therefore cost.

The design of a village as a live and work hub also substantially reduces **transport costs** by having work opportunities within walking distance of living environments. A compact design with up to 200 people also makes vehicle sharing more feasible as access to the shared vehicles will be within walking distance. Quality internet connection at the co-working spaces enhances the option of tele-commuting. Meanwhile the local energy micro-grid would be designed to incorporate an electric vehicle (EV) charging station—a shift to EVs drives fuel costs towards zero.

In addition to these cost-of-living and transport factors, tackling housing affordability requires that the various components of house prices be addressed. The first component is land value, which can be minimised by purchasing rural land and **capturing the land value uplift** when it is rezoned as illustrated in **Figure 3**.



*Figure 3 Rezone rural land into three precincts*

The principal objective of this approach is to internalise the land value uplift. That is, it is well understood that the process of rezoning land increases the value of that land. This increased land value—the land value uplift—currently benefits the land owner at the time the land is identified for rezoning. They may then sell the land and retain all the financial benefit of this value uplift. As the process of rezoning land is a public function, the increased value should provide a public benefit, either in the form of public infrastructure, lower housing costs or a combination of the two. This project intends to make housing more affordable while also funding the local water, food and energy infrastructure by capturing this land value uplift. This would be done by requiring certain activities and infrastructure works to be carried out at certain stages prior to the rezoning of land.



Housing **construction costs** would also be reduced by creating smaller private spaces. Unlike a tiny house village, the reduction in house sizes is compensated by access to a wide range of shared community spaces, such as for work, cooking and eating areas, entertainment facilities, swimming pools and the like.

Infrastructure costs are kept to a minimum by the compact design, which is more like a resort or campus than like current residential subdivisions. Also, rather than subdividing the land and setting up a complex regulatory planning framework for the construction of each lot, the Innovation Hub would be built in a coherent manner by a single entity, thus further reducing construction and financing costs.

Further work is now being undertaken with respect to land tenure and investment structures to minimise property transfer costs and also land speculation. Given that residents would have access to various shared spaces and assets provided in different parts of the site, a collective ownership arrangement would be preferred. The Community Land Trust (CLT) model developed for the Australian context by Crabtree et al (2013) would be an appropriate structure. CLTs provide for collective ownership of the land, which is held in trust in perpetuity to avoid land speculation. We are also proposing to integrate other emerging models in the development industry such as 'build-to-rent' and 'baugruppen' or development collectives.

### 3.4. One Planet Living

Kate Raworth (2017) expands on the concept of One Planet Living by arguing that "wellbeing depends on enabling every person to lead a life of dignity and opportunity, while safeguarding the integrity of Earth's life-supporting systems". As well as an ecological ceiling, an economic system should also provide a social platform. Raworth calls this living within the doughnut.

It is a well-known principle in economics that, for basic necessities, people buy about the same amount whether the price rises or falls. That is, the demand for basic necessities is broadly 'inelastic', which also means that the total amount of food, water and energy needed by households is relatively stable. It is therefore possible to design a place for the needs of a discrete population by estimating their demand for food, water, energy and also living and work spaces. A key design approach for the development is to **match the population to the capacity of the land and its infrastructure**, starting with an assumed population size of no greater than 200 persons. The final design size may be reduced and would be determined by the capacity of the chosen site and its supporting infrastructure to sustain that population. The land area required to feed 200 people will significantly influence total land requirements, so a research project is currently being developed to determine land and water requirements for different nutrition plans.

### 3.5. Healthy Urban Design

According to research by public health professionals, the built environment has an important role to play in supporting human health. In a review of the literature in this field of Healthy Urban Design by Kent et al (UNSW, 2011), three key interventions were identified that could support human health. These are; getting people active, connecting and strengthening communities and providing healthy food options.

The design of the Circular Economy Innovation Hub integrates a food system of significant scale into the built environment providing not just healthy food options but the opportunity to collaborate with others in the community to provide that food. A walkable environment connecting a wide range of daily activities also allows people to get more active. This development model therefore has the potential to significantly improve health outcomes for the resident community.

### 3.6. Regenerative Development

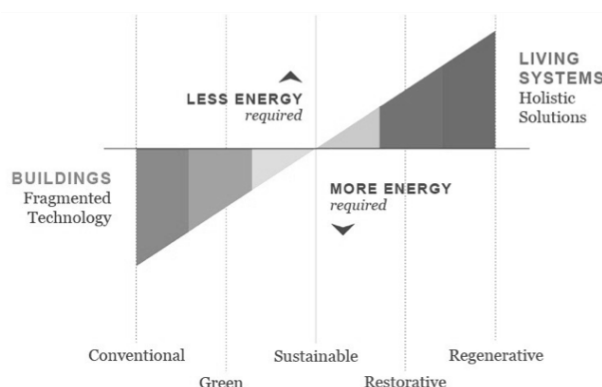


Figure 4 Trajectory of Ecological Design (image used with permission) © All rights reserved. RegenesiS – Contact Bill Reed, [bill@regenesigroup.com.au](mailto:bill@regenesigroup.com.au) for permission to use

The concept of **regenerative development** is emerging as a new approach to land development. Proponents argue that we need to move beyond sustainability—sustaining ourselves and the environment—to regenerative development where we have a positive impact. This is best illustrated in the diagram in **Figure 4** by Bill Reed from RegenesiS. Meanwhile, forward thinking farmers like Charles Massy in his book **Call of the Reed Warbler** are advocating for a revolution in farming practices, calling the new approach ‘regenerative agriculture’.

The Circular Economy Innovation Hub integrates regenerative development with regenerative agriculture.

## 4. Implementation through the NSW Planning System

### 4.1. Strategic Planning

In order for Circular Economy Innovation Hubs to be financed, developed and replicated, the development model must be clearly articulated in local government strategies as a desired form of development. In accordance with section 3.9 of the Environmental Planning and Assessment Act 1979 (EP&A Act, NSW), all Councils must prepare a Local Strategic Planning Statement (LSPS). This will set out a 20-year vision for land use in the local government area. This is a recent amendment to the EP&A Act and regional councils must have their first statement in place by 1 July 2020.

The LSPS provides an ideal opportunity for Councils—in consultation with their community—to introduce this development model into their local planning framework. The LSPS should explicitly refer to Circular Economy Innovation Hubs (or equivalent terminology) and should include objectives such as for future land development to be regenerative in character, that development integrates regenerative agriculture and that it provides for all the energy and water needs plus a specified proportion of food for a discrete population. The LSPS should also:

- Identify the general localities (not the specific sites) where this development would be permitted.
- Refer to a policy document or chapter in the Development Control Plan (DCP) for more information.

### 4.2. Policy Document or Chapter in DCP

The policy or plan should clearly describe the development form and the process through which this development outcome could be achieved. As a minimum the following should be included:

- Requirement to prepare Concept Development Application in accordance with Division 4.4 of the EP&A Act together with a Planning Instrument Amendment in accordance with Division 3.5 of the EP&A Act.
- Requirements at different stages prior to rezoning of land (eg. what must be done on land that is not to be rezoned, what must be done before Council resolves to refer to the Department of Planning, prior to advertisement, prior to final resolution, prior to referral to Minister for signing and publication),
- The minimum total land area and the proportions of the site area for the three precincts (ie. (a) Conservation/ Rehabilitation area, (b) Agriculture and (c) Live/ Work hub),
- Minimum requirements for harvesting, management, storage and distribution of water, food and energy,
- Design principles for buildings,
- Preparation of a transport plan for the site as well as impacts on the surrounding road network.

A useful approach would be to firstly identify one site for a pilot project, the development of which would assist in refining the development controls and wording in the strategy.

### 4.3. Voluntary Planning Agreement Policy

The proposed development will include various facilities, assets and open spaces to service the population within the development site and some of these will also be available to the proximate township and other communities in the broader area. It would therefore be appropriate to prepare a Voluntary Planning Agreement (VPA) policy, including a standard template VPA that provides a framework for the delivery and management of infrastructure both on the subject site and the surrounding area. This should address:

- Effect on any development contributions required pursuant to sections 7.11 or 7.12 of the EP&A Act.
- Effect on any charges for water supply, sewerage and stormwater drainage facilities under s64 of the Local Government Act 1993
- Requirement for the VPA to run with the land pursuant to section 7.6 of the EP&A Act.
- Effect on waste levies
- Effect on ordinary rates or requirement for any special rates.

## 5. Conclusion

With the research and planning theory stage completed, a number of further projects with research partners and local governments are now helping to create a knowledge platform, including infrastructure modelling, planning policies, an architecture brief and financial strategies. These would enable this form of regenerative land development to be incorporated in Local Government planning policies, providing certainty for investors and enabling delivery by developers.

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## DENSITY AND QUALITY OF LIFE IN MASHHAD, IRAN

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### Summary

The Quality of Life (QoL) is a concept, which can be evaluated in urban environments through consideration of social, physical, environmental and economic indicators. The strategy of a high-density building typology, including the need to expand vertical public space as a by-product of this urban planning, also implying rise in the number of urban residents, has gained popularity in Iran. Housing and the way it is shaped, is influencing the Quality of Life. The present study depicts an analytical and comparative assessment of the Quality of Life as an attribute of sustainability in Sheshsad Dastgah residential complex, Firooze residential complex and Eastern part of Goharshad neighborhood in Mashhad, Iran. Quality of Life is seen as an integrated way to describe the experienced quality of the resident's direct environment. The study adopts a descriptive-analytical methodology. Correlation among variables and Step-wise regression analysis are the statistical methods used in the study. The overall population consists of 7033 people, of whom 370 are selected as agents in the investigation. As indicators of the Quality of Life in this research physical, social and environmental aspects used and are measured using sub-indicators pertaining to environmental quality, hygiene, access to recreational spaces, access to educational facilities, security, physical belonging, social solidarity, collaboration, access to daily facilities and housing and infrastructure. The Quality of Life scores revealed that the average score of QoL in Sheshsad Dastgah (SD) is 4.17, while it is 3.46 in Firooze (F) and 2.88 in Goharshad East (GE) while 5 is the highest possible and 1 is the lowest possible score. Hence the overall quality of life in Sheshsad Dastgah is closer to the ideal situation. The conclusion drawn from the three cases studied in this research, is that medium high-density building with a rich amount of green spaces (Sheshsad Dastgah) has a positive effect on improving the residents' Quality of Life rather than a villa pattern of residence (Goharshad East) or a more concentrated high-rise urban fabric without abundant green spaces (Firooze).

**Keywords:** Quality of Life, urban fabric, density, high-rise building, stepwise regression analysis



## 1. Introduction

In recent decades, identifying, measuring and improving the Quality of Life has been a major goal of researchers, planners, and government officials alike. The Quality of Life is highly influenced by time, place and its constituent factors and elements vary from one period, place, and geographical location to another (Mousavi, 2006, p. 91). The World Health Organization defines Quality of Life as “people’s subjective evaluation of their place in life regarding values, cultural systems, and their living environment, in line with their objectives, expectations, benchmarks, and concerns” (Noll, 2004). Although considerable attention has been given to the topic, there is still room for further development of comprehensive and transparent frameworks for the assessment of Quality of Life in urban environments (Faria et al., 2018). A wide range of studies has used QoL-indicators to show the level of sustainability in different regions of the world (Senlier et al., 2009, Lepage, 2009, Turkoglu and Sciences, 2015). The indicators that measure the Quality of *Urban* Life normally contain the concept of sustainability so that they can be used to balance and monitor the need among stakeholders to improve sustainable development (Senlier et al., 2009).

The options to physically expand cities in a horizontal direction is limited, due to cities’ natural localities and the accessibility of urban services. Therefore, on one hand, further outward expansion meets its limitations and on the other hand the increasing and ongoing need for housing as result of population growth, necessitates the construction of high(er) density neighborhoods. The present study is undertaken in line with the previously mentioned necessities and aims to investigate the influence of density and urban pattern on the urban QoL. Regarding the relationship between QoL and urban spaces, the main objective is to improve and enhance the quality and accessibility of these spaces, so that not only the negative effects in urban spaces are prevented but are also improving their residents’ QoL by creating a high-quality public space. This study aims to undertake an analytical investigation of the urban density and patterns, whilst comparing QoL in Sheshsad Dastgah (SD) residential complex representing medium density residential complexes and Firooze (F) is a high-rise residential gated complex while in Eastern Goharshad (GE) two-three story houses are common. Comparing these three cases will make it possible to correlate the indicators of experienced QoL with urban densities and patterns.

Following this, the research objective of this study is to investigate and measure the indicators of QoL in the three densities of urban fabric and to present an appropriate pattern of residence, based on the mentioned juxtaposition in Mashhad. Currently, empirical research is lacking that studies the implications of higher-density neighborhoods for the QoL. While planners increase the density of housing, they do not have data to which they can refer in order to assess the impact of their plans on the QoL of individuals (Mitrany, 2005). This study aims to address the following questions: Which criteria influence QoL and How are urban densities correlated with QoL. In essence, the study emphasizes the relationship between densities in urban precincts and the experienced QoL, as reflected in a range of indicators.

## 2. Background

QoL has been studied in a variety of academic fields, ranging from medicine to the real estate market (Faria et al., 2018). In recent years, many studies regarding urban QoL have been conducted, which denotes the importance of the subject. Most papers review both the objective conditions and subjective satisfaction. As an example, the so-called Q1998 study, entitled Economic Health investigated QoL indicators, such as employment, remuneration, proper housing, and environmental features like supporting family, children, the poor, and elderly together with transportation infrastructure was conducted in 1999, questioning 1888 persons over 18 years old in five neighborhoods of Grand Trawas, USA (Rahnama, 2010).

Sani Roychansyah et al. conducted another research on the effects of urban compactness on the distributions of quality houses. They aimed to find the influence of urban compactness on the quality of houses in the city of Yogyakarta, Indonesia. In the end, they concluded that the region

with the highest level of compactness had higher quality houses (33%) than the region which compactness was medium (22%) and low (18%) (Saniroychansyah et al., 2016).

To date, research into the subjective aspects of high density focuses mainly on the negative consequences of overcrowding. On the contrary, a study by Michal Mitrany outlines positive aspects of higher density in neighborhoods, exploring the physical-spatial environment of two neighborhoods in the city of Haifa, Israel. Where physical planning enabled the potential advantages of high density to be realized, this was positively perceived and evaluated by residents. Such advantages mainly comprise accessibility to a variety of services, more frequent public transportation, and access to open spaces within walking distance. Particularly advantageous were the increased opportunities for social gathering. At the same time, however, high density did not foster increase of social relationships on the neighborhood level (Mitrany, 2005).

### **3. Methodology**

Both descriptive and inferential statistical methods were used in this study. With regards to the inferential statistics, the correlation between variables was measured. To test the significance of the differences among several groups with ordinal variables, Step-wise regression was used. The data derived from the questionnaires, concerning the views of the residents, was analyzed using SPSS. The method consisted of semi-structured interviews with closed questionnaires, designed to obtain residents' evaluations of various aspects of the residential context anonymously.

#### **3.1. Research indicators**

Considering both objective and subjective indicators of QoL, this study aims to investigate the effects of densities and the urban pattern on the residents' QoL. Environmental, social and physical indicators were taken as the main indicators, with variables to environmental quality, hygiene, access to recreational spaces, access to educational facilities, Security, physical belonging, social solidarity, collaboration, access to daily facilities and housing and infrastructure as the sub-components of these main indicators. At the end of questionnaires, respondents have been asked to state their level of satisfaction with living in their neighborhood. There are economic indicators like income level (Soleimani et al., 2014, Forouhar and Hasankhani, 2018), Costs of living, Costs of rent, Costs of utilities (Forouhar and Hasankhani, 2018), that be looked at and we consciously excluded the economic factors because they are very similar in each of the neighborhoods.

#### **3.2. Research population and sampling**

The population of this research consists of all the residents of Firooze district and Eastern part of Goharshad district and Sheshsad Dastgah residential complex in the city of Mashhad, Iran (figure 1). According to the 2016 census, the total population of these areas adds up to 7033 individuals. Using Cochran's formula, with a maximum acceptable error ( $d = 0.05$ ) and confidence level ( $z = 1.96$ ) and ( $p$  and  $q = 0.5$ ) (Khaef and Zebardast, 2016) the sample size of the study was determined to be 370 people.

At the first stage, pilot pre-tests by application of Cronbach's Alpha as a tool to evaluate the reliability of planned questions were directed with 30 households. Cronbach's Alpha rate ranges from 0 to 1. Cronbach's Alpha for this study is 0.88. According to (Nunnally and Bernstein, 1978), values of 0.7 and above are measured as acceptable reliability coefficients. Hence, the test and planned questions could be considered reliable.



Figure 1 Location of the study areas in Mashhad (based on Google Maps)

## 4. Theoretical framework

At the onset of every discussion, it is essential to define the keywords and terms that are used. The first step in assessing urban QoL, based on density and urban patterns, is to provide a comprehensive definition of such terms as the urban patterns, residential complexes, high-rise building, density, and QoL.

### 4.1. Urban patterns

According to the Statistical Center of Iran, housing or the residential unit is a place, space or an area where one or more families inhabit and has passageways to one or more entrances. Urban patterns can be categorized into various types, depending on residential density, number of floors and the number of families or people who live there. Considering all of these indicators, urban patterns can be divided into three major categories: Villas: single-family houses, Condos: multiple-family houses and residential complexes (Tash, 2012).

### 4.2. Residential Complexes

Such dwellings include several residential units which are built on a single piece of land, with shared entrances and common spaces. The distribution of residential blocks in such properties is a function of each block's form and geometry, its surface area, lighting, density, and other construction rules and often results in disconnected units (Naqsh-e-Mohit, 2011).

### 4.3. High-rise Building

Various points of view have offered different definitions of high-rise buildings, each viewing it from their own perspective. From the civil engineers' point of view, a building is called high-rise if its height causes the lateral forces of wind and earthquakes to have a considerable influence on its design (Jordan, 1994, Lundstrom and Rex, 1990, Gane and Haymaker, 2009). Accordingly, in terms of height, buildings with more than 10 stories are considered high-rises. From a fire-safety point of view, a building whose height, the distance between its lowest level of the highest floor and its lowest level within the reach of fire trucks, exceeds 23 meters is considered a high-rise. From a geometrical perspective, a building is considered a high-rise if its height-to-diameter ratio

is equal to or greater than 3.14. Although such definitions exist for high-rise buildings, no specific criterion has been presented for defining such structures. In structures, height is a relative concept and depends on such conditions as social situations, individual's perception of the environment and, to a large degree, is defined by the norms of the location (Craighead and Inc, 2009); (Kwak et al., 2015, Mirrahimi et al., 2016, Samuelson et al., 2016).

Different countries, or even various pieces of legislation within one country, do not use a fixed height or a specific number of floors to define a high-rise building. According to the latest Urban Development Strategic-Structural Plan of Mashhad, buildings that have at least 12 stories are called high-rises (Farnahad 2016).

#### 4.4. Quality of Life

The term quality of life was first introduced by A.C. Pigou (Pigou and Co., 1932) in "the economics of welfare" in 1920. However, its widespread use dates to the 1950's, when it was first used to emphasize materialistic indicators, to the extent that a country's Gross Domestic Production (GDP) was considered its single major criterion. Following a swathe of criticism of this materialistic interpretation of QoL in the late fifties, J.K. Galbraith redefined the concept and added immaterial values within environmental, political and social domains (Galbraith, 1950). Many thinkers and experts within this field believe that education, hygiene, the status of women, defense expenditure, economy, population, environment, social issues, cultural differences, welfare, etc. are all among the factors influencing QoL (Shultz, 2006).

Britannica describes QoL as the degree to which an individual is healthy, comfortable, and able to participate in or enjoy life events (Jenkinson, 2016). Urban QoL is synonymous with attention to social, economic, cultural, environmental and mental indicators, in both objective (quantitative) and subjective (qualitative) terms, throughout the planning process. Criteria for QoL include the accessibility of facilities, quality of housing, quality of leisure spaces, the creation of opportunities for social interaction, social occasions, employment, welfare, social collaboration (Kokabi 2005).

The concept of QoL touches upon two aspects of human life: Objective conditions of the society and the urban environment and subjective-cognitive perception of life experiences by social groups and individuals (Fukuyama, 1995).

#### 4.5. Density

Gross density is measured as the ratio of the total urban population and the total residential area. In contrast to the net or urban density, the values of residential densities are usually larger as the same population size is referred to a smaller reference area (residential instead of the total built-up area) (Wolff et al., 2018).

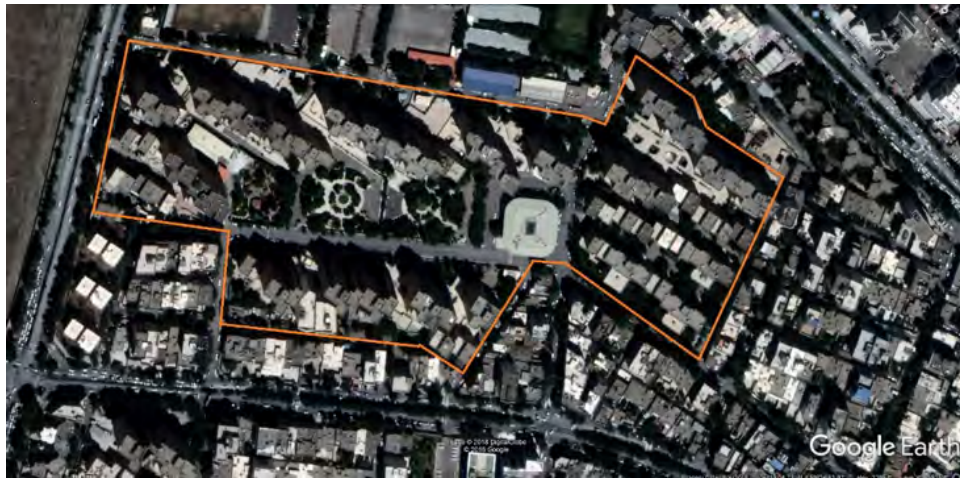
*Table 1 Physical attributes and densities in case studies*

Precinct	Population	Total units	Total gross floor area (m <sup>2</sup> )	Total site area (m <sup>2</sup> ); incl. plots, roads, open spaces	Gross density (#dwelling/ha)	Gross density (#people/ha)	Area of site (m <sup>2</sup> )	Net density (#dwelling/ha)	Net density (#people/ha)	FAR
Firooze	1560	1306	141048	99265	132	157	84291	155	185	1.67
Goharshad E	1386	360	27278	57282	63	242	41293	87	336	0.66
Sheshsad Dastgah	2787	899	82141	222731	40	125	198426	45	140	0.41

Past research on the effects of high density on people has focused either on urban areas (population density) or on the home environment (indoor density) (Mitrany, 2005). In this paper,



we measure Gross density and net density of the three precincts which are analyzed. FAR (Floor Area Ratio) is calculated by dividing the total floor space to the total size of the site/plot.



*Figure 2 Google Earth map of Firooze precinct*



*Figure 3 Google Earth map of Sheshsad Dastgah precinct*



*Figure 4 Google Earth map of Goharshad precinct*



## 5. Findings

As it is mentioned above, the average score in all sections of the research falls within the range of 1 to 5, with 5 indicating a high degree of satisfaction with the item and 1 indicating a dissatisfaction with or paucity of the mentioned factor in the neighborhood in question.

*Table 2 Average Score for each indicator in three case studies*

Precinct	Recreational Spaces	Hygiene	Environmental quality	Physical belonging	Security	Social solidarity	Collaboration	Education	Access to daily facilities	Housing and infrastructure	Total QoL
Sheshsad Dastgah	3.78	3.97	4.59	4.37	4.33	3.99	4.3	4.34	4.49	3.57	4.17
Firooze	3.42	3.42	4.08	3.61	4.31	2.41	2.44	3.22	3.39	4.27	3.46
Goharshad	2.76	3.3	4.25	2.91	2.76	2.16	1.56	3.68	1.81	3.58	2.88

Table 2 shows the residents' satisfaction in each of the case study areas for the different criteria, based on the results of the questionnaire. In Sheshsad Dastgah residential complex the most appreciated aspects are those of recreational spaces, environmental quality, physical belonging, collaboration, security and access to educational and daily facilities. Indicators such as hygiene, housing and infrastructure, and social solidarity are less appreciated but still score relatively well in Sheshsad Dastgah residential complex.

In the Firooze precinct, which can be characterized as a high-density urban fabric, the results show that environmental quality, security and housing, and infrastructure are very well appreciated. Indicators, such as recreational spaces, environmental quality, hygiene and access to daily facilities scored an average level, while social solidarity and collaboration are underperforming.

In Goharshad East (GE) district the residents' average scores for indicators of environmental quality, hygiene, access to educational services and housing, and infrastructure are highest, but, compared to the other case studies score not very high. The scores for indicators of security, social solidarity, physical belonging and access to recreational spaces are all close to mean and close to the two lowest scores amongst all criteria in the other two neighborhoods. The average scores for access to daily facilities and collaboration are the lowest in the entire investigation, and relatively close to 1, being the lowest possible level.

To obtain the overall chart for each individual's quality of life, the measured indicators were normalized and then added. Descriptive statistics for QoL show that the average score for residents of Sheshsad Dastgah (SD) is 4.17, it is 3.46 for residents of Firooze (F) district and is 2.88 for Goharshad East (GE) dwellers.

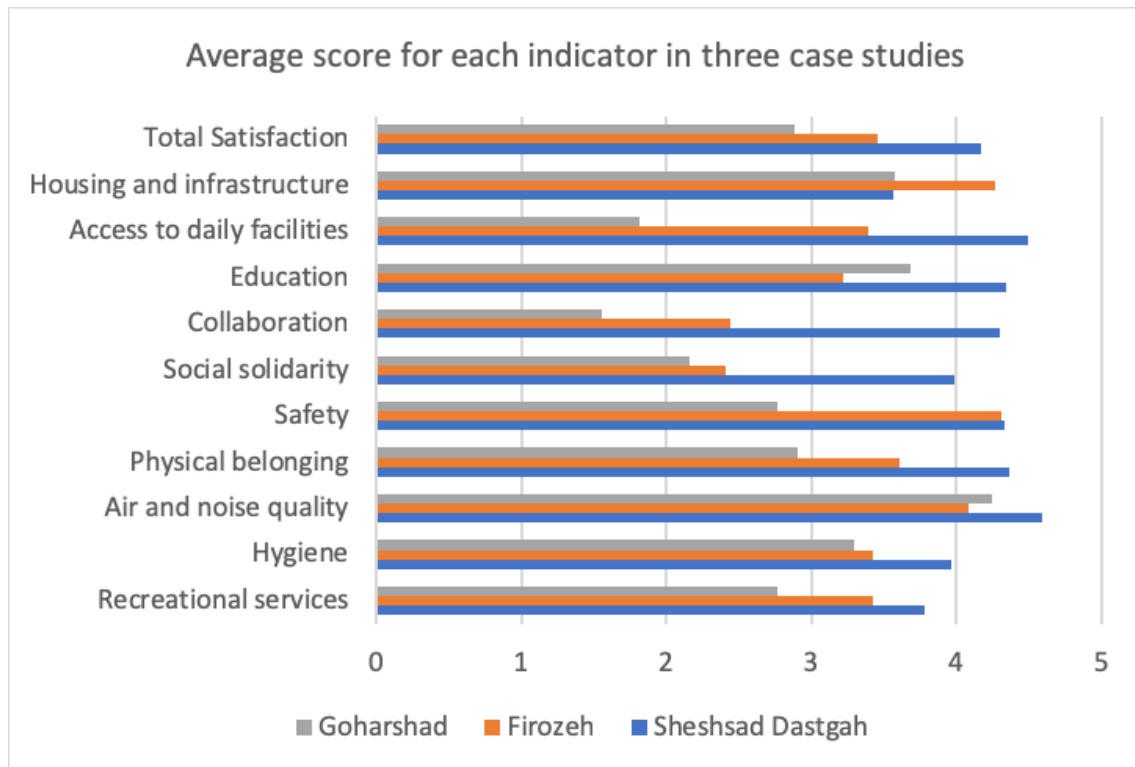


Figure 5 Average score for each indicator in three case study areas

### 5.1. Quantitative Analysis of the Survey Findings

As it is mentioned in the introduction of this article, one of the purposes of this research is examining the existence or non-existence of a correlation between density and QoL in the case study areas. To answer this question, firstly the density of buildings of three different urban fabric is calculated (see table 1). Secondly, the resident's responses to 30 questions on the questionnaire were computed into 10 main indicators. Finally, the correlation between density and every single indicator of QoL is analyzed. Table 3 shows the results of this correlation analysis.

Table 3 Correlation of density and Indicators Quality of Life Indicators

Indicators		Education (I1)	Security (I2)	Physical Belonging (I3)	Social Solidarity (I4)	Collaboration (I5)	Hygiene (I6)	Environment Quality (I7)	Access to Recreational Spaces (I8)	Access to Daily Facilities (I9)	Housing and Infrastructure (I10)
Density	Pearson Correlation	.086	.134**	.459**	-.304**	-.167**	-.272**	.002	.119*	-.460**	.559**
	Sig. (2-tailed)	.099	.010	.000	.000	.001	.000	.977	.022	.000	.000
	N	370	370	370	370	370	370	370	370	370	370

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

As can be derived from table 3, the density (number of floors) and indicators of security, hygiene, physical belonging, social solidarity, collaboration, access to daily facilities, access to recreational spaces, housing and infrastructure are positively correlated because of their calculated sig. is less than 0.05. Correlating every single indicator with the density revealed that the two indicators of education and environmental quality are not correlated (Their sig. is more than 0.05; 0.99 and

0.977 respectively). This means that the availability of education and environment qualities are not related to the density of residential areas as much as other indicators.

On the other hand, there is a direct correlation between density and eight of the ten main indicators of QoL which are applied in this research. Hence, it can be concluded that the density of a residential area influences the quality of dwellers life (objective indicators) and their sense of satisfaction (subjective indicators).

## 5.2. Regression Analysis

In regression, the presence of multiple correlations among dependent and independent research variables is investigated. As the results of a regression analysis on an interval scale are more robust, all the variables are analyzed using an interval scale. To achieve this goal, all questions on different dimensions of QoL were computed and transformed from the Likert spectrum (ordinal) into interval (scale) data. After computing of the QoL indicators, in order to see the extent to which each indicator affects respondents' life satisfaction and the indicator's level of importance, stepwise regression analysis was conducted. Total life satisfaction is considered as dependent variable and the computed indicators of QoL are considered as predictors: Education (I 1), Security (I 2), Physical Belonging (I 3), Social Solidarity (I 4), Collaboration (I 5), Hygiene (I 6), Environment Quality (I 7), Access to Recreational Spaces (I 8), Access to Daily Facilities (I 9), Housing And Infrastructure (I 10). The result of the stepwise regression summary is shown in Table 4.

*Table 4 Stepwise regression model summary*

Model	R	R Square	Adjusted R Square	Std. The error of the Estimate
7	.756a	.572	.560	.543

Table 4 shows the coefficient of determination is 0.560. The coefficient of determination denotes that 56 percent of the variation in life satisfaction in the study area can be explained by the independent variables of the study (i.e. environmental, social and physical indicators). According to the level of significance of 0.000 (the level of significance should be less than 0.05), it can be said, with a probability of 99 percent, that the correlation between the dependent variable and the independent variables is 0.756 and that the independent variables of the study explain 56 percent of variation in the dependent variable. In other words, more than half of the differences in quality of life in these neighborhoods are related to their level of the examined indicators.

*Table 5 Stepwise regression analysis results*

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	0.738	.248		7.005	.000	1.250	2.226		
(I4) Social Solidarity	.259	.051	.313	5.063	.000	.158	.360	.313	3.198
(I3) Physical Belonging	-.522	.057	-.521	-9.209	.000	-.633	-.410	.372	2.691
(I2) Security	.393	.062	.348	6.383	.000	.272	.515	.400	2.502
(I5) Collaboration	.264	.040	.399	6.559	.000	.185	.343	.322	3.107
(I8) Access to Recreational Spaces	-.148	.045	-.213	-3.265	.001	-.238	-.059	.279	3.587
(I7) Environment Quality	.151	.055	.140	2.754	.006	.043	.259	.461	2.169
(I6) Hygiene	.183	.070	.131	2.609	.009	.045	.321	.471	2.121

a. Dependent Variable: Total Satisfaction

According to the results depicted in Table 5, the regression equation is reflected as below:

$$\text{Life satisfaction} = 0.259 (I4) - 0.522 (I3) + 0.393(I2) + 0.264(I5) - 0.148(I8) + 0.151(I7) + 0.183 (I6)$$

$$R^2 = 0.572$$

The above equation displays that there is no statistically significant relationship between life satisfaction and education (I 1), access to daily facilities (I 9) and housing and infrastructure (I 10). In the regression analysis, the beta coefficient denotes the level of importance of each indicator. The beta coefficient in table 5 shows that social solidarity (I 4), security (I 2) and collaboration (I 5) are the three most important aspects of QoL that significantly affect total life satisfaction in the study areas. The negative beta score for physical belonging (I 3) and access to recreational spaces (I 8) could be anticipated since the answers to these questions are very different in each precinct. Especially the access to recreational spaces has widespread responses, because this criterion consists of three variables, indicating access to green, walking/cycling and exercise spaces, while two neighborhoods of the three case studies hardly have any of these facilities. Therefore, their life satisfaction is adversely affected by this indicator.

*Table 6 Excluded Variables*

Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
					Tolerance	VIF	Minimum Tolerance
(I1) Education	.002	.040	.968	.002	.852	1.174	.278
(I9) Access to Daily Facilities	.029	.443	.658	.023	.280	3.570	.251
(I 10) Housing and Infrastructure	.079	1.449	.148	.076	.402	2.490	.191

In fact, many indicators are included in a research that may affect people's subjective QoL. So, to select indicators among all applied indicators that best describe QoL, Step-wise Regression assists us to exclude indicators which statistically are not involved in determining QoL in our case studies. Based on table 6, three indicators (education, access to daily facilities, and housing and infrastructure) can be excluded from the regression model because statistically, the sig amount which is calculated for them is above 0.05.

## 6. Conclusion and Suggestions

To answer the first question of the study which concerned the influence of density on increasing or decreasing urban QoL, considering the urban fabric of the three case studies, one with a low density pattern (East Goharshad), the other with a medium density fabric (Sheshsad Dastgah residential complex) and the latter one as a high-rise building complex (Firooze), a comparison of QoL scores in the three neighborhoods reveal the influence of density on the QoL. Based on the findings of the present research, the correlation analysis shows that there is a direct correlation between density and eight of ten indicators of QoL. Therefore, it can be said that the density of a residential area influences the residents' QoL (objective indicators) and their sense of satisfaction (subjective indicators). The chosen neighborhoods have a similar economic situation. Hence the economic indicators have been excluded out from this research consciously because they do not make a difference in the results.

Descriptive statistics show that the average score for QoL among the residents of Sheshsad Dastgah residential complex equals 4.17, whereas it is 3.46 for Firooze district and 2.88 for East Goharshad. In this study, the highest and the lowest possible scores for quality of life are 5 and 1 respectively. Thus, the overall score of QoL in Sheshsad Dastgah residential complex is closer to the ideal situation (score 5) compared with that of Firooze and Gohahrshad East precincts.

Accordingly, with regards to the cases studied in this research, and drawing on the results of the Step-wise regression, medium rise building with green space amidst them has a positive influence on the residents' QoL, rather than high-rise complex or detached houses.

To answer the second research questions which concerned the criteria and factors influencing the QoL, we should refer to the results of the regression analysis, where the influence of various indicators on residents' QoL was measured. Based on those results, all in all, the independent variables of the study explain 56 percent of the variation in the dependent variable. In addition, the beta coefficient shows that social solidarity (I 4), security (I 2) and collaboration (I 5) are the three most important aspects of QoL that significantly affect total life satisfaction in the study areas. On the other hand, the equation displays that there is no statistically significant relationship between life satisfaction and access to educational facilities (I 1), access to daily facilities (I 9) and housing and infrastructure quality (I 10). This can be concluded from various levels of these indicators in three surveyed neighborhoods which affected the results of regression analysis.

So, we can say that planning schemes for every precinct should consider the preferred density and urban fabric for enhancing the Quality of Life, and as such they should not only consider enhancing physical arrangements (I 1, I 9 and I 10), but more importantly they should try to improve the districts' social (I 4, I 2 and I 5) and environmental (I 7 and I 6) foundations. More emphasis should be placed on achieving higher levels of health, access to walking/cycling infrastructure, these precincts should enhance their social solidarity, create and reinforce local communities and empower neighborhood-based institutions. Taking these measures, along with the physical and spatial improvement of living spaces can increase the quality of life across neighborhoods.

Our investigation concludes that the best quality of life can be developed in the medium dense urban fabric where abundant attention is given to social and environmental quality.

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## Appendices

### Correlation between all indicators

		Correlations										
		Density	Education	Security	Hygiene	Environment Quality	Physical Belonging	Social Solidarity	Collaboration	Access To Daily Facilities	Access To Recreational Spaces	Housing And Infrastructural
Density	Pearson Correlation	1	.086	-.134**	-.272**	.002	.459**	-.304**	-.167**	-.460**	.119*	.559**
	Sig. (2-tailed)		.099	.010	.000	.977	.000	.000	.001	.000	.022	.000
	N	370	370	370	370	370	370	370	370	370	370	370
Education	Pearson Correlation	.086	1	.176**	.174**	.310**	.217**	.239**	.344**	.146**	.239**	.100
	Sig. (2-tailed)		.099	.001	.001	.000	.000	.000	.000	.005	.000	.055
	N	370	370	370	370	370	370	370	370	370	370	370
Security	Pearson Correlation	-.134**	.176**	1	.711**	.431**	.564**	.437**	.303**	.617**	.533**	-.057
	Sig. (2-tailed)		.010	.001	.000	.000	.000	.000	.000	.000	.000	.278
	N	370	370	370	370	370	370	370	370	370	370	370
Hygiene	Pearson Correlation	-.272**	.174**	.711**	1	.321**	.437**	.394**	.251**	.751**	.480**	.058
	Sig. (2-tailed)		.001	.000		.000	.000	.000	.000	.000	.000	.262
	N	370	370	370	370	370	370	370	370	370	370	370
Environment Quality	Pearson Correlation	.002	.310**	.431**	.321**	1	.591**	.578**	.625**	.421**	.634**	.013
	Sig. (2-tailed)		.977	.000	.000		.000	.000	.000	.000	.000	.810
	N	370	370	370	370	370	370	370	370	370	370	370
Physical Belonging	Pearson Correlation	.459**	.217**	.564**	.437**	.591**	1	.410**	.413**	.358**	.733**	.469**
	Sig. (2-tailed)		.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	370	370	370	370	370	370	370	370	370	370	370
Social Solidarity	Pearson Correlation	-.304**	.239**	.437**	.394**	.578**	.410**	1	.779**	.605**	.667**	-.236**
	Sig. (2-tailed)		.000	.000	.000	.000	.000		.000	.000	.000	.000
	N	370	370	370	370	370	370	370	370	370	370	370
Collaboration	Pearson Correlation	-.167**	.344**	.303**	.251**	.625**	.413**	.779**	1	.421**	.639**	-.235**
	Sig. (2-tailed)		.001	.000	.000	.000	.000	.000		.000	.000	.000
	N	370	370	370	370	370	370	370	370	370	370	370
Access To Daily Facilities	Pearson Correlation	-.460**	.146**	.617**	.751**	.421**	.358**	.605**	.421**	1	.599**	-.123*
	Sig. (2-tailed)		.000	.005	.000	.000	.000	.000	.000		.000	.018
	N	370	370	370	370	370	370	370	370	370	370	370
Access To Recreational Spaces	Pearson Correlation	.119*	.239**	.533**	.480**	.634**	.733**	.667**	.639**	.599**	1	.072
	Sig. (2-tailed)		.022	.000	.000	.000	.000	.000	.000	.000		.168
	N	370	370	370	370	370	370	370	370	370	370	370
Housing And Infrastructural	Pearson Correlation	.559**	.100	-.057	.058	.013	.469**	-.236**	-.235**	-.123*	.072	1
	Sig. (2-tailed)		.000	.278	.262	.810	.000	.000	.000	.018	.168	
	N	370	370	370	370	370	370	370	370	370	370	370

\*\* . Correlation is significant at the 0.01 level (2-tailed).  
 \* . Correlation is significant at the 0.05 level (2-tailed).

## Correlation between Density and other indicators

Correlation												
		Density	Education	Security	Hygiene	Environment Quality	Physical Belonging	Social Solidarity	Collaboration	Access To Daily Facilities	Access To Recreational Spaces	Housing And Infrastructural
Density	Pearson Correlation	1	.086	-.134**	-.272**	.002	.459**	-.304**	-.167**	-.460**	.119*	.559**
	Sig. (2-tailed)		.099	.010	.000	.977	.000	.000	.001	.000	.022	.000
	N	370	370	370	370	370	370	370	370	370	370	370

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\*. Correlation is significant at the 0.05 level (2-tailed).

## Cronbach's Alpha result (Test of reliability)

Case Processing Summary				Reliability Statistics	
		N	%	Cronbach's Alpha	N of Items
Cases	Valid	370	100.0	.886	27
	Excluded <sup>a</sup>	0	0.0		
	Total	370	100.0		

a. Listwise deletion based on all variables in the procedure.

## Regression

ANOVA <sup>a</sup>					
	Model	Sum of Squares	df	Mean Square	Sig.
1	Regression	75.399	1	75.399	.000b
	Residual	171.791	368	.467	
	Total	247.190	369		
2	Regression	97.792	2	48.896	.000c
	Residual	149.398	367	.407	
	Total	247.190	369		
3	Regression	119.831	3	39.944	.000d
	Residual	127.359	366	.348	
	Total	247.190	369		

a. Dependent Variable: Total Satisfaction

b. Predictors: (Constant), Social Solidarity

c. Predictors: (Constant), Social Solidarity, Physical Belonging

d. Predictors: (Constant), Social Solidarity, Physical Belonging, Security

e. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration

f. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces

g. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces, Environment Quality

h. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces, Environment Quality, Hygiene

ANOVAa						
	Model	Sum of Squares	df	Mean Square	F	Sig.
4	Regression	134.373	4	33.593	108.7	.000e
	Residual	112.816	365	.309		
	Total	247.190	369			
5	Regression	136.569	5	27.314	89.9	.000f
	Residual	110.621	364	.304		
	Total	247.190	369			
6	Regression	138.585	6	23.097	77.2	.000g
	Residual	108.605	363	.299		
	Total	247.190	369			
7	Regression	140.588	7	20.084	68.2	.000h
	Residual	106.601	362	.294		
	Total	247.190	369			

a. Dependent Variable: Total Satisfaction

b. Predictors: (Constant), Social Solidarity

c. Predictors: (Constant), Social Solidarity, Physical Belonging

d. Predictors: (Constant), Social Solidarity, Physical Belonging, Security

e. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration

f. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces

g. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces, Environment Quality

h. Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces, Environment Quality, Hygiene

## Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					Square Change	F Change	df1	df2	Sig. F Change
1	.552a	.305	.303	.683	.305	161.515	1	368	.000
2	.629b	.396	.392	.638	.091	55.009	1	367	.000
3	.696c	.485	.481	.590	.089	63.335	1	366	.000
4	.737d	.544	.539	.556	.059	47.051	1	365	.000
5	.743e	.552	.546	.551	.009	7.223	1	364	.008
6	.749f	.561	.553	.547	.008	6.738	1	363	.010
7	.754g	.569	.560	.543	.008	6.805	1	362	.000

Predictors: (Constant), Social Solidarity

Predictors: (Constant), Social Solidarity, Physical Belonging

Predictors: (Constant), Social Solidarity, Physical Belonging, Security

Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration

Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces

Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces, Environment Quality

Predictors: (Constant), Social Solidarity, Physical Belonging, Security, Collaboration, Access To Recreational Spaces, Environment Quality, Hygiene

Dependent Variable: Total Satisfaction

## Coefficients<sup>a</sup>

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	1.703	.114	.552	18.480	.000	1.879	2.327	1.000	1.000
	Social Solidarity	.458	.036		12.709	.000	.387	.528		
2	(Constant)	1.095	.171		18.122	.000	2.759	3.430		
	Social Solidarity	.570	.037	.688	15.454	.000	.497	.642	.832	1.202
	Physical Belonging	-.330	.045	-.330	-7.417	.000	-.418	-.243	.832	1.202
3	(Constant)	1.691	.175		14.222	.000	2.147	2.835		
	Social Solidarity	.493	.035	.594	13.902	.000	.423	.562	.770	1.299
	Physical Belonging	-.504	.047	-.504	-10.820	.000	-.596	-.413	.649	1.542
	Safety	.424	.053	.376	7.958	.000	.320	.529	.630	1.586
4	(Constant)	1.518	.165		15.249	.000	2.193	2.843		
	Social Solidarity	.240	.050	.290	4.843	.000	.143	.338	.348	2.872
	Physical Belonging	-.573	.045	-.573	-12.718	.000	-.662	-.484	.616	1.622
	Safety	.483	.051	.427	9.466	.000	.382	.583	.613	1.631
	Collaboration	.263	.038	.398	6.859	.000	.188	.339	.372	2.689
5	(Constant)	1.357	.174		13.514	.000	2.014	2.700		
	Social Solidarity	.282	.052	.340	5.462	.000	.180	.383	.317	3.151
	Physical Belonging	-.485	.055	-.485	-8.770	.000	-.594	-.376	.402	2.488
	Safety	.496	.051	.440	9.770	.000	.397	.596	.607	1.648
	Collaboration	.286	.039	.432	7.333	.000	.209	.362	.355	2.818
	Access To Recreational Spaces	-.123	.046	-.176	2.688	.008	-.212	-.033	.286	3.491
6	(Constant)	1.164	.188		11.492	.000	1.794	2.534		
	Social Solidarity	.272	.051	.328	5.297	.000	.171	.373	.316	3.168
	Physical Belonging	-.526	.057	-.526	9.212	.000	-.638	-.413	.372	2.689
	Safety	.487	.051	.431	9.630	.000	.387	.586	.603	1.657
	Collaboration	.255	.040	.385	6.304	.000	.175	.334	.324	3.083
	Access To Recreational Spaces	-.131	.045	-.188	2.892	.004	-.220	-.042	.285	3.510
	Environment Quality	.144	.055	.133	2.596	.010	.035	.252	.462	2.162
7	(Constant)	0.738	.248		7.005	.000	1.250	2.226		
	Social Solidarity	.259	.051	.313	5.063	.000	.158	.360	.313	3.198
	Physical Belonging	-.522	.057	-.521	9.209	.000	-.633	-.410	.372	2.691
	Safety	.393	.062	.348	6.383	.000	.272	.515	.400	2.502
	Collaboration	.264	.040	.399	6.559	.000	.185	.343	.322	3.107
	Access To Recreational Spaces	-.148	.045	-.213	-3.265	.001	-.238	-.059	.279	3.587
	Environment Quality	.151	.055	.140	2.754	.006	.043	.259	.461	2.169
	Hygiene	.183	.070	.131	2.609	.009	.045	.321	.471	2.121

a. Dependent Variable: Total Satisfaction



## Coefficients<sup>a</sup>

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error				Lower Bound	Upper Bound	Tolerance	VIF
7	(Constant)	0.738	.248	7.005	.000	1.250	2.226		
	Social Solidarity	.259	.051	.313	5.063	.158	.360	.313	3.198
	Physical Belonging	-.522	.057	-.521	9.209	-.633	-.410	.372	2.691
	Safety	.393	.062	.348	6.383	.272	.515	.400	2.502
	Collaboration	.264	.040	.399	6.559	.185	.343	.322	3.107
	Access To Recreational Spaces	-.148	.045	-.213	-3.265	-.238	-.059	.279	3.587
	Environment Quality	.151	.055	.140	2.754	.043	.259	.461	2.169
	Hygiene	.183	.070	.131	2.609	.045	.321	.471	2.121

a. Dependent Variable: Total Satisfaction

## Excluded Variables<sup>a</sup>

	Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	m Tolerance
1	Education	.047b	1.050	.294	.055	.943	1.061	.943
	Safety	.136b	2.840	.005	.147	.809	1.236	.809
	Hygiene	.118b	2.513	.012	.130	.845	1.184	.845
	Environment Quality	.000b	-.004	.997	.000	.666	1.501	.666
	Physical Belonging	-.330b	-7.417	.000	-.361	.832	1.202	.832
	Collaboration	.220b	3.208	.001	.165	.393	2.545	.393
	Access To Daily Facilities	.140b	2.595	.010	.134	.634	1.577	.634
	Access To Recreational Spaces	-.293b	-5.206	.000	-.262	.555	1.801	.555
	Housing And Infrastructure	-.292b	-6.928	.000	-.340	.944	1.059	.944
2	Education	.090c	2.151	.032	.112	.926	1.080	.808
	Safety	.376c	7.958	.000	.384	.630	1.586	.630
	Hygiene	.253c	5.626	.000	.282	.754	1.326	.742
	Environment Quality	.226c	4.087	.000	.209	.516	1.939	.516
	Collaboration	.307c	4.811	.000	.244	.382	2.615	.382
	Access To Daily Facilities	.203c	4.008	.000	.205	.620	1.614	.591
	Access To Recreational Spaces	-.038c	-.507	.612	-.027	.302	3.317	.302
	Housing And Infrastructure	-.159c	-2.957	.003	-.153	.560	1.787	.493

a. Dependent Variable: Total Satisfaction

b. Predictors in the Model: (Constant), Social Solidarity

c. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging

d. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety

e. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration

f. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration, Access To Recreational Spaces

g. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration, Access To Recreational Spaces, Environment Quality

h. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration, Access To Recreational Spaces, Environment Quality, Hygiene

	Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	m Tolerance
3	Education	.084d	2.159	.032	.112	.925	1.081	.630
	Hygiene	.074d	1.371	.171	.072	.486	2.059	.406
	Environment Quality	.216d	4.220	.000	.216	.515	1.941	.515
	Collaboration	.398d	6.859	.000	.338	.372	2.689	.348
	Access To Daily Facilities	.025d	.467	.641	.024	.475	2.104	.475
	Access To Recreational Spaces	-.073d	-1.070	.285	-.056	.300	3.331	.300
	Housing And Infrastructure	-.016d	-.300	.764	-.016	.486	2.057	.335
4	Education	.022e	.588	.557	.031	.868	1.152	.346
	Hygiene	.102e	2.008	.045	.105	.483	2.072	.341
	Environment Quality	.122e	2.367	.018	.123	.465	2.151	.336
	Access To Daily Facilities	.045e	.877	.381	.046	.474	2.110	.298
	Access To Recreational Spaces	-.176e	-2.688	.008	-.139	.286	3.491	.286
	Housing And Infrastructure	.113e	2.107	.036	.110	.432	2.316	.284
5	Education	.019f	.514	.607	.027	.867	1.153	.286
	Hygiene	.124f	2.441	.015	.127	.473	2.115	.281
	Environment Quality	.133f	2.596	.010	.135	.462	2.162	.285
	Access To Daily Facilities	.104f	1.925	.055	.101	.419	2.389	.253
	Housing And Infrastructure	.096f	1.784	.075	.093	.424	2.357	.210
6	Education	.009g	.241	.810	.013	.857	1.167	.285
	Hygiene	.131g	2.609	.009	.136	.471	2.121	.279
	Access To Daily Facilities	.099g	1.854	.065	.097	.418	2.391	.252
	Housing And Infrastructure	.106g	1.981	.048	.104	.422	2.368	.197
7	Education	.002h	.040	.968	.002	.852	1.174	.278
	Access To Daily Facilities	.029h	.443	.658	.023	.280	3.570	.251
	Housing And Infrastructure	.079h	1.449	.148	.076	.402	2.490	.191

a. Dependent Variable: Total Satisfaction

b. Predictors in the Model: (Constant), Social Solidarity

c. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging

d. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety

e. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration

f. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration, Access To Recreational Spaces

g. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration, Access To Recreational Spaces, Environment Quality

h. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration, Access To Recreational Spaces, Environment Quality, Hygiene

## Excluded Variables<sup>a</sup>

	Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	m Tolerance
7	Education	.002h	.040	.968	.002	.852	1.174	.278
	Access To Daily Facilities	.029h	.443	.658	.023	.280	3.570	.251
	Housing And Infrastructure	.079h	1.449	.148	.076	.402	2.490	.191

a. Dependent Variable: Total Satisfaction

h. Predictors in the Model: (Constant), Social Solidarity, Physical Belonging, Safety, Collaboration

# **THE CITY-ZEN URBAN ENERGY TRANSITION METHODOLOGY – THE AMSTERDAM ROADMAP TOWARDS A ZERO-CARBON CITY**

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## **Summary**

City-zen is an EU-funded interdisciplinary project that aims to develop and demonstrate energy-efficient cities and to build methods and tools for cities, industries and citizens to achieve ambitious sustainability targets. As part of the project an Urban Energy Transition Methodology is developed, elaborated and used to create Roadmaps, which indicate the interventions needed to get from the current situation to the desired sustainable future state of a city. For one of the partner cities, Amsterdam, such a Roadmap was developed.

The Roadmap study of Amsterdam revealed that the city can become energy neutral in its heat demand, but not in the production of sufficient electricity from renewables. Even so, an enormous effort is required in order to transform, renovate and adapt parts of the city. It was calculated, for instance, how many energy renovation projects, district heating pipes and photovoltaic panels will be annually needed in order to timely become carbon neutral, energy neutral and 'fossil free'.

The technical-spatial content of the Roadmap was presented to stakeholders of the Dutch capital city, such as politicians, energy companies, commercial enterprises, and not least citizens themselves. Although informed by scientific work, the Roadmap appealed to many, demonstrated by the extensive media coverage.

This paper discusses the approach and methodology behind the City-zen Urban Energy Transition Methodology and will illustrate this by results from the Amsterdam Roadmap study, in numbers and figures.

**Keywords:** sustainable cities, urban energy transition, energy transition roadmap, zero energy, zero carbon, fossil free

## **1. Introduction**

### **1.1. EU goals**

A so-called 20-20-20 target was set by the EU to achieve 20% energy savings, 20% increase in production of renewables, and 20% carbon emission reductions by 2020. This ambition was followed by the EU Energy Building Performance Directive that by 2020 all newly constructed buildings need to be 'nearly' zero energy. These aims have now been surpassed by the Paris Climate Treaty Agreements, which aim for a carbon-neutral built environment by 2050.

The greatest challenge lies in the approach of the existing built environment. Started in 2014, the EU FP7 funded project called City-zen addresses this urban energy transition assignment. It tests new technologies and develops methods and tools, spatial-technical as well as social-economical and legal-political, to help cities getting the transition started. As part of City-zen, so-called Roadmaps are developed for the two partner cities, Amsterdam and Grenoble. These Roadmaps should pave the way towards a desired future state.

### **1.2. Definitions of sustainable ambitions**

Before sustainability-related targets and goals can be set, a clarification of possible ambitions is needed, because in debates there is a mix-up and confusion about terms such as zero carbon, zero energy, fossil free, and circular. Therefore, we first state our practical definitions of these terms.

#### **(Net) zero carbon, carbon neutral, climate neutral**

In a living system as we know on earth, total absence of carbon emissions is impossible, so when people talk of 'zero carbon', they mean 'net zero carbon' or 'carbon neutral', related to a certain period, mostly one year. Since the ambition of carbon reduction is related to climate change mitigation, the goal is actually to become 'climate neutral', encompassing also other greenhouse gases (GHG). Simplification to 'carbon neutral' therefore requires a conversion of other GHG emissions to 'carbon equivalents'. A clean definition of (net) zero carbon, carbon neutral or climate neutral is that, over a year's time, the net GHG emission of the system considered is zero. For this purpose, carbon emissions from fossil fuels may be sequestered, for instance by storage in the underground, or by functional use in horticulture or industry, or compensated by planting green. Indirectly, in order to become climate neutral, compensation is possible through carbon trading (of CO<sub>2</sub> certificates). Being climate neutral therefore does not necessarily mean that a system is 'zero energy'.

#### **(Net) zero energy, energy neutral**

Similar to zero carbon, for a living system 'zero energy' literally means death, so in the light of sustainable cities, the actual goal is to become 'net zero energy' or 'energy neutral'. A clean definition of energy neutral is that in the system considered, over a year's time, the quantity of renewable energy produced equals the energy used. By this definition, the use of fossil fuels is allowed, as long as it is compensated by sufficient production of renewable energy (e.g. sun, wind, water, soil, biomass). An example of this is the Danish island of Samsø: fossil fuels are still used for cars and ferry boats but the island produces more renewable energy than it needs, so it is energy neutral (and climate neutral), actually energy positive, but not yet 'fossil free'.

#### **Fossil free**

Being 'fossil free' eliminates the use of fossil fuels. In this case no use of fossil resources (mineral oil, natural gas, coal) is allowed anywhere in the system considered. In a fossil-free system, all

elements run on renewable energy resources. A fossil-free system can be called circular for the use of energy but not yet for other flows, such as water, materials and food (nutrients).

### **Circular, Cradle to Cradle**

There are two types of circular systems: compliant with the natural cycle, where all resources return to nature in a non-harmful, non-toxic manner, and compliant with the technical cycle, where all resources are being reused. In that sense it is a different term for what McDonough & Braungart (2002) already coined 'Cradle to Cradle'. Circularity is often solely coupled to the use of products, focusing on reusing, recycling and reprocessing of materials, but it also harnesses the energy, water and nutrient cycle, including more complicated biological and chemical processes. A circular system can be defined as a system that reuses all resources and waste flows coming from these resources, with input solely of renewable energy. Overall, a circular system should be able to function by itself, autarkic or self-sufficient.

In a circular system, all resources keep flowing in loops, creating stability from the moment of circularity onwards, but it does not mean that past damages or shortages have been solved. That is what regenerative stands for.

### **Regenerative, Beyond Sustainable, Positive Footprint**

A regenerative system does more than a circular one, in that it regenerates damages and shortages that have evolved over time, before a system became circular. Various scholars have identified that the earth at present is overstretched, that our individual Ecological Footprint (Wackernagel & Rees 1996) on average is larger than our share of earth surface, that we have created an unbalanced situation beyond natural recovery. Becoming regenerative means that a system not just takes care of its own self-sufficient functioning yet also makes amends for the damage created in centuries before. This is also referred to as 'beyond sustainable' (Luscuere et al. 2016), aiming to create 'positive footprints'.

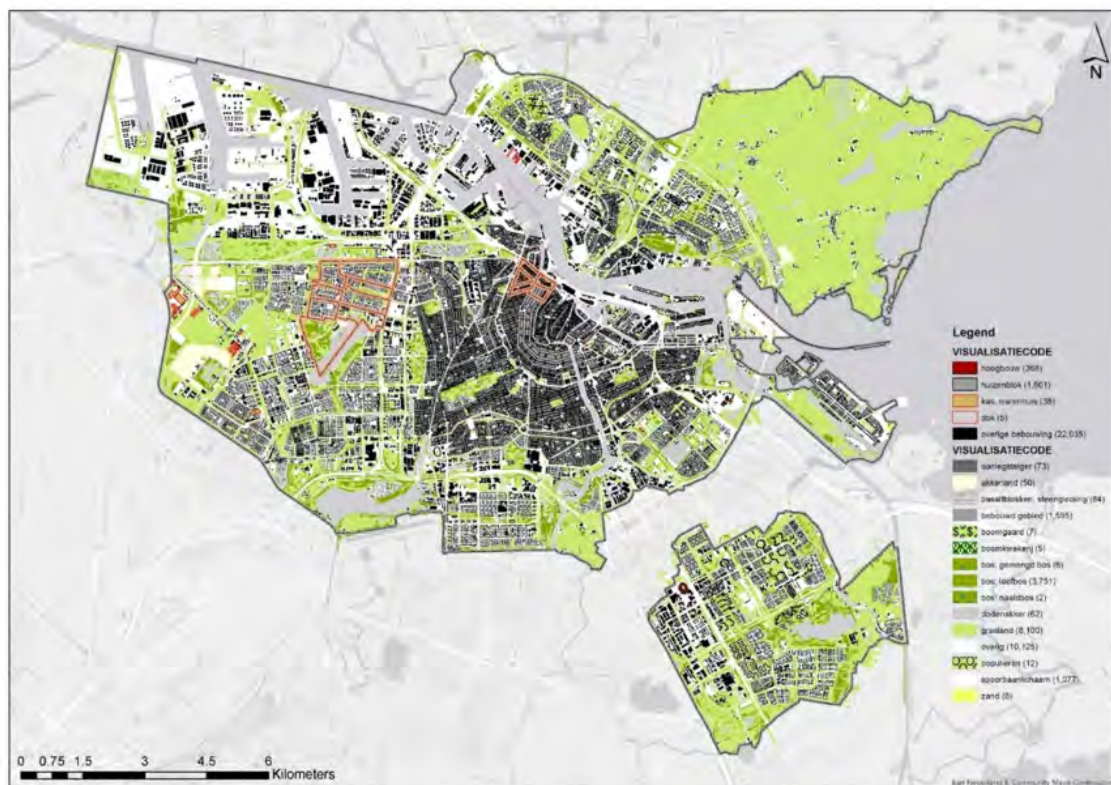
## **1.3. Amsterdam and its sustainability ambitions**

The City of Amsterdam has expressed its sustainability ambitions in numerous documents, most lately in the city council's coalition agreement (Groenlinks et al. 2018). The city wants to become climate neutral and – triggered by the national uproar about earthquakes in parts of the country due to gas drillings – to get rid of natural gas. Amsterdam is getting the energy transition started, and City-zen, in which the city is a partner, is helping out. City-zen does this as well in the other partner city, Grenoble, and so-called Roadshows are held to help ten other European cities in their energy transition (Dobbelsteen et al. 2018).

## **1.4. The Amsterdam City-zen Roadmap**

The Amsterdam Roadmap is based on the City-zen Urban Energy Transition Methodology. The Roadmap will demonstrate how the current fossil fuel based urban energy system can be transformed into one that is running fully on renewables. It will show how different spatial-technical interventions in the built environment, based on local sustainable energy potentials, will be integrated through all scale levels of the city and contribute to the final goal and targets set in-between.





*Figure 1 Municipal borders of Amsterdam and the neighbourhoods of Slotermeer and the inner-city considered for the City-zen Roadmap*

The area that will be addressed in the City-zen Roadmap of Amsterdam is the municipality of Amsterdam as a whole (figure 1). By applying the City-zen methodology, we worked successively from the large (municipality) scale to district and neighbourhood scale. In order to make the urban energy interventions more tangible, special attention was given to two neighbourhoods, which were elaborated into more detail: the historic Amsterdam city centre, in particular a neighbourhood around the Brouwersgracht, and the Sloterveer neighbourhood, a post-war extension area to the west of the city centre.

## 2. The City-zen energy transition approach

European cities usually have ambitious goals in becoming more sustainable, but often are not on track towards their short-term (e.g. EU2020) targets. The pathways to move forward in the transition towards a sustainably built environment are complex to outline. The City-zen methodology helps provide structure within these complex tasks. The output of this is an 'Energy Master Plan' for a city or neighbourhood, based on an energy analysis of several energy maps (demand and potentials) of the city, with a roadmap that will head for a preliminary set of targets and goals (also beyond 2020). The roadmap exists of several energy interventions and measures, both at the technical and strategic level, which are attached to a timeline.

Figure 2 illustrates the the City-zen Urban Energy Transition Methodology. In this figure different steps are highlighted: 1. Energy analysis (present circumstances, current energy demands etc.), 2. Current planning and trends (the near future plan already started), 3. Societal and stakeholder analysis (political, legal, social, economic analysis), 4. Scenarios for the future (external variables that will influence the future state of cities), 5. Sustainable city vision with goals and principles (inspired by a so-called Book of Inspiration, produced from the City-zen project), and 6. The Roadmap, with energy strategies and actions (supported by the City-zen 'Catalogue of Measures').

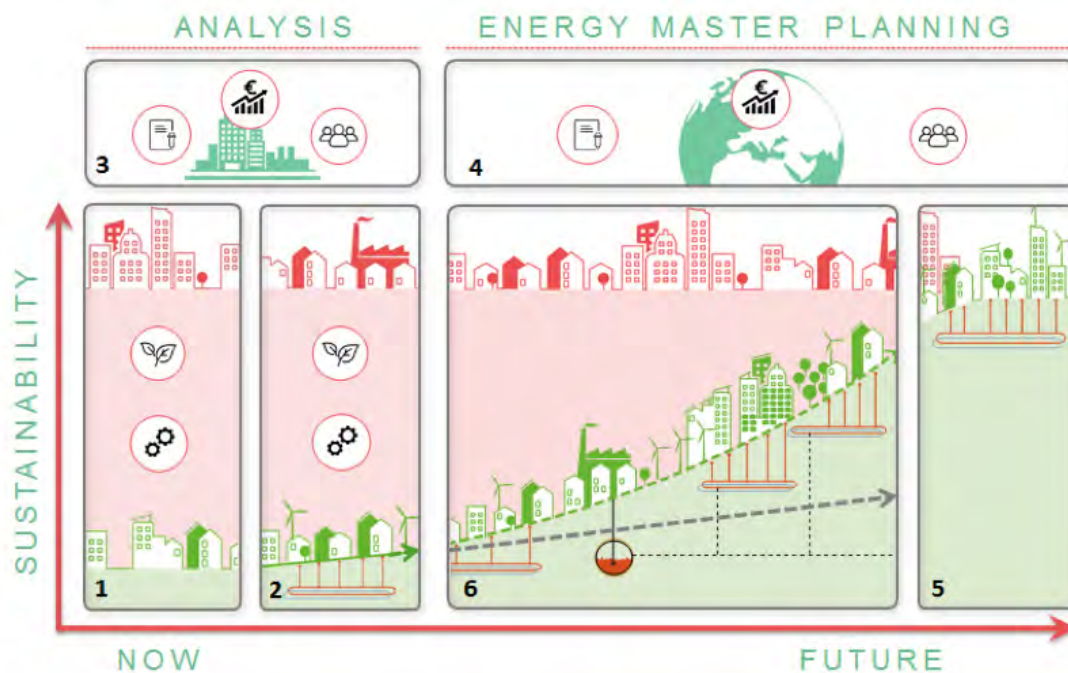


Figure 2 City-zen Urban Energy Transition Methodology

In the study presented, we primarily focused on determining the urban energy interventions required to make the transition to the desired future state of the city, climate neutral. Energy interventions are technical-spatial measures that are specified for a specific location and implementation time frame. Examples are: extending a heat network in a neighbourhood, retrofitting building blocks, or installing of a certain amount of solar power on roofs in a district, within a certain period.

Energy Potential Mapping (Broersma et al. 2013) is used to determine the renewable energy potentials of a city as Amsterdam. This EPM method structurally exposes the geographical-physical and technical layers into local layers of energy potentials. The technical-spatial quantification of demand, reduction potential and renewable supply forms the first analytical step of the approach.

We acknowledge that, to be able to realise these interventions, multiple barriers may exist that need to be dealt with (Amsterdam Economic Board 2018). The solutions for these can be on a non-technical level, such as political decision-making processes, agreements with housing corporations, and economic barriers to establish far-going energy renovations. We analysed these but they are not discussed in this paper.

### 3. Outcomes of the preparative research

#### 3.1. Current demand and sustainable supply

Analysis of the present circumstances revealed the energy usage of the city of Amsterdam. In total, the city uses 15.2 PJ of electricity, of which 2.8 PJ for private homes and 13.3 PJ for business purposes. In addition, 26.1 PJ of natural gas is used, of which 10.5 PJ for homes and 15.8 PJ for businesses. Finally, 2.0 PJ of heat used comes from district heating, of which 0.9 PJ for homes and 1.1 PJ for business. These energy values however say little until we know how much of these can actually be generated in a sustainable way.

Our energy potential mapping analysis, informed by data from the municipality (City of Amsterdam 2017, 2018; Gemeente Amsterdam 2017) and the Energy Atlas of Amsterdam (Boogert et al. 2014), produced interesting findings. First, Amsterdam cannot provide itself with sufficient renewable power; there simply is not enough space and urban surfaces to generate sufficient solar and wind power. Second, the AEB waste incineration plant – now considered as a sustainable source of heat and power – cannot function as a renewable source in the long run; it does not fit the goal of a circular economy. Third, high-temperature (HT, 65+oC) deep geothermal heat sources can replace heat from fossil fuel and waste (Bär et al. 2017; Geodan 2018), but only partly. Fourth, Amsterdam cannot produce enough biogas and hydrogen to replace natural gas significantly. Fifth, Amsterdam has plenty of mid- (MT, 40-65oC)) and low-temperature (LT, 25-40oC) heat sources. Think of natural sources as soil, open water and air, but also anthropogenic sources of waste heat, such as data centres, supermarkets and industries.

In the light of climate change, Amsterdam will also have to cater for cooling demands. Cold can be delivered through electrical systems (air-conditioning) or through environmental sources (soil, water, air). In this research, when ‘heat’ is mentioned, it also refers to ‘cold’.

### 3.2. Scenarios for heat and electricity

The main conclusion of the preparative analytic research is that the city needs to be smart with high-temperature (HT) heat, currently primarily provided by natural gas. Where possible, a shift from HT demand to MT or LT is desired, which is possible if buildings with HT heating systems can be energetically renovated so MT or LT heating systems can replace the old ones. This is difficult with ancient, monumental buildings, which will still mostly need HT heating, possibly to be supplied by geothermal heat or green fuels. New to be constructed buildings however should be based on LT systems, i.e. heat pump systems and local LT heat grids. Other buildings in Amsterdam, after limited energy renovation, might be suited for MT temperatures, which could be the return temperature of HT heat grids. This transition from fossil-based HT sources to a mix of renewable HT, MT and LT sources can be seen in figure 3, left, assuming a growth in new buildings (Amsterdam is expanding), which need to be net zero energy, and potential energy savings in existing buildings.

For electricity, the current supply from the gas-fired and coal-fired power plant, and in due time, most of the electricity from waste incineration, needs to be replaced by renewables. The city has potential for both solar and wind energy, but a considerable part still needs to be supplied from outside. Figure 3, right, illustrates the shift from fossil fuels to renewables in the energy system, again assuming growth in demand, also because of a shift to electric vehicles and heat pumps.

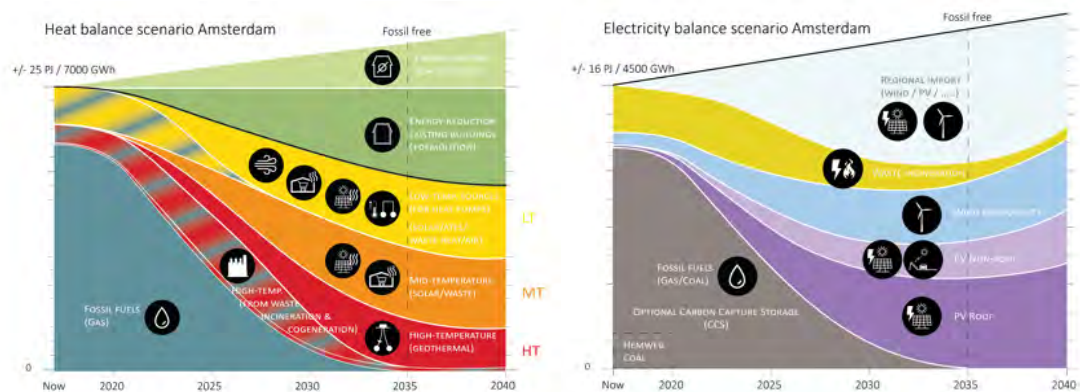


Figure 3 Future scenario for the heat (left) and electricity (right) balance of Amsterdam

## **4. Vision of a sustainable city**

For the future aim of Amsterdam, destination of the city's Roadmap, the following vision was described.

By 2050, the city of Amsterdam is envisioned to be circular, meaning that it has control over all of its resources, energy, water, materials, food and waste flows affiliated with them. The city is clean, has no harmful or toxic fumes anymore, has drastically reduced the number of deaths and loss of life expectancy related to fine dust particles.

Because of a circular system of nutrients, the city and its region have become extremely effective in producing food, clean water and renewable energy, including urban agriculture in formerly vacant buildings, on rooftops, attached to buildings, also serving the need for green outdoor spaces and biodiversity. The city is rich in essential pollinators, such as bees and bumblebees. Citizens are healthy and happy; children grow up in a safe environment.

All transportation is based on renewable energy, mostly human-powered, or otherwise electric or with fuel cells. Biofuels – because of their exhaust gases – are only allowed outside the urban cores. There are no cars in the inner-city. An efficient underground system supplies the city with goods and foods.

Water is cleaner than ever before, a self-purifying natural system that provides plenty of places for swimming and nature everywhere across the city. In spite of global warming, in wintertime some of the canals are frozen by the heat pumps of the canal houses, who take their heat from every second canal. In-between canals remain open for electric touristic boats, operated by robotic systems.

The inner-city has not changed so much as one would expect. Building-integrated PV has turned many of the historic buildings to energy neutrality, in an almost invisible way. While all neighbourhoods outside the Singel canal have become energy neutral by themselves, the historic centre is still supplied to a limited extent with geothermal heat from external plants, transported by the heat and cold system of the city.

Amsterdam has become the ultimate paragon for a sustainable city and attracts millions of tourists for that accomplishment.

The Amsterdam Roadmap and an ambitious municipal action agenda should cater for this.

## **5. Strategy towards the future**

### **5.1. Scale of the entire city**

In order to define the best energy transition strategy for Amsterdam, we first investigated the city's districts and neighbourhoods (see figure 4).



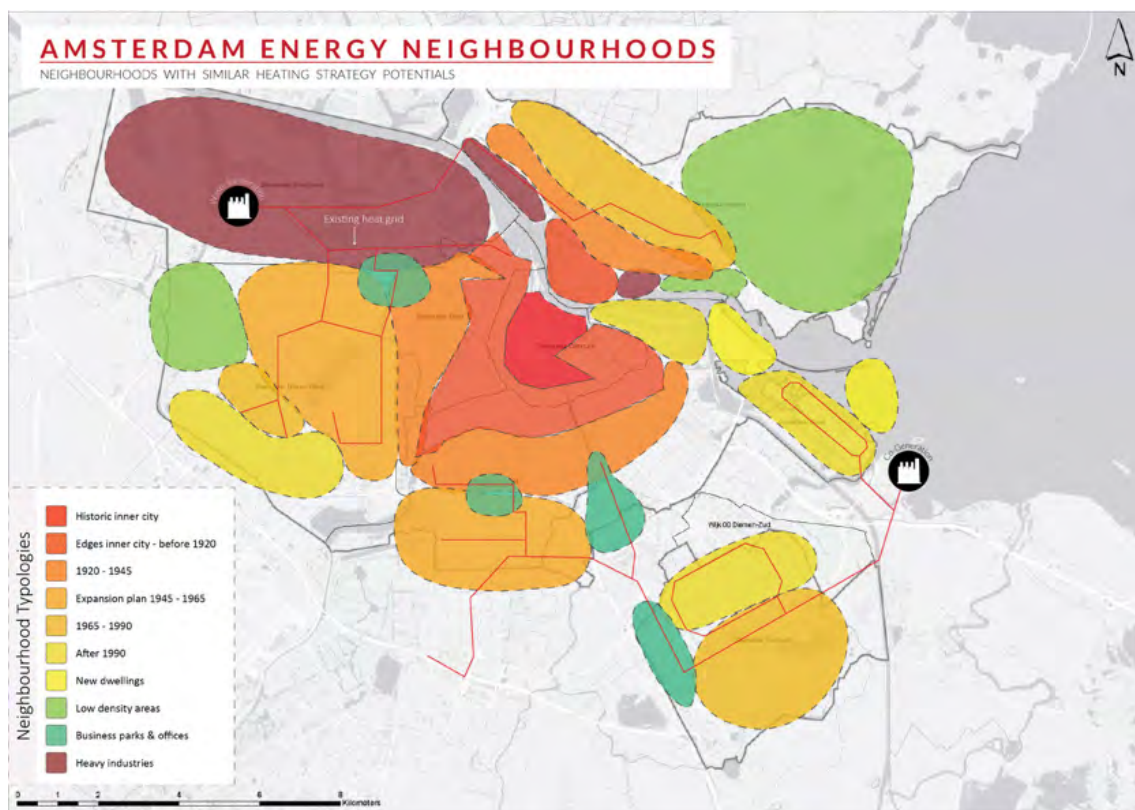


Figure 4 Neighbourhoods of Amsterdam, subdivided by construction era

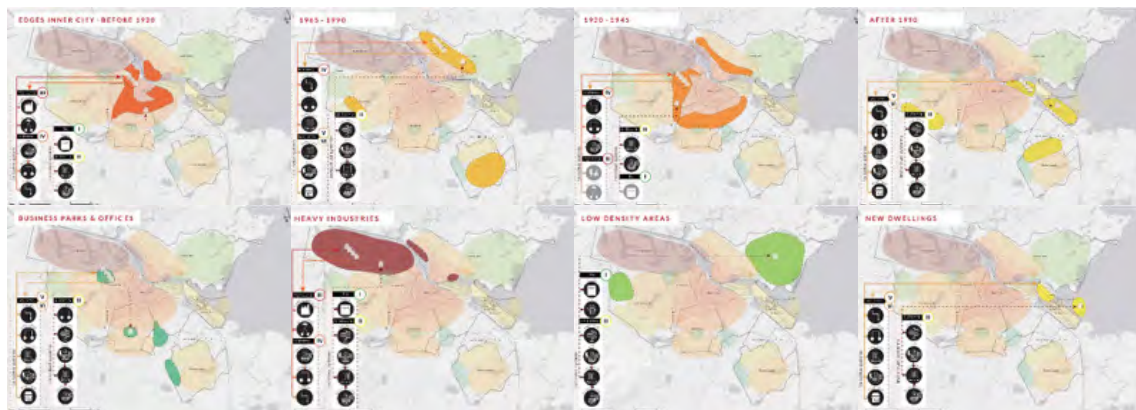


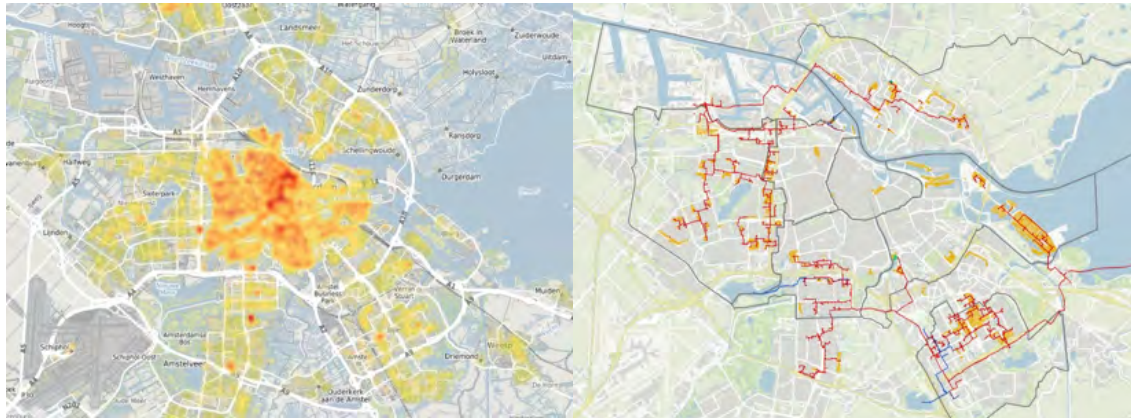
Figure 5 Possible combinations of measures per neighbourhood

By determining the era of construction and building typology and combining these with the current energy labels or energy consumption data of buildings, we could make an estimate of the extent that buildings could be renovated and in how far the energy consumption could be brought down. This then defined the possible energy interventions, for heat and electricity, per neighbourhood. Figure 5 illustrates this.

One of the findings of the preparative research was that although Amsterdam has two unconnected district heating systems – one run on heat from the waste incineration, one on the waste heat from the gas-fired power plant – that serve the outer districts, while the city within the ring road actually needs this heat the most (see figure 6). This part of the city is now mainly served with natural gas boilers, which have to be replaced. Far-stretching energy renovation here is difficult,



mostly due to the age of most of the buildings and because a lot of them are listed as monumental premises. The historic inner-city of Amsterdam is a Unesco World Heritage site, so altering the image of the city is limitedly allowed.



*Figure 6 Discrepancy between the urban areas in Amsterdam where the heat demand is the greatest (left) and the service areas of the Amsterdam district heating (right). Images adapted from [City of Amsterdam].*

In order to elaborate the urban energy transition of Amsterdam in a more practical way, as explained, two neighbourhoods were investigated in greater detail. Figure 7 shows typical images of parts of these areas, the Brouwersgracht and tenement flats in Slotermeer.

In the following sections the energy transition possibilities of these areas will be briefly discussed.



*Figure 7 Image of the Brouwersgracht in Amsterdam Centre (left) and a typical tenement flat neighbourhood of Amsterdam Slotermeer (right)*

## 5.2. Amsterdam City Centre

Considered straightforwardly, there are three main choices for an energy transition: 1. Radical energy renovation to a very low energy demand for heating and with maximum photovoltaics (PV) to supply the remaining demand; 2. Connection to the HT/MT heat grid, thanks to which no radical renovation is needed; electricity can be supplied by invisible PV; 3. Use of the limited amount of sustainable gas, where we now use natural gas. Electricity is either procured sustainably or partly produced by invisible PV.

These three main routes have been elaborated in table 1, with solutions for heat at left and those for electricity at the top. The colour scheme indicated the intrinsic sustainability value for the area

itself. It goes without saying that each of these solutions have consequences and will encounter opposition in all forms.

Table 1 Possible strategies for heat (left columns) and electricity (top rows) for the inner-city of Amsterdam

Possible energy strategies for Amsterdam city centre						
Renovation	Heat source	Individual	Electricity			
			maximal PV-application on all surfaces	PV-roof tiles + panels on invisible places	PV panels on invisible places	No PV
			Collective		Green power coming from Amsterdam (AGP: Amsterdam Green Power)	Green power coming from Amsterdam (AGP: Amsterdam Green Power)
Heating system	Deep renovations	HP on canal water	Interesting, but difficult to realize with the current policies towards monumental buildings			
	Limited renovations	HT heatwork geothermal	Achievable alternative by flexible attitude Monumental care organisation, relatively expensive			
	Limited renovations	Green gas (AGF: Amsterdam Green Fuel)	Good combination chance, gas is a risk, relatively cheap			
	No renovations	HT heat network with residual heat/ waste	Achievable, additional green power required, expensive infrastructure, low ambition			
	No renovations	Green gas (AGF: Amsterdam Green Fuel)	Slightly better than the current situation, cheap, less ambitious, is there enough green gas available for this option?			

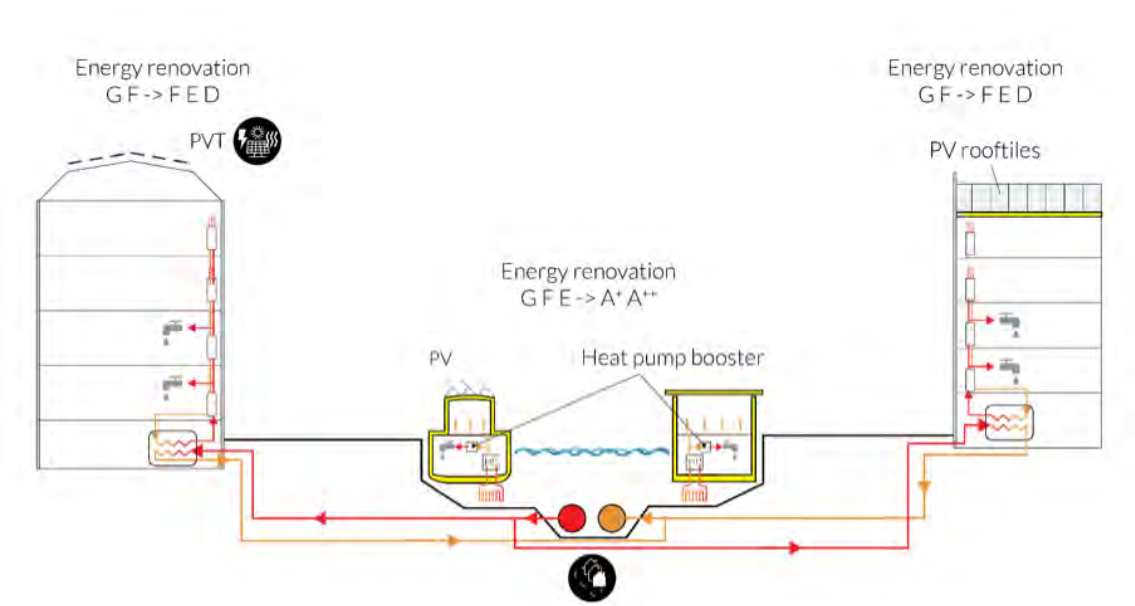


Figure 8 Illustration of the heat grid solution for the inner city of Amsterdam

Most interesting as a case is the roll-out of the district heating towards the inner-city. Figure 8 illustrates the possible solution of that: since roads are already filled to the rim with infrastructure, heat pipes would have to be laid out in the canals. For the historical buildings the change would not be severe: their gas boiler would have to be replaced by a heat exchanger but otherwise no energy renovation would be needed, although some post-insulation and PV on roofs where allowed would improve the energy performance, of course. Boat houses in the canals could provide themselves with heat pumps and PV.

### 5.3. Slotermeer

The New West district of Amsterdam is totally different from the city centre. Here, from 1945 until the 2000s new urban expansion was facilitated, with most of the residential buildings in the neighbourhood of Slotermeer from the 1950s and 1960s. Their energy performance is poor but these buildings usually have few restrictions regarding energy renovation. Therefore, a much greater package of interventions is possible compared to the city centre. Table 1 was also made for Slotermeer, but its size is three times larger.

Some of the interesting energy transition possibilities lie in the creation of localised mini heat grids on MT or LT heat, depending on the extent of renovation. These mini networks could be based on heat pumps with borehole thermal energy storage for inter-seasonal storage of heat, which could be produced largely by PV thermal panels on the buildings (PVT). Figure 9 gives an illustration of this principle.

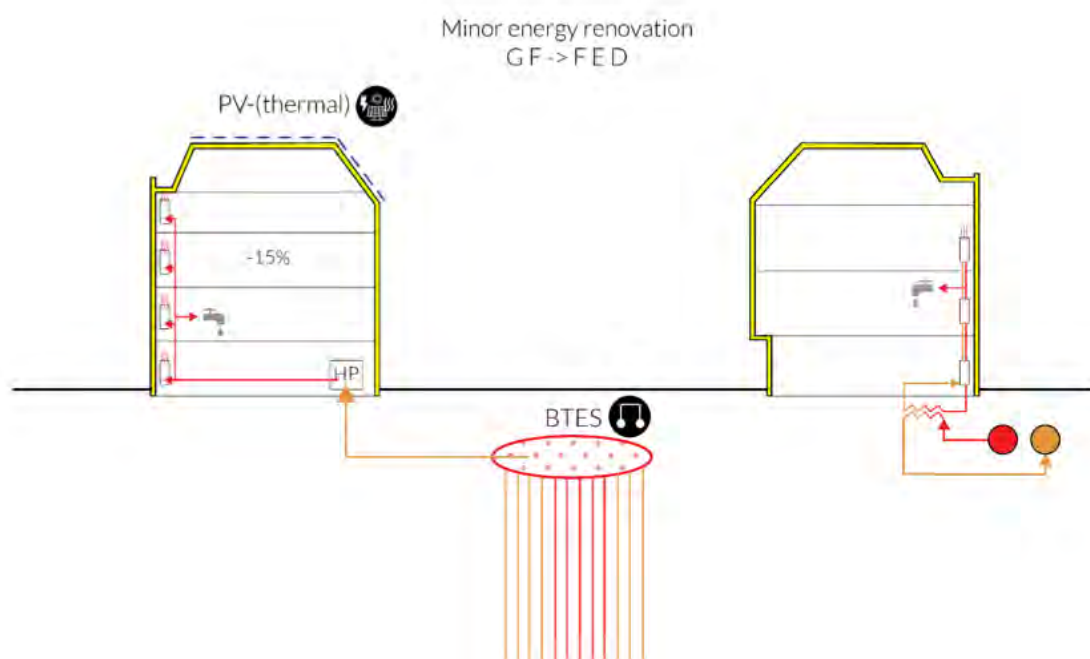


Figure 9 Illustration of the heat grid solution for the inner city of Amsterdam

For Slotermeer, a full set of measures was proposed for heat in the built environment itself, for electricity, mobility and for waste and water management. These are not discussed here. All together, these measures would enable the area to become fully carbon neutral, something that would not be possible for the city-centre.

## 6. The Amsterdam Roadmap

All strategies and measures combined were translated into schedules that show a timeframe within which these measures should be effectuated. Figure 10 gives two examples of these, for electricity (left) and for HT heat (right). MT heat and LT heat are missing, but equally important since these need to be tackled simultaneously.



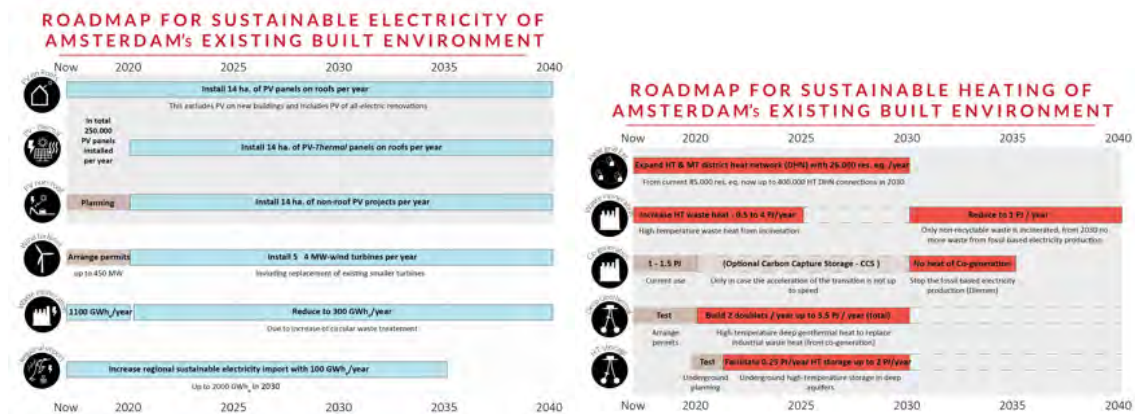


Figure 10 Roadmap schemes for electricity (left) and high-temperature heat (right)

These Roadmap schemes do not entirely speak for themselves. Therefore, we translated them to practical and harsh consequences given Amsterdam wants to be carbon neutral, energy neutral and rid of natural gas by the year 2040.

First, all newly constructed buildings need to be gasless, all-electric and at least energy neutral. Second, starting 2018, until 2040, 7,000 renovation projects need to be up and running simultaneously, offering labour to an estimated number of 14,000 construction workers and 2,000 installers permanently. Third, 26,000 new connections need to be connected to a new heat grid, annually, until 2030. This comes down to the roll-out of 78 km of heat pipe per annum. Fourth, until 2030, 20 geothermal doublets need to be drilled and installed, up to a capacity of 3.5 PJ. Fifth, by 2040, 100 wind turbines of 4 MW need to be placed within the municipal boundaries. Sixth, 28 ha of PV panels need to be laid on roofs and other surfaces, annually until 2040. This equals around 650 panels per working day. Hence, for 22 years, around 100 installers can be continuously on the job.

With these measures mentioned, by 2040, Amsterdam will have become energy neutral and fossil for its heat and cold provision and 60% self-reliant on renewable power. The remainder, 2200 GWh needs to be imported sustainable power from outside the city. For indication: this equals a number of 146 7.5-MW marine turbines on the North Sea, or 14.7 km<sup>2</sup> of PV elsewhere in the Netherlands.

## 7. Conclusion and discussion

The City-zen Amsterdam Roadmap demonstrates that urban energy transition is a demanding process, of which the establishment of a roadmap is just a first step.

The study revealed that a city as Amsterdam can become energy neutral in its heat demand, but not in the production of electricity from renewables. Even so, an enormous effort is required in order to transform, renovate and adapt parts of the city. Many of the energy measures required earn themselves back and start paying off within 10 years. Hence these are a business case for companies and individuals. Nonetheless, there will be interventions that require extra investments facilitated by commercial companies, banks, insurance companies, investment funds, governments and citizens themselves. Eventually all will be felt in the country's economic system, but the advantage is a healthy, liveable, safe world that future generations want to inherit, use and maintain (Kristinsson 2012). Therefore, it is evident that urban energy transition means an operation that will only be accepted if people understand the need and see the benefits.

In that sense, the technical-spatial content of the Roadmap was presented to stakeholders of the Dutch capital city, such as politicians, energy companies, commercial enterprises and not

least citizens themselves. Although informed by scientific work, the Roadmap appealed to many, demonstrated by the extensive media coverage. The people want it.

## Acknowledgements

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# DEEP RENOVATION IN SUSTAINABLE CITIES: ZERO ENERGY, ZERO URBAN SPRAWL AT ZERO COSTS IN THE ABRACADABRA STRATEGY

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## Summary

Energy efficiency challenge in buildings mainly concerns the energy efficient refurbishment and investments in its existing buildings. Yet, today, only 1,2% of existing buildings is renovated every year in Europe. The actual investment gap in the deep renovation sector is due to the fact that high investments are required up-front and they are generally characterized by an excessively high degree of risk, by long payback times and by the general “invisibility of the energy benefit”. ABRACADABRA is an H2020 project that aims to activate a market for the deep renovation of existing buildings through a major transformation of the buildings aiming at the increase of the real estate value. This increase is essentially given by a volumetric addition (Add-ons) whose added value, once capitalized in terms of selling or renting, is able to reduce the payback time of the investment. Several pilot case studies have been used to test the efficacy of the strategy. At this stage of the project, also a challenging sector like the social housing sector is being explored to verify if a retrofit strategy including add-ons and densification could help to boost the renovation of the public and residential housing stock. The process is based on the cost-effectiveness analysis. In this paper, to demonstrate how the densification action could be an effective solution to promote energy efficiency interventions and new business models to shorten the payback time of renovation investments, five different building have been studied. The simulation made on these case studies is divided in three steps: a feasibility study, the energy saving analysis and a payback time calculation. In the last phase of the study the financial assumptions are fundamental. In the case of the social housing the sale, rental and social values were considered and combined to find the best opportunity of incomes and the shortest payback time. Moreover, additional issues were taken into account regarding the regulatory aspects and the technical feasibility of this type of approach. Implementing this strategy means to add new units on the rooftop or on the side of an existing building, and this might face obstacles, such as urban regulation restrictions and the consensus among tenants. To overcome these obstacles, the project promotes new policy recommendations that municipalities could approve and counterbalanced measures to help residents to embrace the ABRACADABRA strategy.

**Keywords:** Energy retrofit, urban densification, add-ons, housing, market attractiveness

## 1. Introduction

It is widely acknowledged that the residential stock in Europe is one of the most energy consuming sectors. The EU is trying to reverse this trend by promoting energy retrofit actions on the existing buildings, notably through the implementation of the Energy Efficiency Directive [1] and the Energy Performance of Building Directive [2]. Despite these efforts, deep renovation actions cover only about 1% of the construction sector activities [3]. There is clearly a lack of investments from the potential investors in deep renovation activities. This is due mostly to the high up-front costs, long payback times and legislative barriers. The European H2020 project ABRACADABRA has identified these key obstacles and aims to overcome them, based on the assumption that an increase of the real estate value of the renovated building could trigger deeper renovation interventions. ABRA strategy is based on volumetric Add-ons and Renewable Energy Sources (named AdoRES), such as facade additions, rooftop extensions or even an entire new building construction, that “adopt” the existing buildings (the so-called “Assisted Buildings”) to achieve nearly zero energy and to activate a new real estate market decreasing payback times. In this paper, we will describe how this strategy is applied in two challenging sectors: the private owned buildings and the social housing showing the results obtained in different cases: two case studies of residential housing in Reggio Emilia, the Student House in Athens, and two cases of residential private buildings in Bologna; demonstrating how the AdoRES can increase the attractiveness of deep renovation market reducing payback times increasing their real estate value and adding new units [4].

### 1.1. Challenges and barriers of energy retrofit in the residential sector

Building renovation is a challenging sector whether in private and social housing sector. Although the social housing sector presents specific character, some of the reasons of the lack of investments in such activities are common to both sectors and are both of social and economic nature. Literature to explain the low renovation rate in the housing sector is abundant. The financial aspects, such as the high upfront costs, long payback times, the lack, instability or complexity of available funding or fiscal incentives are often considered as the main barriers to renovation. But they are not the only ones. Despite the acknowledged non-energy related benefits of energy efficiency renovation – such as health and comfort, architectural and aesthetic improvements, end-users might not recognize the benefits of an energy efficiency renovation. They might also mistrust new technologies and constructions professionals or simply might not be aware of the possibilities. Hence the importance of awareness-raising campaigns about all the benefits of energy efficiency renovation. On top of that, regulatory factors and administrative procedures further hinder renovation. This includes urban planning rules, constructions permit procedures, but also rules linked to property and housing law, such as decision-making rules in multi-apartment block buildings, contractual obligations towards the tenants (including rent increase limitation and relocation obligations). Such barriers are considered to influence the low renovation rate in the entire housing sector, although at different level depending on the sector. Overcoming them has become a political priority in order to foster a more energy efficient building stock. Taking these challenges into account, it is necessary to promote a cultural change among owners and tenants, by informing them about which benefits they might gain after the intervention and by promoting a good habits regarding energy consumption. A non-informed user could indeed make unsuccessful a renovation action (i.e. energy waste) [5]. ABRA strategy promotes a user-orientated renovation to overcome all this difficulties, providing counterbalancing measures such as adding extra-room, balcony or sunspaces (facade addition) to existing units. From a social point of view, it could be an opportunity to reduce social exclusion and a general renovation of the urban area. The specific challenges that energy retrofit has to overcome in public buildings are linked to property regime. It is, in fact, necessary that public bodies start the action and in some cases is very difficult to have a short payback time because they have particular business model to capitalize the additions. It also true that, in general, municipalities and public bodies can burden long-term investments. The simulations in this case have to be modeled on each specific case, taking into account technical, social and market limits.

## 1.2. The methods and the tools

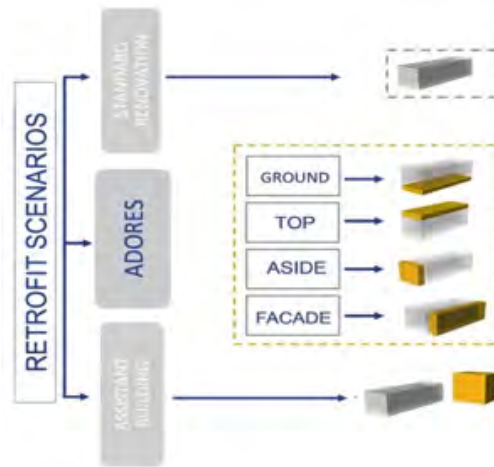


Figure 1 Renovation scenarios.

The research study was carried out following the same process for both the case studies with the following steps:

- An architectural feasibility study of the possible Add-ons for the building;
- The energy consumption analysis before and after the deep renovation using a Simplified Energy Model (SEM);
- The calculation of the renovation and construction costs;
- The Payback time calculation for different scenarios;

Fig 1 illustrates the different renovation options that are ideally possible in a punctual densification at the scale of the building. Starting from the standard energy renovation of the original building, which is also assumed as a constant in all the incremental scenarios, other five options are displayed. This feasibility study is the starting point of the ABRA strategy since it is very rare that all the AdoRES can be applied to one single case study due to regulatory or architectural issues. In addition, for a renovation resulting in a successful intervention it is necessary to know the amount of possible surfaces that can be added. The renovation measures include action on the envelope (external coating, windows replacement) and the HVAC system. The necessary actions are identified by targets to maximize the energy savings (i.e. specific U-values for each opaque surface). Subsequently the energy consumption analysis was conducted using a Simplified Energy Model (SEM) calculator. The calculation is conducted in stationary mode according to EN ISO 13790 [6] and ISO EN 52016-1 [7]. The main inputs needed for calculation are the principal climate and energetic data (geometric values of the building, heat sources, transmission and ventilation properties, set points etc.). As a result of the calculation model, the SEM gives as outputs monthly and annual energy needs of the building before and after the deep renovation. All energy parameters are calculated as monthly mean values and then used to calculate seasonal values (Fig, 2).

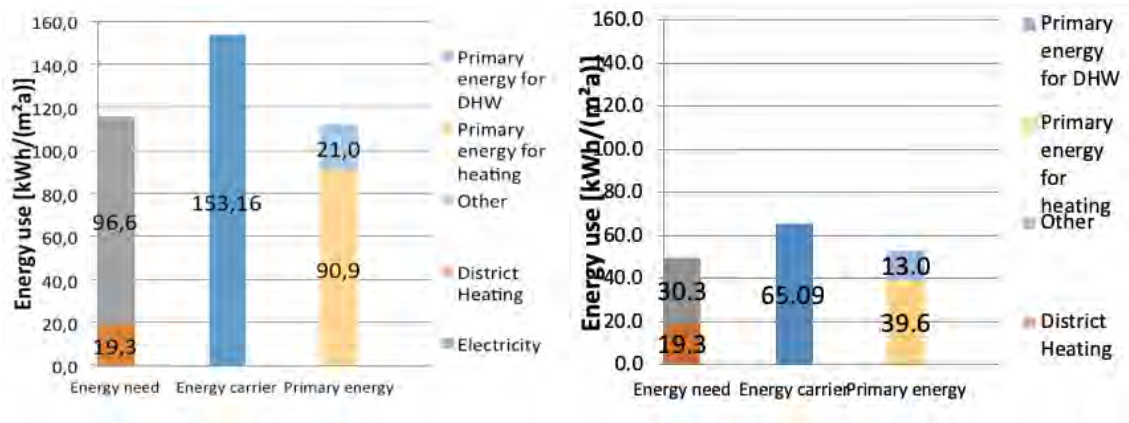


Figure 2 Energy use BEFORE (on the left) and AFTER the deep renovation (right)

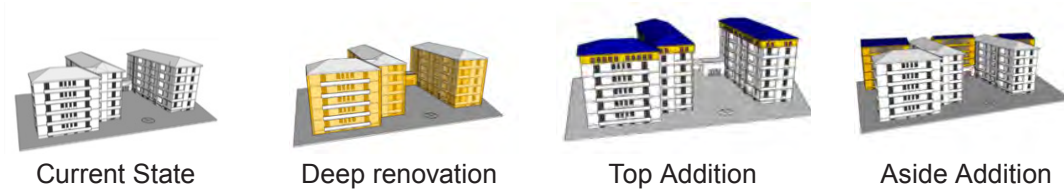
Those results are fundamental for the economic evaluation of the deep renovation; in fact, since there is a standard to reach, every case study will have different parametric renovation cost (€/m²) depending on the current state of the building. Regarding the construction cost, it is obviously necessary for conducting the feasibility study to have an idea of the intervention, and to agree on a standard construction. The Add-ons are built with timber panel for opaque surfaces and aluminum triple glaze windows filled with argon in order to reach a zero energy target with the use of PV panels and heat pump for heating and cooling. Renewable Energy Sources (RES) like photovoltaic panels are also installed in the existing building to reach the nZeb target. Renovation and construction costs [8] and the energy consumption are the principal inputs for the assessment and the calculation of the payback time. Energy savings compensates the negative cash flow linked to the renovation and construction costs and the profit realized from selling or renting the added units. In the case of sale transaction we simulated that all the new dwellings would be sold in the first two years (this is a hypothesis based on the state of the market). This cost-effectiveness comparison allows for immediate identification of the most relevant scenarios for the investors and stakeholders. Fig. 3 shows the cost estimation units and input for the deep renovation and construction.

COST ESTIMATION											
DEEP RENOVATION COST FOR THE SCENARIOS											
CONSTRUCTION COST FOR THE SCENARIOS											
DEEP RENOVATION AND ADDRES CONSTRUCTION COST FOR THE BUILDING											
Total											

Figure 3 Cost estimation summary

## 2. Residential housing case studies

Several case studies have been used to test the retrofit action through Add-ons or ADORES, as named in the ABRACADABRA project. The first two cases shown in this study are both owned by ACER RE (a social housing corporation), in Reggio Emilia area, Emilia Romagna, Italy. Here, in case of the construction of a stand-alone assistant building, they could sell or rent at market prices. To prove the technical and architectural feasibility of the Add-ons, the building and the additions have been 3D modeled.



*Figure 4 3D model of the ADORES illustrating the possible options for the Reggio Emilia case of Viale Magenta*

As fig 4 shows, in this case, it is not possible to add a facade addition or an assistant building. Therefore, the only scenarios that can be taken into account to calculate the payback times are the top addition and the aside addition. As the figures demonstrate, in this case the optimal scenario is the one that maximizes the densification (aside addition). Similar results have been performed in other residential buildings, both public and private owned buildings: Bagnolo in Piano, Zografou in Athens, tower buildings and block buildings in Bologna.

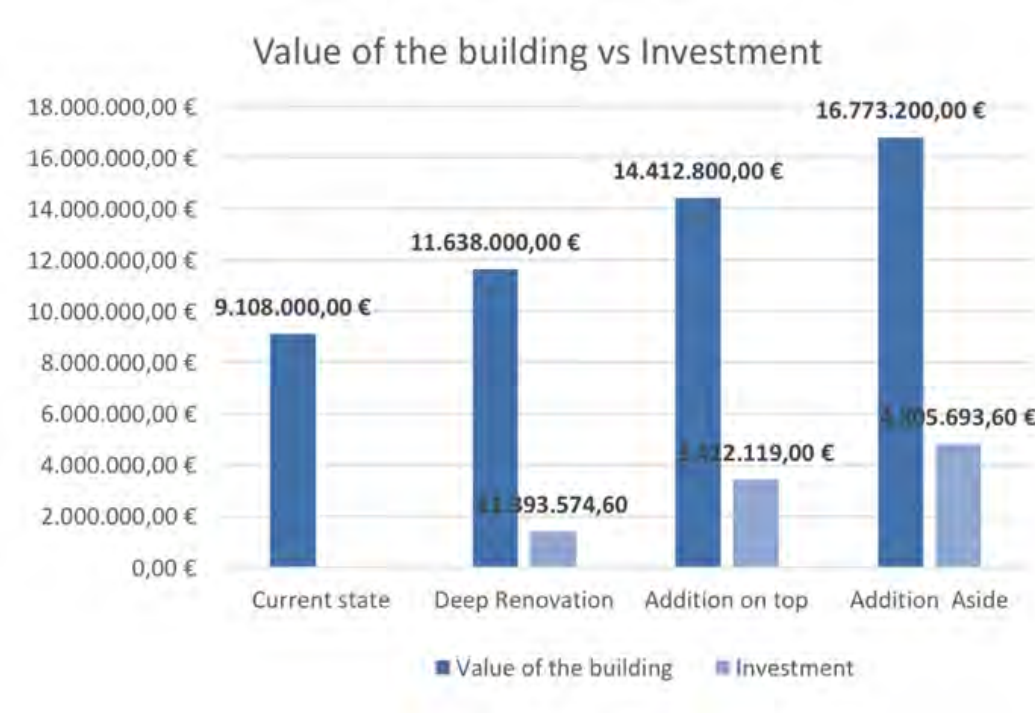
The main economic data assumed for the calculations are reported in table 1.

*Table 1 Economic data assumed for the calculations of the pay back time and the real estate value*

Real estate value	1.800,00 €/m <sup>2</sup>
Real estate value (add-ons)	2.800,00 €/m <sup>2</sup>
Monthly rent for new units	8,80 €/m <sup>2</sup>
Social monthly rent for new units	5,00 €/m <sup>2</sup>

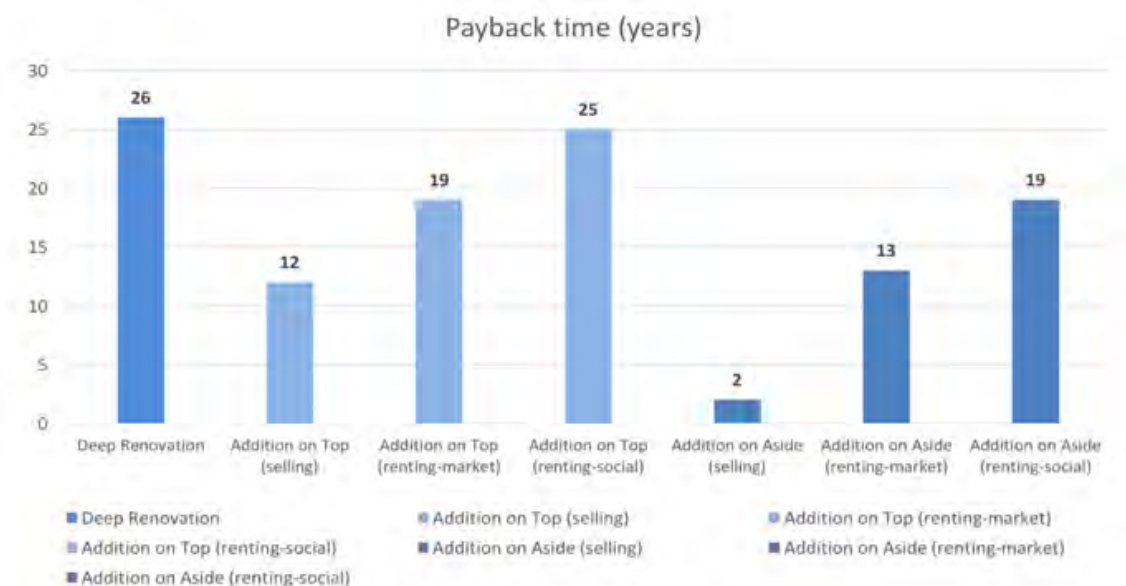
Based on the values provided by the economic data illustrated in table 1, a comparison between the value of the building and the investment can be achieved, as illustrated in fig. 5.





*Figure 5 Add-ons Feasibility tables in different cases*

However, the most interesting results are provided by the assessment of the different volumetric options in relation to the pay back times in the various market contexts, as displayed in fig. 6.



*Figure 6 Comparison of the payback time in the different volumetric options in the various market contexts (selling – private market; renting at market prices and renting in the social housing sector)*

As the results in fig. 6 demonstrate, each scenario is competitive if compared to the deep renovation option. However, the optimal scenario is the side addition, as it maximizes the densification and the rentable/selling surfaces.

Similar studies have been performed in other residential buildings, in particular for other two buildings on the social housing market (Bagnolo in Piano, in Reggio Emilia, and Zografou in Athens) as illustrated in fig. 7, and the tower buildings and block buildings in the private market of Bologna, reported in fig.8.

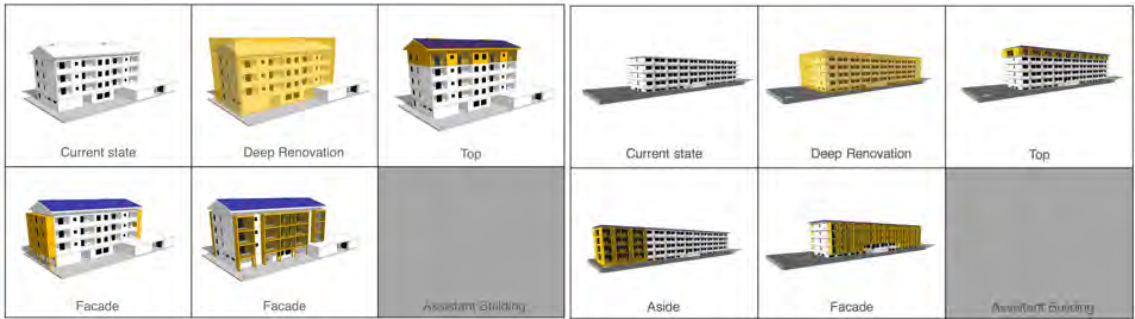
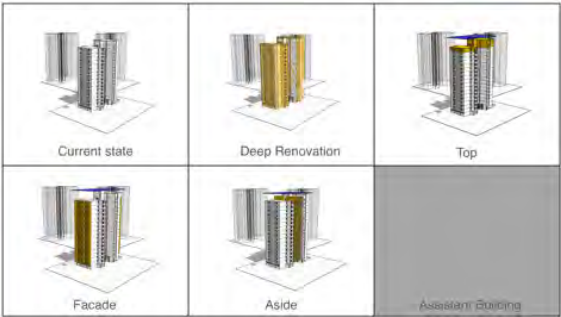


Figure 7 Add-ons feasibility studies for Bagnolo in Piano, Reggio Emilia on the left and the students' house in Zografou, Athens, Greece, on the right



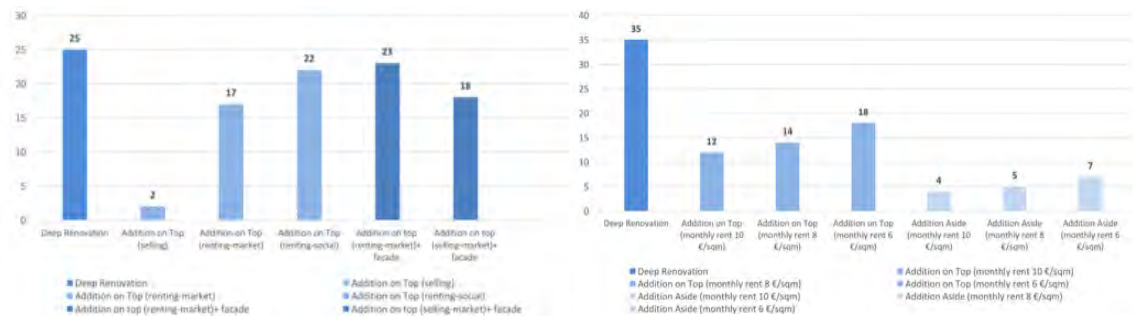
Tower building, Bologna



Block buildings, Bologna

Figure 8 Add-ons Feasibility tables in two different cases of the private market in the city of Bologna, Italy

As for the case of Viale Magenta, the most interesting results are provided by the assessment of the different volumetric options in relation to the pay back times in the various market contexts, as displayed in fig. 9.



Bagnolo in Piano, Reggio Emilia

Zografou, Athens

Figure 9: Comparison of the payback time in the different volumetric options in the various market contexts (selling – private market; renting at market prices and renting in the social housing sector) for the second case of Reggio Emilia (on the left) and the Students house in Athens (on the right)

As for the previous cases, also for the private real estate market, the most interesting results are provided by the assessment of the different volumetric options in relation to the pay back times, as displayed in figures. 10 and 11.

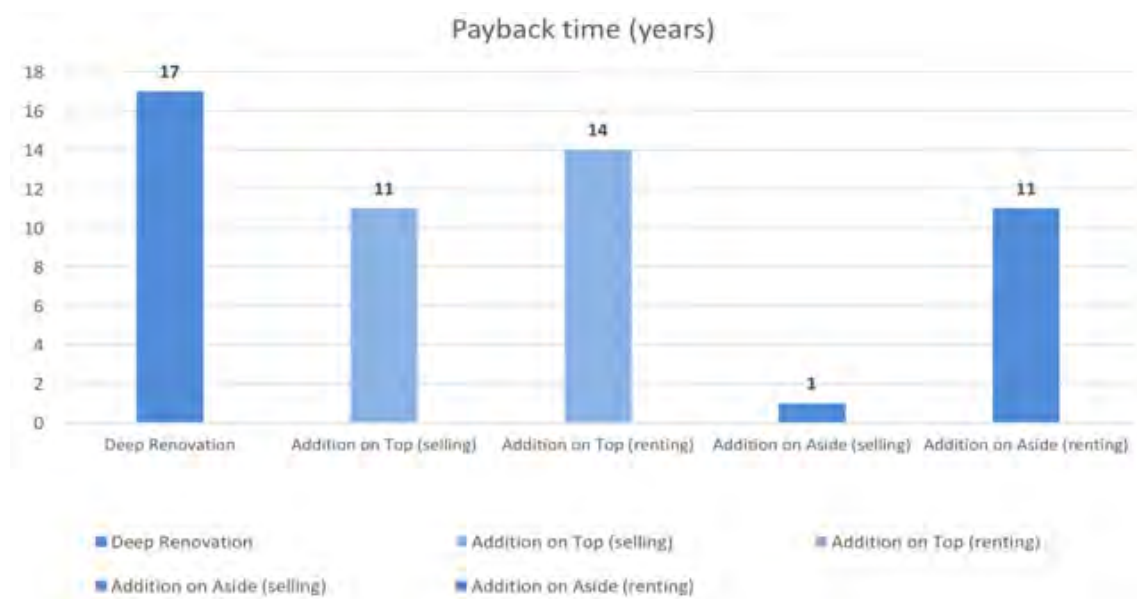


Figure 10 Comparison between the payback times in the two different volumetric options (on Top and Aside) in the private market context (selling – private market; renting at market prices) for the case of the Towers in Bologna.

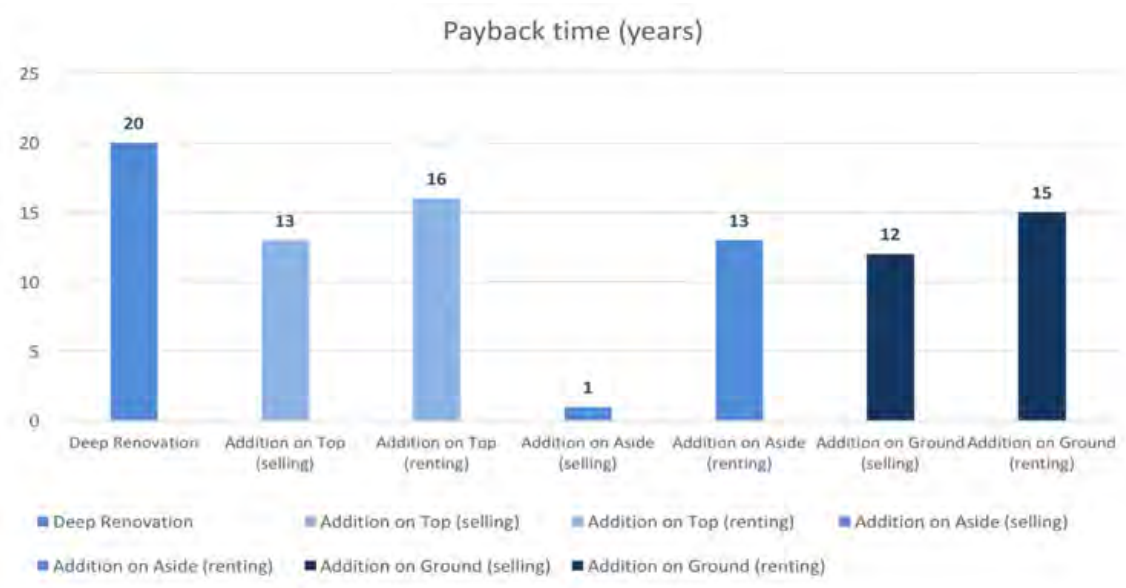


Figure 11 Comparison between the payback times in the three possible volumetric options (on Top, Aside and ground) in the private market context (selling – private market; renting at market prices) for the case of the block buildings in Bologna.

As the results in fig. 10 and 11 demonstrate, each scenario is competitive if compared to the deep renovation option. However, the optimal scenario is given by the aside addition, as it maximizes the amount of rentable/selling surfaces.

### **3. Brief discussion of the results and conclusions**

the simulations in the different scenarios have been conducted with specific assumptions. Clearly, using social prices for renting and selling does not have the same effectiveness of using market values. However, the facade addition when combined with the vertical extension (top addition) has various benefits, such as a major increase of the real estate value of the existing building and the space extension in the existing units, that is certainly a measure to encourage the acceptance of the roof-top addition from the tenants. From the obtained results it can be observed that the real estate value of the building is always far higher than the value of the deep renovated building in all the cases. Although the results are very different in terms of quantity, which are in turn depending from the possible amount of space addition in the different cases, there are many common aspects. In almost all the cases the aside addition is the best option for the building, presenting the major increase of the value of the building with a minor investment. This case is an example of a valid implementation of renting business model and densification actions that can be replicated in other public buildings of the same typology.

Moreover, in all the cases the cost-benefit evaluation has been proved to be a valid method to identify the optimal scenario [10]. Implementing such an approach would allow the addition of new surfaces avoiding soil sealing, and could be a strategy for the urban and architectural renovation, including the social housing sector. In this framework though, there are some issues to be solved. Some are specific to social housing sector other might be more general and linked to the split incentive dilemma. A possible solution is to create a new business model where the Social housing associations could act like ESCO (Energy Service Company). In the case of public buildings, it would be a very interesting option to add new spaces to rent in order to shorten the payback times. Furthermore, there is the possibility to implement this strategy on other typology of building not only the ones with residential function. Altogether, the results of ABRACADABRA, very briefly discussed in this paper, demonstrate that Add-ons are a solution that can help to boost deep energy efficiency renovation. The impact of these solutions will however vary according to the local market(s). The estimated payback time will moderately or considerably differ if the property renovated and its extension are to be sold or rented, if the rents are subject to market restrictions – as it is the case in the social housing sector and in rent-controlled housing regimes.

### **ACKNOWLEDGEMENTS**

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## SMART CITIES



# APPLICATION OF FUZZY AHP<sup>1</sup> FOR RANKING AND SELECTION OF INNOVATION IN INFRASTRUCTURE PROJECT MANAGEMENT

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## Abstract

In the absence of strong market forces driving innovation in the infrastructure construction environments, the role of the project owner becomes critical for creating the motivation to innovate. Successful infrastructure projects addressed innovation systematically by employing incentivizing mechanisms. Whilst this is recognized, this study seeks to answer the question: In what order can innovations be ranked when infrastructure projects are set for developing innovation incentive system? Addressing this, a Fuzzy Analytic Hierarchy Process (FAHP)-based questionnaire was used to run a pairwise comparison matrix for the classified types of innovation. These were ranked, and unique weights were developed for each of the classified innovations. This paper proposes a procedure for determination of the weights of alternative innovations in the FAHP which is based on expected values of the fuzzy numbers and their products. The result show that classified innovations have various levels of importance in infrastructure projects. A case study of SCIRT's infrastructure rebuild in Christchurch, New Zealand that reported more than 500 innovations has been undertaken and analyzed. This enables current research to gain a better insight and understanding of the behaviors of innovation in different types. As a main contribution, the study demonstrates how the classification system could be used by project owners to put in place mechanisms to influence the development and adoption of various types of construction innovation. In addition, the findings inform industry professionals of how to enable classified innovations in infrastructure projects to maximize productivity performance.

Keywords: SCIRT (Stronger Christchurch Infrastructure Rebuild Team), innovation, incentivizing

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1 Analytic Hierarchy Process

## 1. Introduction

Internationally, the construction industry is identified as a traditional or low-technology sector with insignificant contribution (3% of total expenditure) to Research and Development (R&D) activities associated with innovation (Seaden, Guolla, Doutriaux, & Nash, 2003). Challenges with performance and productivity, quality achievement, and uptake of innovation are endemic in the industry (Xue, Zhang, Yang, & Dai, 2014). Substantive research has found that innovation is a requirement for organizations to survive in any dynamic economy (Gambatese & Hallowell, 2011; Smith & Estivals, 2011). In general terms, innovation is an avenue to improve productivity and efficiency (Maghsoudi, Duffield, & Wilson, 2016), hence it appears to be a crucial subject for research (Maghsoudi et al., 2016). Firms have been pushed to stay cost effective instead of high-quality intensive due to the low-cost competitive contracts as a predominant approach in construction (Kale & Arditi, 2002). Reichstein, Salter, and Gann (2005) comprehensive survey of UK construction firms indicated that many construction firms do not motivate to innovate, and hence remain competitive. They can sustain by meeting local needs of their undemanding customers. This increases the tendencies for clients and companies involved in project delivery to continue with the conservative approaches to practice, thus resulting in slow innovation uptake (Tawiah & Russell, 2008). As evidenced in a recent study of the Australian construction industry, Loosemore and Richard (2015) observed that most construction clients are not interested in innovation. Instead they seem to be driven mainly by price. To help motivate the global industry, Loosemore and Richard (2015) suggested that project owners need to have a better understanding of what innovation is and how it can benefit them.

In the absence of strong market forces driving innovation in the construction industry, the role of the client or project owner becomes critical for creating the motivation to introduce or develop innovative solutions throughout the various phases of the construction project (Mahpour & Mortaheb, 2018). To entice construction companies to be more innovative, some clients (especially local or national governments) have started to incentivize firms by incorporating innovation related performance indicators as part of the construction contract. A systematic attention to innovation was launched by New Zealand government by targeting a 20% performance enhancement (innovation included) by 2020 (Wilkinson et al., 2012). This industry-level attention to innovation is still being followed by NZ government under a national program named as "National Science Challenge 11: Building Better Homes, Towns and Cities Strategic Area 6: Transforming the Building Industry" (Wilkinson et al., 2018). Numerous studies have shown that clients can use their purchasing power to demand innovation (Egbu, 2008; Ozorhon, 2012; Widén, Atkin, & Hommen, 2008). The need for a strategic plan to incentivize innovation has been identified by various innovative infrastructure projects around the world. 'Crossrail' is an innovative infrastructure project that introduced an innovation strategy as a practical plan intended to improve innovation potential through a project. This plan is considered as uniquely positioned to lead innovation in the construction industry" (L. Crossrail, 2015). 'Crossrail', as a partnering infrastructure project is one infrastructure project which developed a successful innovation strategy (Davies, MacAulay, DeBarro, & Thurston, 2014). "Innovation has been defined as one of the visions in different layers of our organization" (Crossrail, 2013). The London Olympic Park is another successful mega-project that formally managed innovation by employing a strategic plan throughout the project (Davies et al., 2014). Stronger Christchurch Infrastructure Rebuild Team (SCIRT) as a current research case study is another successful infrastructure project, defining an innovation strategic plan throughout the project's life.

Despite recent successes in innovation awarding systems around the world, there are still rooms of opportunity for upgrading innovation benchmarking mechanism. Since innovation has not been defined in a comprehensive manner, different types of innovation have been treated in a same way in existing awarding system. This single-view approach has miss-motivated teams to innovative not through an ambitious approach but just to meet simple expectations. A new approach is needed in order to first identify innovation from variety of different viewpoints, then ranking the identified types and finally award teams based on both the number/month and the correspondence importance of reported innovations. Towards this mechanism, different classified

types of possible innovations should first be identified. Each of the identified innovation types should be ranked in order find the correspondence importance in the awarding system. Instead of a sole treatment for every single types of innovation, the multiple-view approach of awarding mechanism provides an opportunity to motivate teams based on both number/months and the innovation types.

The AHP approach has been widely used as a practical method in multi-criteria decision- making (Andrić & Lu, 2016; Mahpour & Mortaheb, 2018). However, the conventional AHP method is not found capable of dealing with uncertainty and vagueness involved by the criteria such as 'innovation topic' in construction by Jato-Espino, Castillo-Lopez, Rodriguez-Hernandez, and Canteras-Jordana (2014). Taking this into account, they proposed "AHP + FSS" as a "hybrid approach" that can deal with the vagueness of innovation. To the best of the knowledge of the researchers, the application of the concept of Fuzzy AHP and Fuzzy logic theory for innovation assessment has not been studied yet. Andrić and Lu (2016) introduced the main advantage of the Fuzzy approach as "the ability to operate with linguistic variables since some events cannot be described numerically".

Current research is set to address a fundamental question: what are the innovation benchmarks that could take into account both quality and quantity of innovation in order to award teams throughout project lifecycle? To date the effectiveness of a financial-based incentive system to improve innovation has not been tested through empirical research. This is an important question because if research findings verify variations in innovation awards through various classified types, it strengthens the argument for developing an innovation incentive approach in the construction industry that is sophisticated and contingent on the both 'Quality' and 'Quantity' of monthly reported innovations in projects.

This research aims to empirically verify whether there are variations in the importance level of innovation throughout seven classified types, by analyzing experts' opinions who ranked innovations. Using the developed ranking result, this study further aims to upgrade an innovation assessment protocol, currently used in SCIRT as a case study. At first, a fuzzy logic-based innovation assessment framework is proposed in order to rank seven classified types of innovation. Using the result of this ranking, an upgrade is proposed on SCIRT innovation awarding system. The proposed upgrade classifies innovation monthly scores in three identified levels considering both 'Numbers/Month' and 'Seven classified types'. The findings of the review show the result of fuzzy-based framework and how the changes were applied in order to upgrade the SCIRT benchmarking model. The result of this application is then discussed more at the discussion section.

## **2. Research Background**

Financial-based awarding systems have been widely used (T. M. Rose & Manley, 2005) in various managerial areas such as waste reduction (Mahpour & Mortaheb, 2018), safety management (Hasan & Jha, 2013; Hinze, 2002) and sustainability (Pitt, Tucker, Riley, & Longden, 2009). Almost all of awarding systems consist three main stages; 'well-defining the indicator', 'designing performance benchmarks' and finally 'award teams financially'. Through these three steps, 'identifying key performance indicators' (Lauras, Marques, & Gourc, 2010; Marques, Gourc, & Lauras, 2011) and the 'pavement system' (Love, Davis, Chevis, & Edwards, 2010; Shen, Li, Drew, & Shen, 2004) have been well addressed in literature. Meanwhile, researchers, technically ignored the 'benchmarking method' as one of the main components of financial-based awarding system.

"One of the fastest ways to reach maturity and excellence in project management is through the use of benchmarking" (Kerzner, 2017). Benchmarking is defined as; "A benchmark is a measurement or standard against which comparisons can be made. Benchmarking is the process of comparing business processes and performance metrics to industry bests or best practices from other industries (Kerzner, 2017)". Performance improvement can be failed as a

result of an incapable benchmarking system. Benchmarking mistakes was already identified as a key to benchmarking failures (Kerzner, 2017). He stated this as; “Some of these mistakes include: Failing to have a benchmarking plan and not knowing what to look for”. “Without effective metrics, managers will not respond to situations correctly and will end up reinforcing undesirable actions by the project team - keeping the project team headed in the right direction cannot be done easily without effective identification and measurement of metrics”. Teams were encouraged through vague benchmark which resulted unwanted performance. Innovation should first be measured appropriately in order to be improved throughout the project lifecycle. This fact is also well-supported by Kerzner (2017) as; “You cannot correct or improve something that cannot be effectively identified and measured”.

A ‘Three-level’ benchmarking model has been widely used by recent infrastructure projects. ‘Crossrail’, ‘SCIRT’, ‘London Olympic park’ and ‘Heathrow Terminal 5’ (Basu, Little, & Millard, 2009; Crossrail, 2015; Wilkinson, Kempton, & Gleeson, 2012) are examples of infrastructure projects that identified a ‘three-level’ benchmark for innovation assessment. Considering the amount of monthly reported innovations by project teams, they were categorized in one of the three level. In SCIRT, as the case that is studied in this paper, three levels of “Minimum condition of satisfaction”, “Stretch” and “Outstanding” were identified. This approach of awarding that considered only the ‘number/month’ means that, team in SCIRT were not well –incentivized for harder types of innovation. They just relied on more numbers of monthly reported innovation regardless of the types and the importance. This study found this as an inefficient approach that was as a consequence of incomplete benchmarking in this project. T. M. Rose and Manley (2005) introduced this as “Disruptive Justice-Reward Intensity” in fifth ‘Motivational variable’ of their framework. He stated that “the award must be significant enough to motivate the agent but should not exceed the value of the benefit to the principals”. Addressing this, an upgrade is proposed by this study as a key contribution to knowledge. Using the result of this study, the project practitioners are able to identify a multiple-dimensional innovation assessment method that awards project teams, based on both the quantity (number/months) and quality (seven types) in appropriate timeframe throughout project lifecycle.

### **3. Research method**

A fuzzy-based theory is used by this paper in order to first rank different types of innovation, and then award teams based on the ranking result. A case study approach was also employed by this research in order to further investigate the ability of the proposed assessment framework in a real context in construction sector.

#### **3.1. Fuzzy logic-based innovation benchmark for incentivizing teams in project**

Developing a tool for project managers to assess project team's innovation level can be divided into three main parts. This assessment tool begins with an innovation classification model. This model is used as a comprehensive definition that divides different types of innovation. Then the identified types of innovation will be ranked based on expert's judgments, using a fuzzy logic-based questionnaire. Finally, an upgrade will be suggested on innovation benchmarking system using indexed classified types of innovation. As a result, a three-level innovation benchmark is recommended as the final outcome of the innovation framework in SCIRT.

##### **First part; Innovation types identification**

Innovation should clearly be defined with a comprehensive and multiple-view classification model as the first stage. Different types of innovation with variety of levels of Novelty and Benefits have been identified through literatures in various classification models (Garcia & Calantone, 2002; Lim & Ofori, 2007; OECD, 2005; Tidd, Bessant, Pavitt, & Wiley, 1998).



One of the most recent classification models, developed by Noktehdan, Shahbazzpour, and Wilkinson (2015) consolidated a variety of innovation types with relative levels of 'Novelty' and 'Benefits' in single and multiple-view conceptual model. Six different types of innovation were identified by this model as; 'Technology', 'Method', 'Design', 'Product', 'Function', and 'Tool'. This study will use this classification model component in order to rank different types of innovation. With adding a seventh category that was named as 'Hi-Technology', this study optimized the model before it is used in this paper. Hi-Technology is defined as: a new Technology that is coupled with a new Method. Gaining an in-depth understanding about the seven categories, the authors strongly recommend to study Noktehdan et al. (2015)'s innovation classification model.

## Second part; Fuzzy AHP-based method for seven types ranking of innovation

A method based on the fuzzy AHP concept is proposed to estimate weights of innovation types and perform innovation ranking. Opinions of decision makers are used to estimate innovation rankings by the proposed procedure. Every decision maker has been asked to express their judgment on innovation seven types importance compared to other types in the designed questionnaires. The fuzzy knowledge representation technique was used for denoting the importance of each type, to form fuzzy judgement matrices. Furthermore, fuzzy weights have been computed. Afterwards, a single value will be formed using the fuzzy weights from different decision makers that have been aggregated. The aggregation process is carried out by aggregation operator. At the end, fuzzy weight values are converted into numerical values which will be used in process of innovation seven types assessment. The process of ranking classified types of innovation is categorized in seven sets which have been outlined below;

**Step 1: Linguistic scale for evaluation of fuzzy judgment matrix:** Judgement matrix or pairwise comparison matrix (table 4-7) are used in traditional AHP approach in order to shape the relationships between goal and factors, and between factors and sub-factors. An element in row  $i$  and column  $j$  represents the judged value of attribute  $i$  over the attribute  $j$ . Despite the crisp numerical values in the traditional AHP, in fuzzy AHP, a linguistic scale with linguistic variables is used to compare the importance of sub-factors and fuzzy judgment matrix.

**Step 2: Data collection for establishment of pair-wise comparison matrices:** The experts' opinion is collected using the designed questionnaire. The experts are asked to compare each pairs of the classified types. Their decisions are collected through set of questionnaires. Further, the fuzzy judgement matrices are created using the collected data. The linguistic scale (table 2) and the triangular fuzzy number are used through this data collection process.

Table 1 Scale of relative importance used in the pair-wise comparison of fuzzy AHP.

Linguistic variable	Fuzzy number	Membership function
Equally important	1	(1,1,3)
More important	3	(1,3,5)
Strongly more important	5	(3,5,7)
Very Strongly more important	7	(5,7,9)
Absolute important	9	(7,9,9)

**Step 3: Consistency test:** The next step is to check the consistency. The triangular fuzzy numbers should first be converted into crisp values in order to run the consistency test. So the fuzzy comparison matrices will be firstly converted into traditional comparison matrices using the defuzzification process. The 'center-of-centroid' method is suggested to be used for defuzzification process which represents central value of triangular fuzzy numbers, because of its symmetry. If the traditional comparison matrix is consistent, then the fuzzy comparison matrix is consistent too.

Firstly, the maximum eigenvalue,  $k_{\max}$  from the comparison matrix  $X$  should be estimated. Then, the consistency test of the comparison matrix is performed in two steps:

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \text{ where CI – consistency index, } n \text{ is the dimension of square matrix.}$$

$$CR = \frac{CI}{RI}, \text{ where RI – random consistency index and CR is consistency ratio.}$$

Random consistency index RI is the consistency index value from the random generated matrix. Saaty (1980) has generated randomly reciprocal matrix using scale 1/9, 1/8, . . . , 1, . . . , 8, 9 and the average value for random consistency index of the randomly 500 generated matrixes for different values of  $n$  is specified in Table 2. If the value of CR is smaller than 0.1, then the judgment matrix has good consistency. Otherwise, the judgment matrix doesn't have acceptable consistency, hence it should be modified.

Table 2 Random consistency index RI

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

**Step 4: Priority weights are developed:** The next step is to calculate the weight of innovation types with respect to an element on higher level. First, the *eigenvector* is computed by normalization of the geometric mean:

$$\tilde{v}_i = \left( \prod_{j=1}^n x_{ij} \right)^{\frac{1}{n}}$$

Where  $n$  is the dimension of fuzzy matrix  $\tilde{U}$ , and  $u_{ij}$  is the element in matrix  $U$  belong to the  $i$ -th row and  $j$ -th column,  $\tilde{v}_i$  is the geometric mean of criterion and it is given as triangular fuzzy number since the elements of the matrix are fuzzy triangular numbers.

The weights for each innovation types  $w_i$ , which is a triangular fuzzy number are developed by calculating as;

$$\hat{W}_i = \frac{\tilde{v}_i}{\sum_{i=1}^n \tilde{v}_i}$$

**Step 5: Opinions of experts are Aggregated:** When the weights of each of the seven types are obtained, then the next step is to aggregate the results of different experts into single combined preference for each innovation. The aggregation value of innovation weights calculated based on the experts' opinions is estimated by;

$$FW_i = \frac{1}{m} \sum_{k=1}^m \hat{W}_{ik}$$

Where  $FW_i$  represents fuzzy weight of the  $i$ -th innovation,  $m$  – is the number of experts, and  $\hat{W}_{ik}$  is the fuzzy weight for the  $i$ -th innovation types which is result from the opinion of the  $k$ -th experts.

**Step 6: Defuzzification of the priority weights:** Defuzzification is a process of transferring triangular fuzzy number to the crisp number. This should be happened at the end of the ranking process when the innovation types are ranked, and the relative weights are developed. In this case, the representative method which is applied for defuzzification of fuzzy weights is based on Leung and Cao (2000):

$$W_i = \frac{w_1 + 2w_2 + w_3}{4}$$

Where  $W_i$  is crisp value of i-th innovation weight; and ( $w_1$ ;  $w_2$ ;  $w_3$ ) is the triangular fuzzy value of i-th innovation weight

**Step 7: Normalization:** Further, crisp weights of innovation types are normalized.

### Third part; Designing innovation benchmark

The innovation factors developed as the crisp numbers are used at this stage in order to classify project teams in three different levels. Covering the main concern of current paper, the innovation benchmarking system is upgraded using the outcome of the previous seven steps. SCIRT's three-levels benchmarking style is focused as a case study in next section for proposing an optimization. '*Minimum Condition of Satisfaction (MCOS)*', '*Stretch*' and '*Outstanding*' are the three levels that indicate the amount of awarding.

## 4. Case study

The above proposed innovation benchmark is being tested through a real infrastructure project that incentivized innovation through a strategic plan. In fact, the idea of upgrading the innovation benchmark in previous section was actually triggered after a deep study that was conducted by the researchers on a real innovation benchmarking system. Actually the entire process of upgrading was shaped based on the three-level style of benchmarking that SCIRT used for incentivizing innovation. The 'three-level' innovation benchmarks in SCIRT project counted just the numbers of monthly reported innovations regardless of the types (Table 3).

*Table 3 SCIRT innovation benchmark*

Innovation Benchmark	Scale
Minimum Condition of Satisfaction (MCOS)	2 innovations a month
Stretch	3 innovations a month
Outstanding	5 innovations a month

This research followed the result of Noktehdan et al. (2015) as a literature that assessed the innovation stance of SCIRT by applying the innovation classified on the 500 innovations database. The result clearly showed a weakness of the benchmarking system that cause a biased trend through the developed innovations. Innovation with higher importance level were in the minority and the simpler problem-solving types shaped the majority of the SCIRT innovations. This was identified as a disability of the benchmarking system that counted just the number/month regardless of the type for awarding innovation throughout the teams. Addressing this limitation, current research proposed an upgrading on the benchmarking system by ranking seven types of innovation. This is in order to prioritize bigger innovation by awarding more through the benchmarking system. In this section, FAHP as a well-known method was used to rank the seven types of innovation based on the SCIRT people judgments. After the weights are developed, a new benchmarking system is proposed as the main contribution to knowledge by this paper.

Stronger Christchurch Infrastructure rebuild Team (SCIRT) is an organization established under an alliance agreement and is responsible for rebuilding horizontal infrastructure in Christchurch following the earthquakes of 2010 and 2011. Innovation was given a special consideration from the outset, when the SCIRT alliance was formed. In fact, members of the alliance were encouraged to innovate and report on their innovations on a monthly basis as one of their KPIs. These KPIs were linked directly to the pay/reward aspect of the contract. As a result, the alliance members had ample motivation to report their innovations. To date more than 500 innovations have been

reported by SCIRT. This has provided a unique opportunity to analyses and better understand the relationship between construction innovation and productivity improvements.

#### 4.1. Procedure of innovation prioritization for the SCIRT

**Step 1:** Linguistic scale for evaluation of fuzzy judgment matrix: The linguistic scale of relative importance for pair-wise comparison with a triangular fuzzy number adopted from Cheng (1997) is used to measure subjective judgements of experts.

**Step 2:** Data collection for establishment of pair-wise comparison matrices: In this survey, eight Professors from the University of Esfahan have been asked to give their opinions for ranking the seven classified types of innovation. These experts were all well-informed about the construction projects condition since they were all very active in several national construction projects. After the consistently test was applied, four of the eight responses were found inconsistency and therefore they were dismissed for future research. Another four questionnaires were very consistency according to the testing results. The pair-wise comparisons are made according to Tables 4-7. The innovation classification model includes, Product (P), Design (D), Tool (T), Function (F), Method (M), Technology (Te) and Hi-Technology (HT). The pair-wise comparison matrices of the factors and the sub-factors are summarized in Tables 4-7.

**Step 3:** Consistency test: The consistency test for every matrix is performed and results of the test are provided at the bottom rows of Tables 4-7. Every judgment matrix is consistent.

**Step 4:** Calculation of the priority weights: The priority weights are expressed as triangular fuzzy numbers, and the results are given in the last Column in Tables 4-7.

**Step 5:** Aggregation of decision group's opinions: After the aggregation process of decision maker group's is completed, the estimated values of fuzzy weights for each hazard are given in Table 8. The decision of each decision maker is weighted equally.

**Step 6:** Defuzzification of the priority weights: The fuzzy weights are converted into crisp value and the result is shown in the 3rd Column in Table 8.

**Step 7:** Normalization: When the crisp ranks values are assigned to hazards, the next step is the normalization process of the ranks value. The results are obtained in the 4th Column in Table 8.

*Table 4 Computed weights of appraisal factors by DM1.*

	Product	Design	Tool	Function	Method	Technology	H-Technology
P	(1,1,3)	(1/5,1/3,1)	(1/3,1/2,1)	(1/5,1/3,1)	(1/7,1/5,1/3)	(1/9,1/7,1/3)	(1/9,1/8,1/7)
D	(1,3,5)	(1,1,3)	(1/3,1/3,1)	(1/3,1/2,1)	(1/5,1/4,1/3)	(1/7,1/5,1/3)	(1/9,1/7,1/5)
T	(1,2,3)	(1,1,3)	(1,1,3)	(1/5,1/3,1)	(1/7,1/5,1/3)	(1/7,1/6,1/5)	(1/9,1/8,1/7)
F	(1,3,5)	(1,2,3)	(1,3,5)	(1,1,3)	(1/3,1/2,1)	(1/7,1/5,1/3)	(1/9,1/8,1/5)
M	(3,5,7)	(3,4,5)	(3,5,7)	(1,2,3)	(1,1,3)	(1/5,1/4,1/3)	(1/7,1/5,1/3)
Te	(5,7,9)	(3,5,7)	(5,6,7)	(3,5,7)	(3,4,5)	(1,1,3)	(1/3,1/2,1)
HT	(7,8,9)	(5,7,9)	(7,8,9)	(5,7,9)	(3,5,7)	(1,2,3)	(1,1,3)

Consistency check:  $\lambda_{\max} = 7.66$ ;  $CI = (7.66 - 7)/6 = 0.111$ ;  $CR = CI/RI = 0.111/1.32 = 0.083 < 0.1$ .

*Table 5 Computed weights of appraisal factors by DM2.*

	Product	Design	Tool	Function	Method	Technology	H-Technology	
P	(1,1,3)	(1/5,1/3,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1/7,1/5,1/3)	(1/9,1/7,1/5)	(1/9,1/9,1/7)	(0.0125, 0.027, 0.098)
D	(1,3,5)	(1,1,3)	(1/3,1,1)	(1/3,1,1)	(1/5,1/3,1)	(1/7,1/5,1/3)	(1/9,1/7,1/5)	(0.0199, 0.057, 0.169)
T	(1,3,5)	(1,1,3)	(1,1,3)	(1/3,1,1)	(1/5,1/3,1)	(1/7,1/5,1/3)	(1/9,1/7,1/5)	(0.024, 0.057, 0.199)
F	(1,3,5)	(1,1,3)	(1,1,3)	(1,1,3)	(1/5,1/3,1)	(1/7,1/5,1/3)	(1/7,1/6,1/5)	(0.028, 0.057, 0.228)
M	(3,5,7)	(1,3,5)	(1,3,5)	(1,3,5)	(1,1,3)	(1/5,1/4,1/3)	(1/7,1/6,1/5)	(0.047, 0.124, 0.376)
Te	(5,7,9)	(3,5,7)	(3,5,7)	(3,5,7)	(3,4,5)	(1,1,3)	(1/5,1/3,1)	(0.116, 0.248, 0.574)
HT	(7,9,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,6,7)	(1,3,5)	(1,1,3)	(0.185, 0.431, 0.751)

Consistency check:  $\lambda_{\max} = 7.57$ ;  $CI = (7.57 - 7)/6 = 0.096$ ;  $CR = CI/RI = 0.096/1.32 = 0.072 < 0.1$ .

*Table 6 Computed weights of appraisal factors by DM3.*

	Product	Design	Tool	Function	Method	Technology	H-Technology	
P	(1,1,3)	(1/3,1/2,1)	(1/3,1,1)	(1/5,1/3,1)	(1/3,1/4,1/5)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(0.020, 0.049, 0.171)
D	(1,2,3)	(1,1,3)	(1/3,1,1)	(1/3,1/2,1)	(1/3,1/2,1)	(1/3,1/2,1)	(1/3,1/2,1)	(0.030, 0.091, 0.274)
T	(1,1,3)	(1,1,3)	(1,1,3)	(1/3,1/2,1)	(1/3,1/2,1)	(1/5,1/3,1)	(1/5,1/3,1)	(0.033, 0.074, 0.324)
F	(1,3,5)	(1,2,3)	(1,2,3)	(1,1,3)	(1/3,1/2,1)	(1/3,1/2,1)	(1/3,1/2,1)	(0.041, 0.131, 0.425)
M	(3,4,5)	(1,2,3)	(1,2,3)	(1,2,3)	(1,1,3)	(1/3,1,1)	(1/3,1/2,1)	(0.063, 0.179, 0.625)
Te	(3,5,7)	(1,2,3)	(1,3,5)	(1,2,3)	(1,1,3)	(1,1,3)	(1/5,1/3,1)	(0.067, 0.189, 0.675)
HT	(3,5,7)	(1,2,3)	(1,3,5)	(1,2,3)	(1,2,3)	(1,3,5)	(1,1,3)	(0.074, 0.288, 0.725)

Consistency check:  $\lambda_{\max} = 7.27$ ;  $CI = (7.27 - 7)/6 = 0.046$ ;  $CR = CI/RI = 0.046/1.32 = 0.035 < 0.1$ .

*Table 7 Computed weights of appraisal factors by DM4*

	Product	Design	Tool	Function	Method	Technology	H-Technology	
P	(1,1,3)	(1/3,1,1)	(1/5,1/3,1)	(1/3,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1/9,1/9,1/7)	(0.018, 0.036, 0.096)
D	(1,1,3)	(1,1,3)	(1/5,1/3,1)	(1/3,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1/9,1/9,1/7)	(0.021, 0.036, 0.125)
T	(1,3,5)	(1,3,5)	(1,1,3)	(1/3,1,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1/9,1/7,1/5)	(0.028, 0.067, 0.230)
F	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1/9,1/9,1/7)	(0.032, 0.058, 0.182)
M	(3,5,7)	(3,5,7)	(1,3,5)	(3,5,7)	(1,1,3)	(1/3,1,1)	(1/7,1/5,1/3)	(0.091, 0.165, 0.431)
Te	(3,5,7)	(3,5,7)	(1,3,5)	(3,5,7)	(1,1,3)	(1,1,3)	(1/7,1/5,1/3)	(0.091, 0.165, 0.460)
HT	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)	(3,5,7)	(3,5,7)	(1,1,3)	(0.247, 0.473, 0.754)

Consistency check:  $\lambda_{\max} = 7.78$ ;  $CI = (7.78 - 7)/6 = 0.131$ ;  $CR = CI/RI = 0.131/1.32 = 0.0996 < 0.1$ .

*Table 8 Fuzzy, crisp and normalized innovation rank*

Innovation	Fuzzy weight of the hazards	Crisp rank	Normalized rank
Tool	(0.015, 0.0352, 0.114)	0.049	0.039
Function	(0.022, 0.059, 0.178)	0.079	0.064
Design	(0.027, 0.06, 0.224)	0.092	0.074
Product	(0.0325, 0.081, 0.26)	0.113	0.091
Method	(0.068, 0.150, 0.444)	0.203	0.165
Technology	(0.10, 0.217, 0.55)	0.271	0.220
HI-Technology	(0.173, 0.397, 0.723)	0.422	0.343

## 4.2. Designing benchmark

The project team innovation could be categorized in three levels depending the innovation index developed for each of classified types and the monthly number of reported innovations. The



SCIRT innovation benchmark could be divided not only based the monthly reported number but also based on the seven innovation indexes that developed for the classified types. Seven different crisp innovation values have been computed by defuzzification process using 'Center-of-Gravity' method and corresponding to such crisp values, three possible innovation categories (innovation Category 1–3) are defined with an index range of;

*Minimum condition of Satisfaction*: two monthly innovation classified in Tool; Innovation index;  $2 \times 0.049 = 0.098$

└─┐ Up towards;

└─┐ *Outstanding*; five monthly innovations all classified in Hi-technology; Innovation index;  $5 \times 0.422 = 2.11$

Therefore, the upgrade on innovation benchmarking describes three innovation categories as: Minimum Condition of Satisfaction (MCOS), Stretch (ST) and Outstanding (OU) as it is summarized in figure 1.

*Minimum Condition of Satisfaction (MCOS)*; is used as a level of awarding if project teams introduce at least two innovations both in 'Tool' type. The minimum range of innovation index at this level was identified as; innovation index:  $(0.049) \times 2 = 0.98$ . Team will be categorized at this level at most up until the innovation index of 0.73. This means the team will still have awarded at this level even by fifteen monthly innovations that all are classified in 'Tool':  $(0.049 \times 3 = 0.735)$ . Furthermore, even if the team would come up with two innovations that are highly ranked in this paper, such as one Hi-technology and one technology the award would be placed in this level as innovation index will be calculated as;  $(0.422 \times 1 + 0.271 \times 1 = 0.693)$ .

*Stretch*; is where the team will come up with innovation index range from (0.74 to 1.36). This index range might be started whether with at least sixteen monthly innovations in 'Tool' type or three innovations that would be classified in two 'Method' and one 'Technology'. This level of award will continue, up far towards whether with eight monthly innovations, five 'Method' and three 'Product' ones, or with four monthly innovations, three 'Hi-technology' and one 'Design'.

*Outstanding*; is the highest level of innovation award that would be happened for the innovation index range between (1.36 to 2.11). This index range could be covered by a team with at least whether twenty-eight 'Tools'  $(28 \times 0.049 = 1.37)$  or only four Hi-Technology'. This could be continuing toward five Hi-technology innovations that would be reported by a team in one month.



Figure 1 Proposed Three- Level innovation benchmark

#### 4.3. Preactical application

The whole concept of this study has been developed based on an in-depth knowledge about the SCIRT's innovation awarding system. This was an opportunity for the proposed benchmarking system to be well-fitted to a real project. A full access of the researcher to the SCIRT project provided a unique opportunity to study about the awarding system by analyzing the 500 innovation database. The result of this study has been presented by (Noktehdan et al., 2015) . They showed

clear trends toward simpler innovation types due to a single-view approach applied by the SCIRT's innovation awarding system. This biased-trends triggered a need of further studying about any optimization available for upgrading the SCIRT innovation awarding system. Reviewing literature also showed a similar biased-approach through awarding mechanism recently used by other infrastructure projects. Bearing in mind that any optimization should be based on a practical context, current research focused on the SCIRT awarding system in order to propose a well-practiced innovation benchmarking system. This approach guarantees the practical application of the proposed benchmarking system. a classified and easy to understanding format provides an opportunity for the proposed innovation benchmarking to practically applied in future infrastructure projects.

## 5. Discussion

Owners in infrastructure projects often encourage project teams by using financial incentives (T. M. Rose & K. Manley, 2010). The impact of incentive systems on performance improvement was identified by Meng and Gallagher (2012) as; "On the whole, the embrace of incentives proves to play a driving role in encouraging best practice and ensuring project Success". Despite the fact that financial awarding system is being used widely in construction project, there is still rooms of opportunity about the means of optimizing outcomes. T. Rose and Manley (2007) indicated this as "yet, very little empirical research has been conducted into *how* financial incentive should be applied in the context of particular project types in order to maximize their effectiveness". This means that not all incentive systems should necessarily be considered as successful mechanism in order to improve performance. Volker and Rose (2012) identified this fact as "Despite a general belief that incentive mechanisms can improve value for money during procurement and performance during project execution, empirical research on the actual effects is nascent". A significant impact was identified as a result of failure in an incentive system implication by T. Rose and K. Manley (2010b). He stated this as; "Aligning the motivation of contractors and consultants to perform better than 'business-as-usual' on a construction project is a complex undertaking and the costs of failure are high as misalignment can compromise project outcomes". Addressing this predominant concern throughout literature, current studied investigated an optimization on an innovation incentive system by focusing on a case study in NZ construction industry.

Different types of innovation with variety of levels of importance were not separated by SCIRT and hence they all awarded in a same manner by the incentive system. This study found this as an unfair approach that decrease the motivations for more important types of innovation. T. Rose and Manley (2011) defined this inefficiency as; "Distributive justice theory". "Distributive justice theory suggests that the financial reward amount offered will be judged by its fairness relative to the effort required achieve the reward" (T. Rose & Manley, 2011). Avoiding this biased trend, innovation should have been monthly measured considered both the quantity and quality. This is exactly where SCIRT innovation benchmarking system was failed to do. This study recommended more flexibility on the awarding system by developing variety of awarding levels for different types of innovation. The importance of flexibility for developing a sustainable awarding system was also identified by T. Rose and K. Manley (2010a) as; "Interviewees from Projects A and B felt a lack of flexibility in the incentive goal and measurement process negatively impacted on their perceptions of fairness". Addressing this, a fuzzy theory was employed in order to rank seven types of innovation based on the experts' judgments. Questionnaires were designed based on Fuzzy theory concept and sent to the experts. After analyzing the data, each of the seven types of innovation was given an individual importance index which was further used in upgrading the SCIRT benchmarking system. The SCIRT innovation benchmark was upgraded using a fuzzy based innovation assessment framework. This achievement is based on a theory that takes into consideration the types of monthly reported innovation in assessing monthly innovation scores. The result shows that innovation with variety of different importance levels will be treated differently using the upgraded benchmarking system. This is a very important finding since teams are being awarded fairly using the new benchmarking system. According to the new concept, teams are not miss-motivating to just improve the number/month but with also considering the

type and importance of reported innovation. The biased-trend of the team towards the simple types of innovation as a result of an inflexible benchmarking system is well-addressed by using this paper result. This means that according to the new benchmarking system, even with almost 15 monthly innovations which all reported in 'Tool' category, the corresponding team will be still awarded in the lowest level (MCOS). On the other hand, with only five monthly innovations which all classified in 'Hi-Technology' category, the corresponding team will be awarded in highest level (Outstanding). Since this upgrade was applied on a real case study, the results of this study were kept away of personal bias. This finding at least can improve the project practitioners' knowledge of different types of innovation definitions. This mean that, innovation is not a single concept but a multiple-type that should be classified in different types. Another contribution of this paper is about the notion that identified individual importance levels for different types of innovation and then awarded each of the seven types respectively.

## 6. Conclusion

Innovation has recently been identified by huge infrastructure project as one of the project KPI's in construction industry. Financial-based awarding models has been used by these projects in order to improve innovation. Innovation level of teams should be measured through the benchmarking system. Afterwards, teams are awarded based on their monthly innovation scores. This strategic attention requires researchers to develop tools for identifying, measuring and awarding innovation in construction projects. Recent attentions to innovation awarding mechanism by some successful infrastructure projects around the world shows the importance of current study. Current paper well-addressed this opportunity by focusing on an innovation awarding mechanism that was used by an innovative infrastructure project in New Zealand. The SCIRT innovation incentive system was deeply studied by the researchers in order to address an area of weakness. This weakness was about an unfair awarding mechanism that miss-motivated teams to just improve the monthly numbers of innovation regardless of the importance. The three-level awarding mechanism was found inefficient to improve more important types of innovation in SCIRT. Innovation was identified in a single definition by SCIRT which caused the benchmarking system to award all types of innovation the same. This was misunderstood by SCIRT team in the way that innovation is a single-view value that would be awarded not based on the importance but just based on the number/month. This research criticized this view as a cause of a biased trend through the +500 innovations. Therefore, a new method was proposed in order to award teams. The fuzzy set theory is suitable to express expert's logic opinion about innovation indicators. Seven classified types of innovation have been identified from literature. Further, the fuzzy AHP procedure is applied to rank and developed innovation weights. Based on the result, an upgrade was proposed on the SCIRT's three-level awarding format. The new benchmarking system considers both the quality (types) and quantity (number/month) of innovation through awarding teams. This means that, the overall monthly scores are calculated not only based on the numbers but also considering the developed seven crisp numbers for seven types of innovation. At the end, according to the calculated innovation scores, the team would be awarded based on one of the three levels. The authors believe that there is still room for future researchers to keep digging deeper in the incentive systems in the construction sector.

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## Appendix

### Questionnaire

This questionnaire is based on our research into the viability of a flexible incentive system for construction contracts based on innovation – Innovations would be ranked using seven types of measure and those that score higher would be awarded more. The innovation classification model below aims to rank the seven types based on expert opinion from construction industry professionals. Your response to this questionnaire is important in order for us to validate our research.

Step 1: Read a description of the 7 different definitions developed for each type of innovation (Table 1 details an example from the SCIRT project).

*Table 1 Example of innovation in SCIRT project*

Innovation	Example SCIRT Innovations
Hi Technology	"Pressure waste water system" was one of the breakthrough innovations that was used by SCIRT project.
Technology	"Lightweight Localized Storm Water Pump Station"
Product	"Bridge St Cathodic Protection": Whilst working on the repairs to the piers of Bridge St Bridge, we have installed cathode protection to the piers.
Design	"Rationalization of waste water pipe in Hawkesbury Ave": When the drawings for Hawkesbury Avenue were reviewed by the Delivery team they identified that a section of pipe could be removed if one additional manhole was installed at the position of the first lateral.
Method	"Pipe bursting the water main in Buckingham "
Function	"CSS Workshop": These workshops were a great way to communicate the updates to the team at once, also discussed was the best way to communicate the changes to our subcontractors.
Tool	"Hydraulic Aluminum Shoring ": Aluminum hydraulic shores and shields are an excellent lightweight resource for working around existing utilities, supporting trench walls near structures, curbs, or sidewalks.

Step 2: Examples of 7 new innovations and their various features are detailed in the diagram below;

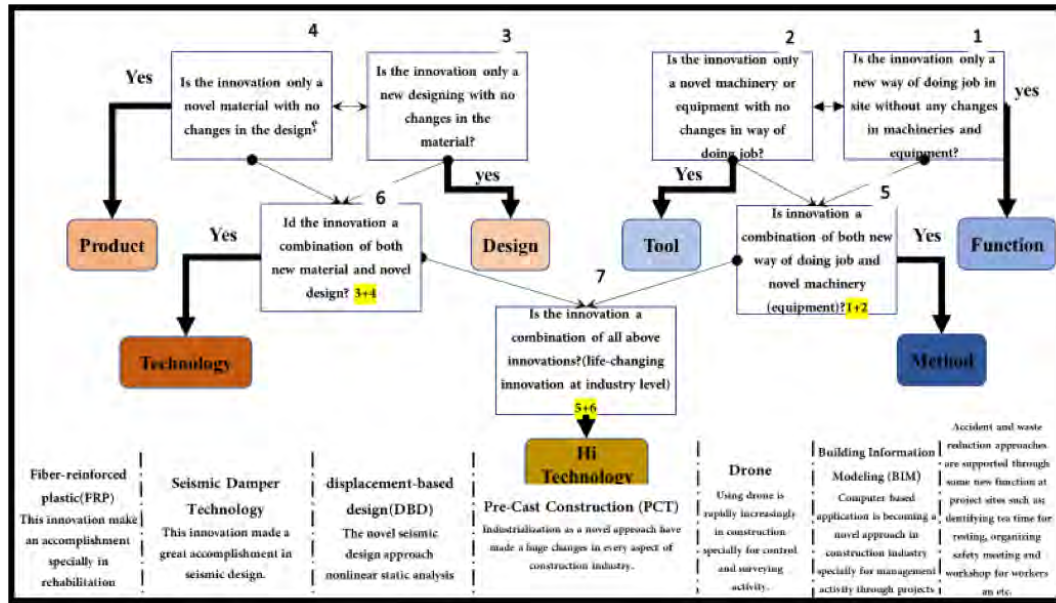






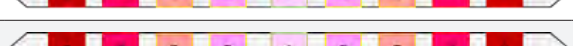








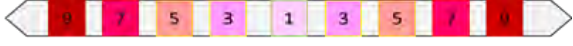





Figure 1 A guideline for innovation classification model

Thinking about this group of new innovations, would like you to compare the relative importance of their performance in the following categories and complete Table 2;

<b>Function</b> <b>Tool</b> <b>Design</b> <b>Product</b> <b>Method</b> <b>Improved Technology</b> <b>Brand New Technology</b>	<i>Value of <math>a_{jk}</math></i>	<i>Interpretation</i>
	1	$j$ and $k$ are equally important
	3	$j$ is slightly more important than $k$
	5	$j$ is more important than $k$
	7	$j$ is strongly more important than $k$
	9	$j$ is absolutely more important than $k$

For example: In line 1, if you think 'Tool' is a more important innovation-type in comparison to 'Function', it is ranked 9 (on the left-hand side of the row). But in the case you found 'Function' as much more important, it would be ranked 9 (on the right-hand side). Finally, in the case you found out that both are equal in importance, the rank would be 1(in the middle row).

Table 2 Pairwise comparison

<b>Tool</b>		<b>Function</b>
<b>Tool</b>		<b>Product</b>
<b>Tool</b>		<b>Design</b>
<b>Tool</b>		<b>Method</b>
<b>Tool</b>		<b>Technology</b>
<b>Tool</b>		<b>Hi Technology,</b>
<b>Function</b>		<b>Product</b>
<b>Function</b>		<b>Design</b>
<b>Function</b>		<b>Method</b>
<b>Function</b>		<b>Technology</b>
<b>Function</b>		<b>Hi technology</b>
<b>Product</b>		<b>Design</b>
<b>Product</b>		<b>Method</b>
<b>Product</b>		<b>Technology</b>
<b>Product</b>		<b>Hi Technology,</b>
<b>Design</b>		<b>Method</b>
<b>Design</b>		<b>Technology</b>
<b>Design</b>		<b>Hi Technology,</b>
<b>Method</b>		<b>Technology</b>

## SMART CITY INITIATIVES: A CATALYST FOR MEANINGFUL COLLABORATION

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### Summary

This paper explores the potential of smart cities initiatives as a driver of partnership formation. It presents lessons learnt from the collaboration between the Faculty of Built Environment at the University of New South Wales Sydney, Street Furniture Australia, and Georges River Council, New South Wales, as partners in a Commonwealth funded smart cities grant awarded in 2017. The research pilots how environmental sensors can inform the potential to improve the amenity and use of public open spaces and contribute to the asset management system of small-scale street furniture. This project provides a basis from which to explore the opportunities and challenges of collaboration across three domains (academia, industry, government) while conducting a smart cities project. We demonstrate how mutually collaborative efforts can better harness real-time data to identify and address citizens' needs, interests and demands, for public space in parks and plazas, in addition to assisting council with developing an efficient asset management system.

These critical insights (concerning processes, outputs and outcomes) can be applied to develop an effective model of research, practice, and local government collaboration that stimulates urban innovations to address complex problems of 21st century cities.

**Keywords:** smart cities partnership, triple helix model, interdisciplinary collaboration

## 1. Introduction

As cities are growing and densifying, they are struggling with challenges such as overcrowding, traffic congestion, noise, pollution and infrastructure that needs updating to meet current demands. In response, technology is being seen as a panacea, but this promise should be met with caution. Contemporary urban issues are different from what occurred in the past. Smart cities require transdisciplinary knowledge and collaboration amongst different industries to address 'wicked' (complex and interlinked) problems. Innovative solutions which transcend disciplinary boundaries, are needed.

We are at the tipping point of the smart city. Local and state governments, alongside private industry and academia are jockeying for position to be leaders in the space. As a result, disparate initiatives and pilot projects in this space are often less informed by evidence-based research. In turn, documented efforts of conceptualizing and testing innovative smart city methodologies go unnoticed and hence have limited impact and/or remain with a select few. Meaningful collaboration to advance the field is essential.

This paper positions and demonstrates a working cross-sectorial collaboration, outlining the strengths and challenges associated with complex smart city projects which seek to benefit the community and its governance structures.

## 2. Smart Cities

Much of the initial research about smart cities attempted to interrogate the concept and develop definitions (Hollands 2008; Allwinkle & Cruickshank 2011; Albino et al. 2015). Key elements of these definitions include the utilization of new technologies (mainly Information and Communication Technologies), enabling sustainable economic, social, and urban development, an urban entrepreneurial element (mostly hi-tech), and knowledge-based economy (knowledge/information capital). Smart cities can also focus on human and social capital, social learning and community development (Hollands 2008). Kitchin (2014) signifies the role of data analytics to understand, monitor, regulate and plan the city; this is widely recognized as contributing to the big data industry. This paper draws on Albino et al. (2015), who propose that smart cities can be applied to 'hard' domains such as buildings, energy grids, natural resources, water and waste management, and mobility, as well as 'soft' domains including education, culture, policy innovations, social inclusion, and government. The discussion and practice surrounding smart cities is often about big data sets, large scale infrastructure projects, reconfiguring urban systems that involve major technological applications and sometimes, altering business culture (e.g. Tel Aviv, Start-Up City). What is often overlooked are different scale projects and their impacts which may be at a local scale and directed at specific human-centered problems. These projects are aimed at enhancing people-place relationships using open, accessible, and user-friendly technologies.

Different urban issues operate at a national to micro local scale (e.g. Australia's National Broadband Network [NBN] initiative down to a local government's place-based smart initiatives). The range of potential problems need different solutions at varying scales. As Cruickshank (2011) notes, the innovative and creative capacities of the Smart Cities partnership is needed to deal with this complex and multi-scale landscape. The smaller scale projects tend to enable urban entrepreneurialism through getting start-ups and tech-based companies engaged in these projects/initiatives and public-private partnerships to support new digital businesses. Citizens also have a role in creating smart cities and need to be involved to ensure the outcomes are beneficial to them at human scale. The Australian Federal Government has the following four priority areas that encapsulate different scales of smart city projects: smart infrastructure, smart precincts, smart services and communities, and smart planning and design (Australian Government *Smart Cities and Suburbs* grant program 2017). The span of content areas and scale of these priority areas indicate interdisciplinary and cross -sectorial collaboration is a necessity.



### 3. Collaboration

To frame collaboration in a smart city project, this paper draws on the triple helix model. This model is based on genetics and DNA coding. “The triple helix of university-industry-government interactions is a universal model for the development of the knowledge-based society, through innovation and entrepreneurship” (Etzkowitz & Zhou 2017 p. 4). “The university is the generative source of knowledge-based societies ... Industry ... a key factor as the locus of production, government as the source contractual relations that guarantee stable interactions and exchange” (Etzkowitz & Zhou 2017, p. 23).

The triple helix model has been applied in many circumstances: for instance, “University-Industry-Government (U-I-G) interactions and relationships provide an optimum methodology for entrepreneurship and innovation, moving research/knowledge into practice/use.” (Etzkowitz & Zhou 2017, p. 2). For Leydesdorff and Deakin (2011), “the triple-helix model ... proposes that the three evolutionary functions shaping the selection environments of a knowledge-based economy are: (i) organized knowledge production, (ii) economic wealth creation, and (iii) reflexive control” (p. 56).

Cruickshank (2011) has applied the triple helix model to the smart city, arguing that collaboration is needed for the intellectual capital of universities and wealth creation of industry. He focuses on the underlying institutional relations that support the involvement of universities, industry, and government in knowledge production processes. In a more recent study, Dameri et al. (2016, p. 2974) note that “the smart city success depends on the synergic action by the triple helix key actors: public bodies, universities, and private companies”. They further argue that there are differences in smart city vision among these actors with respect to three factors: technology, human factor, and institutional factors. They conclude that “without a central direction, coordinating the interests of all the key actors with the stakeholders’ expectations and needs, the smart city will remain an interesting innovative laboratory, but failing in creating public and private value for all in the long term” (Dameri et al. 2016, p. 2980).

### 4. Design Thinking

Smart city issues are more than technical problems to be solved by computer engineers, data scientists or business administrators. They require creative and collaborative approaches to develop innovative solutions to address urban challenges. Design thinking is an often overused and somewhat misunderstood term (Dorst 2010). However, when applied at the front-end of a design or planning process, design thinking can lead to meaningful insights and greater understanding of opportunities to address problems. At its simplest, design thinking can be information gathering, but more sophisticated approaches involve analytical (benchmarking and data acquisition) and observational (ethnographic or other) techniques, collaborative design strategies, and the testing of iterative prototypes. These methods can heighten empathy and understanding by placing people at the center of the process and thereby propose new insights to solve problems (Brown 2008; Adams et al. 2011).

The collaboration between university, industry and local government enables an inter-institutional project team to take a transdisciplinary approach (Brown & Katz, 2009). A range of methodologies, from qualitative observational studies to quantitative data capture and analytics, builds a rich and nuanced understanding of people and place.

Design thinking also refers to the iterative approach which is applied to the current project. As it is a pilot project, insights were gathered from the information and data collected and used to revise and fine-tune our approach and interpretation of the data based on this feedback loop.

## 5. Equal Contributors in the Triple Helix Model

Employing the triple helix model of collaboration to achieve smart cities objectives and aspirations, each partner plays important roles and the resulting outcomes vary as discussed below.

### 5.1. University

Boyer (1990) suggests that the university can function as the scholarship of integration and application; to explore how knowledge can be applied to consequential problems; and how it can be helpful to individuals and institutions. In doing so, universities serve the interests of the larger community (see Ian Jacobs' talk to the National Press Club in which it is stated that 'for every \$1 investment in universities it creates a \$10 return in the community!' <https://youtu.be/trNPuFp9Doo>). Boyer argues that the process should be dynamic rather than one-way in which knowledge is first "discovered" and then "applied": "New intellectual understandings can arise out of the very act of application... theory and practice vitally interact, and one renews the other" (Boyer 1990, p. 23). He highlights "the need to move beyond traditional disciplinary boundaries, communicate with colleagues in other fields, and discover patterns that connect" (p. 20). Charles (2011, p. 282) who discusses the role of universities in building knowledge cities, notes that "ensuring that the knowledge assets of the university are applied to meet the needs of the local community, in terms of business or indeed in wider social and cultural impacts, requires a set of policies and initiatives, and a form of scholarship, to ensure that local needs inform the development of high-quality research and teaching, that those activities engage with local partners".

Researchers can scientifically observe, identify, and evaluate innovations and provide directions for further smart city investigations. This is difficult for others who might not have the time, resources or training. The relevant outputs that research-intensive universities require are publications, grant monies and industry networks. This requires researchers to **explore, create, innovate** without immediate commercial gain, which is the prime concern of industry. Researchers can enquire without citizen pressure to deliver goods and services which are normally the focus of government.

### 5.2. Industry

The private sector plays a key role in smart city projects. At times, it is not only a partner in Public-Private Partnerships, it can also be one of the essential driving forces behind projects, alongside city and public-sector initiators. Private sector businesses are interested in widening their business interests and are keen to boost their image by being publicly concerned about the future of cities (Hatzelhoff 2012). Businesses also want to be perceived as having a 'green' and 'social' conscience, alongside their need to make a profit. Smart city projects, like the one presented here, are an excellent opportunity for industry to identify and test before going to market.

There is value in prototyping products *in situ*. It "allows for the testing of the potential solutions early on in the design process ... [it] involves turning design concepts into functional solutions... In particular, in urban environments, the process of turning a design concept into a functional solution is not straightforward" (Tomitsch 2018, p. 153). Industry cannot do this without a partner who has a need and a place for their products to be tested in a real urban setting.

### 5.3. Government

Local government can benefit from the living lab concept as it is at the forefront of assisting research and practice to identify and solve real-world problems affecting the local community. Despite local governments competing with each other for businesses and reputations as sustainable and liveable place creators, government administrations are networked with each other and share knowledge and solutions to urban problems. They learn from each other. They

also reach out to universities and industry because they need and want cutting-edge knowledge and access to the latest technology, which they do not have in-house, to address their local challenges.

Local governments offer the place to host technology and trial innovative solutions and to collect evidence for new, potentially beneficial outcomes for the community. As the Australia Government noted:

*smart infrastructure to improve efficiency, smart precincts to make communities more liveable, smart services and communities that will deliver community-focused local government services and smart planning and design to build adaptable and resilient cities (Australian Government Smart Cities and Suburbs Program 2017)*

## **6. Case Study: A Smart Cities Partnership**

This smart city case study involves a collaboration between the Faculty of Built Environment at the University of New South Wales Sydney [UNSW], Street Furniture Australia [SFA], and Georges River Council [GRC], in the southwest district of the metropolitan area. The study provides an opportunity to design, test and implement new, smart street furniture in the public domain. It also pilots a flexible and smart infrastructure management system. This is significant for smaller local government areas that are typically 'lower-tech' and cannot afford complicated, outsourced, technical infrastructure needed to run a 'smart city management system'. The project overall will give the local council hard evidence to inform open space, urban design and public infrastructure decisions. Both components of this project are designed to improve healthy and connected living.

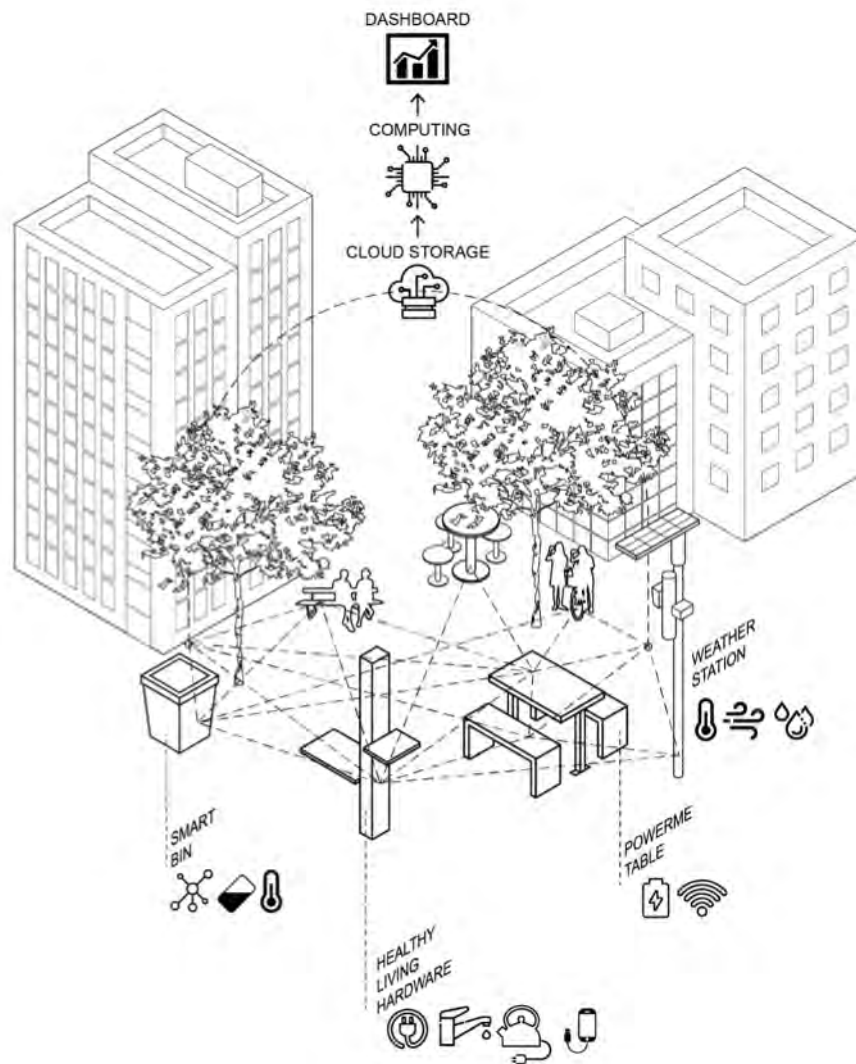
This project is a case study, which we present in detail in this paper. Findings from this study are not intended to be generalizable. However, a case study can include 'lessons learnt' from within the project scope (Patton 2002). These details, although specific to this case study, are relatable to other local governments with similar small-scale projects where collaboration is critical for success.

This research project entitled 'Smart Social Spaces: Smart Street Furniture Supporting Social Health' was a recipient of the Australian Government's *Smart Cities and Suburbs* grant program, 2017-2019. There were 49 successful projects in round 1 of funding worth \$27.7 million; round 2 funding is valued at another \$22 million and will be distributed in late 2018. The program demonstrates the Australian Federal Government's commitment to the smart cities movement. Our research pilots the use of environmental sensors to determine the extent to which improvements can be made to increase the amenity and use of public open spaces and the asset management system of small-scale street furniture.

Using digital sensors installed on street furniture and existing park facilities, sensors record real time use of urban furnishings in two public spaces in the GRC – a plaza, Memorial Square in Hurstville, and a park, Olds Park in Penshurst. These different types of public space were selected: one an urban setting that is intensively used on a daily basis, and the other, a park less intensively used during the week and more heavily used for recreation on the weekends. Figure 1 below illustrates the basic components of the project that compose a smart system based on IoT (Internet of Things) technology. The IoT technology as a network of sensors embedded in devices and physical objects provides a means to monitor and manage urban assets and their use. The 'Smart Social Spaces' project has been aimed to collect data from environmental sensors, store it in cloud servers, process and analyze it in real-time, convert it into useful forms and insights, and displays it on a city dashboard. This provides local councils with live user data about public open space and the use and performance of their public furnishings.

A key component of the project was fitting out new and existing street furniture installations with a range of digital wireless sensors that operate on several different transmission platforms to provide data about the use of these urban furnishings. For example, we were able to determine

how long people spend in the vicinity of the site; how often a piece of equipment is used; and whether the equipment needs servicing. Sensors also provide data on how long people sit on the benches, and whether they are alone or with someone. We can cross reference this data with sound and location-specific weather data that we are also collecting. This gives GRC a rich and detailed picture of the patterns of use for the assets in these settings. The project has introduced a novel data system provided by IoT sensors.



*Figure 1 Schematic diagram of Smart Social Spaces*

This project has been an opportunity for the industry partner, SFA, to test a new product: the 'PowerMe' table that includes two General Purpose Power Outlets, USB ports, wireless charging and inbuilt power monitoring integrated into a new range of seating. This is a first in Australia. We have also invented a (cigarette) ash receptacle that measures the heat inside the unit. We have installed sound sensors and a weather station in both case study areas to measure those environmental factors. These products, alongside smart bins (measuring fill levels, heat and passing pedestrians), are being combined into an IoT of diverse and extensive data. This evidence base is the start of GRC's new smart asset management system.

In addition, we provided an entirely new product, the Healthy Living Hardware (HLH). This is an innovative street furniture product that aims to improve public health by providing power and water in proximity to heavily used public areas. The HLH includes WiFi, General Power Outlet

[GPO], USB and power outlets. The units allow people to recharge their phones, wash their hands, or make a cup of tea. They also include a timed water tap, a grate for drainage at the base, and side counter tops for food preparation. With the HLH, people can bring a cooking appliance like an electric BBQ, wok, or hot plate, extending the range of activities that can take place in a public setting, introducing an element of domestic activity into the public space. The HLH has been adapted by SFA to fit their existing product range by integrating elements of their products' design materials and features, such as timber fittings and other fixtures. The result is that this unit, albeit a prototype of a new typology of street furniture, now looks and feels like it belongs to the existing range of an established repertoire of street furniture options.

Key stages of the project were as follows (also represented in Figure 2):

- **Proposal Development** was mostly conducted by UNSW and SFA. This included identifying sites, preparing the plan for the refurbished sites, identifying opportunities and constraints, refining the initial proposal, developing concepts of smart furniture and turning concepts into products. Feasibility planning and cost assessment was undertaken to ensure the project components are aligned with the budget and schedule.
- **Innovation Legality** included drawing up an agreement between UNSW and GRC to address liability issues associated with the installation of the HLH as a piece of untested in the public realm.
- **Installation**, conducted through the collaboration of SFA and GRC, included site preparation, furniture installation, ensuring water flow and power supply through GPO and USB outlets, and setting up a network connection via 4G modems to enable sending data to cloud servers.

## 6.1. Roles of the Collaborators in the Smart Social Spaces Project

Figure 2 illustrates the three contributors to the project and the dynamic nature of their relationships. It also shows the iterative nature of the design thinking behind the project and amongst the players. As well, Figure 2 summarizes the major roles of each collaborator.

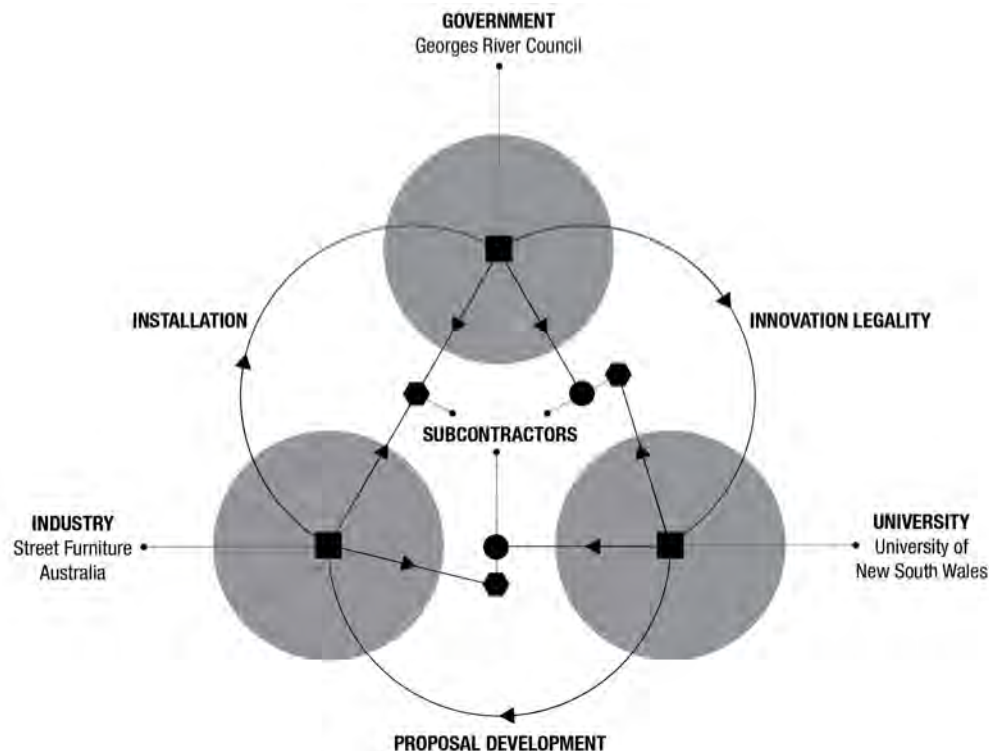


Figure 2 Cross-sectoral collaboration in Smart Social Spaces project (Source: the authors, 2018)



A summary of tasks by collaborator is as follows:

#### UNSW

- Wrote and submitted the grant (driver and now leader)
- Led discussions about legalities of the innovative part of the project
- Operationalized the data collection and management systems
- Positioned the location of street furniture in the plaza and park
- Documenting knowledge through journal articles and conference publications (ongoing)
- Promoted the project through social and other media outlets
- Managing the project overall to be completed within time and budget

#### SFA

- Designed and developed smart street furniture
- Prepared engineering and structural drawings for new furniture
- Managed subcontractors for technical aspects of the project
- Produced, assembled and delivered the smart street furniture

#### GRC

- Agreed to be formal grant partner and host the project
- Identified the public domain case study sites which have some current social and place-based issues requiring research
- Participated in discussions about legalities of the innovative part of the project
- Prepared the site and installed new street furniture
- Communicated regularly with their local community

#### SUBCONTRACTORS

- Developed IoT sensors to install on street furniture
- Advised on the selection of technology to be used
- Provided the data platform for data capture and data visualization

## 6.2. The Role of the Disciplines in the Smart Social Spaces Project

Collaboration across the various disciplines (planning, landscape architecture, industrial design) and scales (from individual furniture to a public space, street, neighborhood and beyond) in the Smart Social Spaces project is essential to its success. There are always opportunities and challenges collaborating across different disciplines that work at 1:1 // 1:200 // 1:2500 scale drawings from objects to site plans to maps, and of course, all involving interactions with people. The UNSW team is made up of industrial designers, city planners, a healthy built environment expert, a landscape architect, an environmental psychologist and an architect who work at these different scales. The SFA team includes industrial designers, engineers, graphic designers, and construction/production staff. The Council team includes project managers, an infrastructure manager, engineering operations staff, electricians, tradespeople, parks crews and the communications coordinator. Collectively, the complexity of the project can be successfully addressed by the expertise in the multidisciplinary teams from across the partners.

## 7. Lessons Learnt

Beyond developing technical and design solutions, there has been a highly cooperative and productive partnership between local government, academia and industry. By working collaboratively, we have been able to provide a better understanding of the use of public space, so that Council can make informed decisions that support and optimize the use of shared public space, encourage social interaction and ultimately, improve public health.

The critical insights (concerning processes, outputs and outcomes) presented below can be applied to develop an effective model of research, practice, and local government collaboration that stimulates urban innovations to address complex problems of 21st century cities:

1. Processes

- Start developing the MOUs and legal agreements necessary for the project at the outset or during planning phases
- Appreciate that knowledge creation can happen through experiential learning or 'learning by doing' which means that new knowledge and innovation cannot be rushed
- Innovation emerges as collaboration occurs
- Communication between parties is vital
- Decide early in the process which collaborator owns the Intellectual Property, including the data generated
- Enable urban entrepreneurship through supporting start-ups and tech-based companies
- identify what you do not know which could interfere with the project and seek solutions

2. Outputs

- Aim to commercialize new products to ensure the private industry partner benefits
- Allow the industry partner to experiment/test and improve its products in a real-world setting for both social and economic benefit
- Ensure these innovative projects provide the industry partner with opportunities for publicity
- Be aware that new products take time to be designed, tested and launched into the marketplace
- Improve the public amenity or services by using smart technologies with the end user in mind

3. Outcomes

- Develop proposals for future projects that can benefit from the established collaboration
- Assess and reflect on what has been done in order to learn from mistakes or run future projects more effectively
- Do not underestimate the potential for 'scaling up' or the transferability of findings
- Set future research agendas
- Continue to invest in collaboration (with partners and their relationships)
- Look for non-traditional partnerships

## 8. Conclusion

The Smart Cities Movement is here to stay and can be a catalyst and driver of meaningful partnership formation. Local councils, private industry and academia need to realize the power of collaboration at large or very small scales. Connecting all three groups of collaborators can increase the effectiveness of their individual efforts and initiatives that aim to make cities smarter. Despite "the project partners having differing objectives and cultures" (Hatzelhoff 2012, p. 190) there is much to be gained from working together.

This paper highlights one case study and discusses the many lessons learnt about the process, outputs and outcomes of smart city initiatives across a range of scales. Mutual trust amongst the players can help ensure the overall success of these projects as innovation often 'tests' and ideally strengthens these relationships.

The effective use of technology for improving infrastructure, precincts, services, planning and design needs an interdisciplinary collaboration. Roles and responsibilities may be blurred or overlap at times, but it makes the triple helix a stronger and more dynamic model of collaboration to deliver a smart city.

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# A TECHNO-ECONOMIC ANALYSIS ON APPLYING SMART DISTRIBUTION NETWORK FOR SOLAR PHOTOVOLTAIC SYSTEMS IN EDUCATIONAL BUILDINGS

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## Summary

The renewable energy sources (RES) and sustainable infrastructures are rapidly reshaping the world because of the growing awareness of sustainability. Among all the RES, solar energy is considered as one of the cleanest and the most cost-effective electricity generation approaches. However, the development of solar photovoltaic (PV) is severely hindered due to the limitations of solar exposure, technologies and market conditions. Apart from improving cell efficiency and enhancing the competitiveness of solar energy in the market, optimising the distribution of electricity is also an effective approach to improve the performance of solar PV. By coordinating the energy outputs in response to real-time demands, smart distribution networks such as microgrid, smart grid and virtual power plant can play important roles in improving the energy efficiency of the solar PV systems. However, the application of these systems in building clusters is rare, and there is only a limited number of study looking into applying smart distribution networks for decentralised solar PV systems in Australia. To investigate the energy performance and profitability of the smart distribution system and the feasibility of applying smart distribution system in an educational facility, a case study of rooftop PV system in an educational institute in Victoria has been conducted. A PV system is designed to reduce campus's carbon footprints by reducing the energy demands from the public grid. To optimise the energy distribution and the overall performance of the PV system, a smart distribution system for six buildings is designed and simulated based on modelling software. Electricity usage data and energy generation with a 15-minute interval for one year is obtained for each building. The energy output and economic performance of applying the smart distribution system are analysed. The results show that by applying the smart distribution system, the PV arrays can further reduce the demand of electricity from the grid as well as increase the net present value (NPV) of the PV system. Considering the high initial cost of implementing and operating smart distribution system which results in a long payback period of over nine years, this design is not recommended for small-scale application in this case study with only six buildings but more suitable for the building clusters where more PV modules are deployed. Overall, this study can improve the understanding and awareness of the demand-shaping capacity and profitability of smart distribution system and can assist the decision-making process for the future solar PV applications in educational buildings.

**Keywords:** Building photovoltaic (PV) system, smart distribution network, educational building cluster, techno-economic analysis;

## 1. Introduction

There is a growing awareness for the private sector in promoting the transformation of a sustainable built environment. Under the guarantee of supportive policy, adopting energy conservation techniques (ECTs) means not only less carbon emission but also better economic performance of the projects. As an important ECT to reduce the building's reliance on fossil fuels, distributed renewable energy resources (DERs) has been populating in Australia since the announcement of Australian Renewable Energy Target (RET) and a series of supportive policy launched by state and commonwealth government. Among all the distributed energy sources (building mounted wind turbine, combined heat and power unit, solar photovoltaic, biomass etc.) solar PV is the most popular technique in Australia.

According to the 2017 IEA report (IEA, 2017), Australia has 5985 MW of installed capacity of solar PV, which provides 3.3% of the annual electricity demand. However, solar PV has long been known to have a low photoelectric conversion rate and low capacity factor due to the nature of PV technique (Denholm & Margolis, 2007). Moreover, the feed-in tariff rate (11.3 c/kWh) of PV generation in Australia is significantly lower than the electricity rate (19c/kWh for peak and 14c/kWh for off-peak plus daily supply charges) (AEMC, 2017). Hence, it has become an important task for PV industry to seek solution improving the efficiency of the PV system and improve the economic benefits to encourage the installation of PV system.

Smart distribution is an important concept to improve the efficiency of DERs to ensuring the highest energy quality, the lowest cost and trustworthy reliability (Nosratabadi, Hooshmand & Gholipour, 2017). From the energy saving perspective, the smart distribution systems such as microgrid and virtual power plant (VPP) are designed to maximise the self-consumption and reduce the reliance on the electricity from the grid (Asmus, 2010, Kasaei, et al., 2017, Song et al., 2013). And from the economic perspective, these networks can reduce the users' electricity bill or create profits by reducing the electricity imported from grid (Asmus, 2010, Nosratabadi et al., 2017) or encouraging peer to peer (P2P) energy trading (Liu et al., 2015, Mengelkamp et al., 2018). Although many previous studies focus on assessing the impact of applying smart distribution network on a large scale, the study of applying smart distribution network in small-medium scale in educational buildings is rarely found.

Therefore, this study aims to investigate the energy and economic performance of implementing a smart distribution system to a university building cluster by conducting a techno-economic analysis. Base on the findings, the discussions will be provided on how to improve the efficacy of the smart distribution network as well as other potential benefits of adopting this technology for educational buildings.

## 2. Investigation Process

The investigation process of this study comprises several different steps. For technological analysis, a 3D model for the PV system with optimised tilt angle and orientation is built. The annual solar irradiation has been calculated, and the efficiency of the PV system is also calculated and justified. Based on the 3D model and the computational model, two options are proposed for further analysis. As for economic part, a cost and benefit analysis (CBA) is conducted using the indicator of net present value (NPV) and payback years (PY) to assess the economic performance of each option.

### 2.1. Establishing a 3D model for rooftop PV system

The investigating site is located at a university campus in Victoria 3056. The university has launched an energy efficiency project with budgets of \$128 million to improve the sustainability of the buildings (RMIT University, 2017). The campus is laid six kilometres north to the Melbourne



CBD. The investigation site has a total area of 3.90 hectares and has six buildings with a total built-up area of 21,369.45 m<sup>2</sup> (Figure 1).

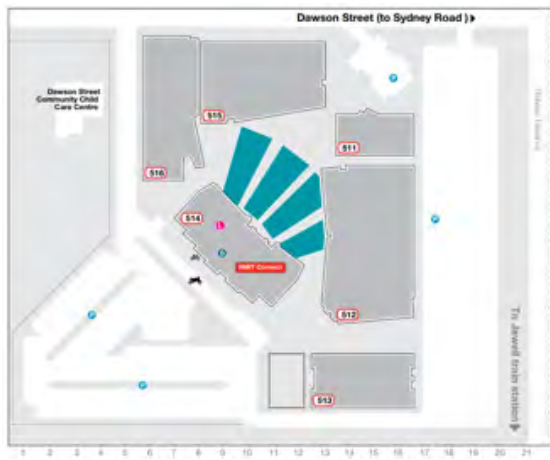


Figure 1 RMIT Brunswick Campus layout



Figure 2 Solar array layout on rooftop with tilt angle of 30° and orientation of 10° East

The six buildings are divided into three groups. Each group is controlled by a smart meter. Meter 1 (M1) controls building 515 and 516. Meter 2 (M2) controls building 511, 512 and 514 while building 513 is controlled by Meter 3 (M3). Defined by Australian Energy Regulator (Australian Government, 2017), a smart meter (also called 'type 4' meter) is a device that can measure the real-time electricity consumption, communicate with supplier remotely and control the power connection as required. By using smart meters along with a local distribution management software, the property management team of the investigated buildings can optimise the electricity distribution within the building cluster and reduce the energy reliance on the public grid.

The PV module selected for this study is the Suntech Power's 250W polycrystalline PV module. It has cells number of 60 on a 1.63 m<sup>2</sup> surface. According to the typical meteorological year (TMY) data (Morrison & Litvak, 1999), Melbourne has an annual horizontal global irradiation of 14.5 MJ/m<sup>2</sup> and global irradiation on 37.83 sloped surface of 15.9 MJ/m<sup>2</sup>. Roof-mounted PV arrays are proposed for all six buildings. During the investigation, it has been found that no adjacent buildings have shading projected to the rooftops where the PV array is proposed. However, shading effects among the six buildings do cause the loss to the PV array.

Necessary documents for the investigation site including building layouts, site plans, building section drawings, the layout of adjacent properties and annual electricity consumption record are provided by the property management contractor of the owner. Additionally, Google Earth has been applied to obtain geographic information for the investigation site, such as altitude, latitude, orientation and landscape. Based on these data, a detailed 3D building model is built using SketchUp modelling tool and the PV system is added to the 3D model using Skelion plug-in. The model has an appearance shown in Figure 2.

## 2.2. Simulating energy output

Hourly solar irradiation data is calculated using PVWatts® calculator. The hourly irradiation is calculated based on the isotropic diffuse model provided by Liu and Jordan (1963). The model calculates the sloped surface irradiation using the product of total irradiation on a horizontal surface and the ratio of total irradiation on a sloped surface to that on a horizontal surface (Equation 1).

$$I_T = \left[ \frac{I_b}{I} R_b + \frac{I_d}{I} \left( \frac{1+\cos\beta}{2} \right) + \rho_g \left( \frac{1-\cos\beta}{2} \right) \right] I \quad (1)$$

The total hourly irradiation on the sloped surface can be calculated by equation 1, where  $I_T$  is the total hourly irradiation on the sloped surface ( $\text{MJm}^{-2}$ ),  $I$  is the total hourly irradiation on horizontal surface,  $I_b$  is the beam component,  $I_d$  is the diffuse component,  $\beta$  is the slope angle of receiving surface and  $\rho_g$  is the reflectance of ground (Duffie & Beckman, 2013). After obtaining the hourly irradiation data, the efficiency of the system is estimated. Most solar PV cells made of polycrystalline silicon have an overall efficiency of  $21.3 \pm 0.5\%$ , while the PV modules of polycrystalline silicon usually have efficiency at around 20% (Green et al., 2016). The losses of energy are caused by photoelectric conversion rate, shade and heat transfer. Normally, the PV array efficiency is expressed by instantaneous array efficiency ( $\eta$ ) which is an hourly efficiency of the PV array affected by cell temperature, wind speed and configuration parameters of the PV products (Duffie & Beckman, 2013):

$$\eta = \eta_r \eta_{Pt} [1 - \beta_t (t_a - t_r) - \beta_t G_t (\tau\alpha) (1 - \eta_r \eta_{Pt}) / U_L] \quad (2)$$

where  $\eta_r \times \eta_{Pt}$  is the system conversion efficiency ( $\eta_{Pt}=1$  if there is no power tracking equipment),  $\beta_t$  is the temperature coefficient of efficiency,  $t_a$  is the ambient air temperature (K),  $t_r$  is the reference operating temperature of PV array (K),  $\tau\alpha$  is the transmittance-absorptance product  $G_t$  and the instantaneous solar radiation on the array ( $G_t = I_t$  of equation 1). However, since the objective of this study is to investigate the impacts of applying smart distribution system for small-medium scale building cluster, equation 2 has been simplified as below (equation 3):

$$\eta = PR \times \eta_r \quad (3)$$

where  $PR$  is the performance ratio of PV array and  $\eta_r$  is the reference efficiency of the PV module. For the estimation of  $PR$ , the loss caused by heat transfer and wire connection is assumed to be 10%, while shading loss (%) is calculated by SunCast simulation tool for each building. Hence, the actual hourly energy output of the system can be calculated with equation 4:

$$E = A \times I_T \times \eta \quad (4)$$

where  $A$  is the surface area of PV array and  $E$  is the hourly energy output (kWh).

*Table 1 Half-yearly average shading loss and performance ratio (PR) for each building*

		B.511	B.512	B.513	B.514	B.515	B.516
First Half	Shading loss	2.2%	4.1%	9.5%	3.0%	3.0%	3.0%
	PR	87.8%	85.9%	80.5%	87.0%	86.9%	86.9%
Second Half	Shading loss	1.5%	3.14%	7.8%	3.0%	2.0%	2.0%
	PR	88.5%	86.9%	82.2%	87.0%	88.0%	88.0%

With the hourly energy output data, simulations have been conducted to investigate the optimal settings of the PV arrays.

### 2.3. Implement smart distribution system with the best PV array configurations

To decide the best configurations (tilt angle, panel orientation, module number, etc.) of the solar PV modules, ten different design schemes are considered in this study. With the energy output model previously introduced, the annual total energy outputs of 10 different design schemes

for M1, M2 and M3 are calculated and compared (Table 2). Table 3 summarises the electricity demand of each group of building and the PV array electricity generation with different settings. Due to the timeframe and the large amount of calculations, this study did not consider tilt angle over 30 which may provide the PV array with higher annual solar irradiation.

*Table 2 Number of solar panels for each group of building as per the design case*

Slope/orientation	Design Scheme	M1 (No. of modules)	M2 (No. of modules)	M3 (No. of modules)
Flat	1	951	1157	367
10° /10° West	2	768	1035	326
10° /0° Azimuth	3	782	1012	342
10°/10° East	4	800	1271	378
20° /10° West	5	774	1046	353
20° /0° Azimuth	6	810	1070	366
20°/10° East	7	829	1298	384
30° /10° West	8	722	1018	338
30° /0° Azimuth	9	764	1073	346
30°/10° East	10	868	1276	411

Shown in table 2 is the number of modules for each group of buildings with different design schemes. The quantity of PV modules is estimated using Skelion plug-in in SketchUp by applying different configurations to the PV array on the rooftop. Based on the quantity of PV modules, table 3 displays the total electricity generation under different design schemes and the percentage of total demand that can be satisfied by the PV system. The best design for each group of the building is M1 with design scheme 10, M2 with design scheme 7 and M3 with design scheme 10. The total module number of the best design is 2577 with a total installed capacity of 644.26 kW.

*Table 3 Annual energy generation and % satisfied of the total consumption for each meter*

Design Scheme	M1			M2			M3		
	Total demand (MWh)	Total generation (MWh)	% of demand satisfied	Total demand (MWh)	Total generation (MWh)	% of demand satisfied	Total demand (MWh)	Total generation (MWh)	% of demand satisfied
1	714.70	323.17	42.20	1379.17	392.31	28.40	390.12	117.57	30.10
2	714.70	277.96	38.90	1379.17	373.46	27.10	390.12	111.12	28.50
3	714.70	295.34	41.30	1379.17	366.20	26.60	390.12	116.91	30.00
4	714.70	290.63	40.70	1379.17	460.32	33.40	390.12	129.32	33.10
5	714.70	290.75	40.70	1379.17	391.49	28.40	390.12	124.76	32.00
6	714.70	305.91	42.80	1379.17	402.62	29.20	390.12	130.05	33.30
7	714.70	313.52	43.90	<b>1379.17</b>	<b>489.10</b>	<b>35.50</b>	390.12	136.63	35.00
8	714.70	274.77	38.40	1379.17	385.77	28.00	390.12	120.92	31.00
9	714.70	292.90	41.00	1379.17	409.61	29.70	390.12	124.68	32.00
10	<b>714.70</b>	<b>333.45</b>	<b>46.70</b>	1379.17	488.03	35.40	<b>390.12</b>	<b>148.41</b>	<b>35.00</b>

To investigate the impacts of smart distribution system on the three groups of buildings, two different options have been proposed. Option 1 (Figure 3): Each meter operates individually and only exchange electricity with the public grid; and Option 2 (Figure 4): A smart distribution system is operating to allow the electricity exchange within three meters and with the public grid.

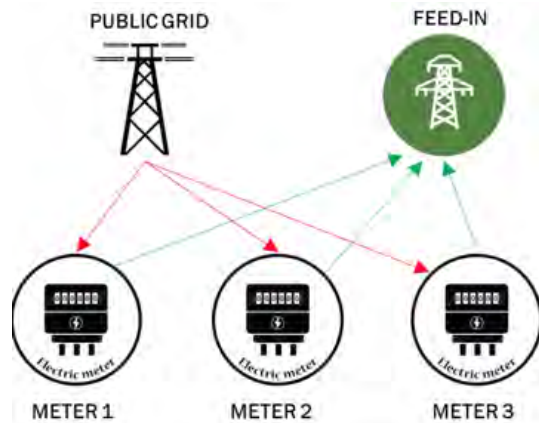


Figure 3 Option 1, individual metering system

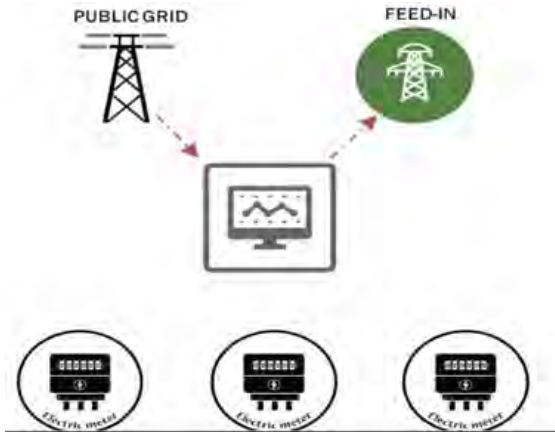


Figure 4 Option 2 Smart distribution system

For Option 1, the electricity generated by the PV system in each cluster of buildings will firstly be used to satisfy the current demand of each cluster. If the generated power is greater than the demand, then the extra amount of electricity will be fed back to the grid. As for option 2, the overall electricity generated by all the PV array will be used to satisfy the demand of all the buildings under three meters before the extra amount can be fed back to the grid.

## 2.4. Cost-benefit analysis (CBA)

To investigate the economic performance of the smart distribution system, cost-benefit analysis (CBA) with indicators of net present value (NPV) and payback years (PY) is applied. Using NPV, the economic performances of different options for a 25-years' period is assessed. Discount rates ( $r$ ) of 3%, 7% and 10% are adopted in the CBA as per recommended by Australian Government authority (Parliament of Australia, 2018). Due to the low risks of the proposed PV system, 3% discount rate is selected for further analysis of the economic performance.

The cost of implementing the proposed PV system for two options includes initial cost (device, labour, delivery etc.), operating cost and maintenance cost. Normally, the PV module has a lifespan of over 20 years (Jordan & Kurtz, 2011). It is assumed that there is no need to change parts of the PV system in 25 years' period. And the degradation rate of the PV system output is set to be 5% for the first year and 0.5%/year for the following 24 years (Jordan & Kurtz, 2011).

The initial cost of implementing the system is calculated using rates provided by the supplier. The rate is \$1.40/watt for PV modules, mounting seat and other material, \$0.20/watt for inverters and \$0.70/m<sup>2</sup> for installation cost. Since there are no reliable sources for the cost of establishing and operating a smart distribution system at this scale, no additional cost is considered for implementing option 2.

As for the benefit of the PV system, Australian Renewable Energy Target (RET) is considered. According to Australian Clean Energy Regulator (2017), the feed-in tariff (FITs) in Victoria has been increased to 11.3 cents/kWh. This rate is selected for the calculation of benefits. Apart from FITs, the PV system also has the benefit of saving electricity bill. To calculate the electricity bill saving, peak and off-peak electricity rates are applied. Peak time is Monday to Friday from 7 am to 11 pm while all other times are considered as off-peak. For this study, the electricity rate per unit for peak time is 19c/kWh, and for off-peak, it is 14c/kWh.

### 3. Results and Discussion

#### 3.1. Results of economic analysis

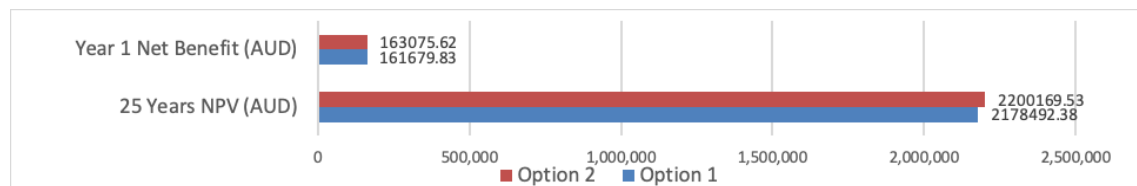
The net benefits of each year for both option one and option two has been calculated with a discount rate of 3%. Table 4 shows the calculation for each meter. It can be found that the PV array of each group can satisfy over 30% of annual demand. All the meters have positive net benefit values with M2 listed the top due to the larger installation capacity. However, the payback period of all the PV systems is relatively long due to the high initial cost.

For both option 1 and 2, the total energy output should be the same. The major difference between the two options is that option two allows the generated electricity to be distributed within the three groups and satisfy as much self-demand within the building cluster as possible before being exported to the grid. It is found that option two can achieve 42.65% of the total annual demand, which is slightly higher than option 1's 39.09%.

*Table 4 Summary of first-year energy output, first-year net benefit and 25 years' NPV of the option 1*

Meter	1st Year Energy Output (MWh)	% of demand satisfied	1st Year Net Benefit (AUD)	25 Years' NPV (AUD)	Payback Years
M1	333.45	46.70	54923.73	735669.85	9
M2	489.10	35.50	82217.07	1129721.60	9
M3	148.41	38.00	24539.03	308061.48	11
Option 1 total	970.96	39.09	161679.83	2178492.38	9

However, it can be found from figure 5 that although the option 2 has a higher NPV than option 1, there is the only a minor difference between the two options. This may occur due to the similar load pattern of the three building groups (e.g. High electricity usage during the daytime, weekdays and low usage during night and weekends). Under this circumstance, the solar PV system can achieve good energy and economic performance without adopting smart distribution system to optimise the energy distribution, since the electricity generation can be fully consumed to satisfy the demand.



*Figure 5 Comparison of first-year net benefit and 25 years NPV between the two distribution options*

Summarized in table 5, option 1 and 2 has the same payback period of around nine years, while the NPV of option 2 is slightly higher than option 1. However, considering the cost of establishing and operating a smart distribution network, which is not included in the calculation, the actual NPV of option two will be lower than option 1.

*Table 5 Summary of the economic performance indicators of option 1 and 2*

Option 1		Option 2		Difference of NPV
NPV (AUD)	Payback years	NPV (AUD)	Payback years	
2178492.38	9	2200169.53	9	21677.15



### 3.2. Applications of the smart distribution system in educational buildings

As a result, the smart distribution system is not recommended for the application in this case of small-scale building cluster from the perspective of economic performance. Although the smart distribution system can improve self-consumption within the cluster, due to the similar load patterns of these buildings and the limited size of the PV system, this effect is not obvious.

However, it is still possible to improve the efficiency of smart distribution system by reshaping the load profile of the building cluster. For educational building cluster, the load profile can be reshaped by optimising the schedule and venue of teaching and learning activities. The total demand for electricity for lighting and air-conditioning can be reduced if the classes are concentrated in the one group of buildings. Also, the percentage of electricity demand satisfied can be further improved by scheduling the classes according to the intensity of solar irradiation.

Apart from the energy efficiency, the following benefits can be considered for educational building:

**Benefits for reducing reliance on the public grid.** The smart distribution network allows the electricity generated by the PV system to be allocated in response to the real-time demand. This system can further reduce building cluster's reliance on the electricity from the public grid which is majorly generated using fossil fuels.

**Benefits for research.** Although there are many studies investigated the impacts of applying smart distribution network such as microgrid, and virtual power plant, the real-world case of these types of project is rare, especially in Australia. Also, the smart meters in the smart distribution network are capable of recording and communicate real-time electricity generation and usage data, which can bring great convenience for relevant research projects.

**Possible benefits of integrating electric vehicles (EV).** EV is an alternative transportation option which has zero emission and does not require fossil fuels. For educational institutes located outside the metropolitan area, EV can be a good option to reduce the carbon emission caused by transport. By integrating EV into the smart distribution system, the energy generated by the PV system will be prioritised to EV to reduce the expenditure of fossil fuel. Moreover, EV with large battery capacity can play a role in energy storage which may increase the electricity security and further reduce the amount of electricity imported from the grid during peak hours. However, further investigation is necessary to assess the benefits of EV integrated smart distribution system.

## 4. Conclusion

This study investigated the energy and economic performance of implementing smart distribution system in a small-medium sized building cluster in an educational institute. A techno-economic analysis is conducted to assess the system's performance. The main findings of this study are shown as below:

- The optimal PV module settings for each group of the buildings have been determined based on solar irradiation, shading and rooftop area;
- The smart distribution system can improve self-consumption within building cluster. A higher percentage of demand is met by PV system using smart distribution network in this study;
- Due to the PV system size and similar load profile of the buildings in this study, smart distribution network's contribution for increasing energy efficiency is minor, and the NPV of option 2 (Smart distribution network) is estimated to be lower than option 1;
- For university user, the efficiency of smart distribution system can be further improved by optimising the schedule and venue of teaching and learning activities;
- The smart distribution system in an educational building can provide the investor with other potential benefits such as facilitating research and reducing carbon emission of transportation by integrating EV in the network;

Through this study, it can be concluded that cooperating with renewable energy resources, the smart distribution network can improve the sustainability in the built environment of educational institute. Further study is required to investigate how can the efficacy of this technology be further improved.

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## **A USER-LED APPROACH TO SMART CAMPUS DESIGN AT A UNIVERSITY OF TECHNOLOGY**

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### **Summary**

A South African university of technology (UoT) has embarked on a transformative journey towards achieving a SMART campus status. Due to the plurality of perspectives concerning the meaning of the SMART campus concept among end-users and other stakeholders, and for the avoidance of pitfalls associated with end-user apathy towards new innovations, a user-led approach (participatory design) was adopted. This study provides a detailed narrative on the utility of the participatory design process in the design of the SMART campus initiative at the UoT. Relevant user categories within the UoT were identified, and a pre-determined number of individuals purposively recruited from each of these categories. A workshop was convened to elicit their opinions concerning the SMART campus concept. Discussions at the session were recorded and subsequently transcribed. Data emerging from the discussions were analyzed thematically relying on a coterie of pre-set themes. Findings from the study highlight the benefits accruable from the proper usage of the participatory design approach. The adoption of this approach enabled among other things, a consensus on an institution-wide/institution-specific definition of the SMART campus concept, an identification of the state-of-the-art of the institution's ICT platform, users' perception of the performance of extant ICT platforms, their expectations as well as aspects of the SMART campus they believe should be prioritized during implementation. The study highlights the utility of the participatory design approach in the design and implementation of innovative solutions like the SMART campus initiative in organizations.

**Keywords:** SMART Campus, South Africa, Participatory Design, User-Centrism

## 1. Introduction

Successive governments have expressed commitment to Sustainable development and SMART City/Campus initiatives (Happaerts et al., 2010). This is evident in the number of national governments that are signatories to the sustainable development goals (SDG) framework and its precursor, the millennium development goals (MDGs) (Waage et al., 2015). Presently, society is witnessing an increase in the adoption of sustainable development tenets by organizations.

The criticality of data and its subsequent deployment towards enabling new approaches to sustainable consumption cannot be overemphasized (Mellouli et al., 2014). Yet, the management of the unprecedented inflow of data due to the advent of the internet makes the need for a veritable platform for data analytics, interpretation and utilization, imperative. This has given rise to the concept of smartness. SMART cities are salient facets of the smartness concept which have evolved to cater for this aspiration, albeit from a city-wide perspective. Therein, information and communication technologies are deployed to collect and manage data related to patterns of consumption within cities (Angelidou, 2015). The processed data is used in making futuristic projections whilst allowing for effective decision-making processes and, development of interventions to cater to the resolution of the present challenges confronting society (Celino and Kotoulas, 2013).

The time-honoured position of universities as microcosms of society effectuates the need for them to play pivotal roles in the transformation of society towards smartness (Leal Filho, 2011). Such roles proceed beyond the normal boundaries of knowledge creation for SMART cities. Societal expectations dictate that these institutions should, relying on multi-, inter- and transdisciplinary skill-sets domiciled within, constitute themselves into living laboratories of the SMART city scenario. The SMART Campus initiative has taken off across several universities in response to these expectations. Universities in South Africa are not left out from this broad-based initiative as a cursory look at the websites and associated marketing paraphernalia of most universities indicate their aspirations to transform their approach to operations, pedagogy, and research through internet-enabled communication and digital technologies. These efforts are not solely aimed at process optimization and efficiency savings but also at transforming learner-experiences within these institutions (Malatji, 2017). In short, it has become a value proposition to attract students and staff. Although transition efforts are yet on-going and have been alluded to enhance user-experience in these institutions, there is little evidence to show that the views of the users are being incorporated during the initiative's conceptualization and design stages. Rather, scholars bemoan the uni-directional nature of SMART city implementation programmes (Rha et al., 2016).

The SAUoT is an institution where the systemic transition to a SMART campus is at embryonic stage. The desire to make a success of this initiative in this institution necessitates that the programme's proponents/designers elicit and incorporate the views of users at this stage. This study seeks to report on the engagement process adopted in eliciting such worldviews- a juxtaposition of the user-centered systems design and participatory design approach, and the benefits accruing from this methodology.

The rest of the paper is structured into: a review of the theoretical perspectives of the study's underlying concepts, a description of the case study's institutional context, a narrative on the research methodology adopted, a report on the reflections of the authors on the outcomes of the user-engagement brainstorming session, and a conclusion.



## **2. Theoretical Perspective**

### **2.1. SMART Campus- a review**

A SMART Campus is a campus that is an efficient, safe, sustainable, responsive and enjoyable place to live and work, underpinned and enhanced by digital/internet-based technologies. Its evolution has been linked to the need to foster a new paradigm in higher education due to the overt reliance on the information and communication technologies (Rha et al., 2016). Considered as a microcosm of a SMART city, a SMART campus can be described as an environment which aligns the aspirations of the “university as a city” and stronger connections across and outside the campus. As universities embrace the concept of a “SMART campus”, three elements need to be incorporated (Davies, 2015): One is the concept of the university as a city in its own right, a collection of people, amenities and assets which respond to, and are shaped by, the values, expectations and shifting demands of its “citizens”. A second is the idea of connectedness, which includes some of the more operational and transactional capabilities that come with the idea of a SMART campus. The notion of a SMART campus encapsulates sensor-based SMART parking and new ways to use digital lighting to make campus facilities more accessible, safer and more energy technologies to totally reshape the spaces for learning and interaction and to broker new and more nuanced relationships between students, those relationships extend to the wider communities of alumni and business and community partners in which a university is embedded. And thirdly, it requires investments in infrastructure and services on which the two first concepts rely. A SMART campus is one that aligns the aspirations of “university as city” and stronger connections across and outside the campus with the necessary investments in requisite technology assets and capability.

Abuarqoub et al. (2017) observe that significant investments were being made by higher education institutions in the transition towards smartness due to a desire to optimize service delivery to members of the university community. Furthermore, they opined that universities with SMART campuses will fare better than those without, in terms of cost and time savings, protection of the environment, effective monitoring of attendance of staff and students as well as effective space planning and utilization efforts. In furtherance to these, the adoption of implementation of SMART campus projects in universities will enable the collection of critical data about operational facets thus enabling optimal decision-making.

Examples of the SMART campus initiative implementation as chronicled in the literature include: the development of an anytime-anywhere learning within a SMART campus environment (Hirsch and Ng, 2011), SMART parking (Bandara et al., 2016), frameworks for modelling movements on a SMART campus (Fan and Stewart, 2014), development of platforms for energy management and optimization on campuses (Barbato et al., 2016), dynamic timetabling systems (Campuzano et al., 2014), as well as the use of apps for location directions and information dissemination purposes (Dong et al., 2016). These examples go to prove utility of SMART Campus in engendering better learning environments as well as effective and efficient resource (mostly energy, time and space) allocation and usage. In a nutshell, it can be adduced that the SMART city and SMART campus initiatives are both aimed at enhancing the standards of livability of cities whilst enhancing the productivity levels of its citizens through participatory decision making and governance based on the availability of credible data.

### **2.2. A Case for User-centricity in SMART Campus Design through Participatory Design**

The failure of strategy and policies in organizations and society has been attributed to the inability of policymakers and strategists to incorporate the viewpoints of not just the implementers but also the expected beneficiaries of the policy/strategy (Hupe et al., 2014). A cursory look at implementation-related studies indicates a tendency among strategists/policymakers to believe that they have an integral understanding of the needs of the expected beneficiaries (Ritter et al.,

2014). Yet, this assumption has culminated in significant instances of beneficiary apathy and opposition to the policy/strategy programmes thus leading to underwhelming performance.

Most conventional methods for new product design have been described as uni-directional. In this instance, the developers source information from users about their preferences, design, develop and deliver systems which have been configured to those initially elicited preferences and then gauge the levels of usability afterwards. This is case with user-centered design. But this has often resulted in failed delivery of products and solutions especially within the technological domain where rapidly changing features remain the norm (Ritter et al. 2014).

According to Muller (2003), participatory design (PD) refers to the procedural framework which chronicles the incorporation of potential end-users as critical participants in the activities which culminate in the design and development of software and hardware computer-based solutions. This framework enhances the designer's ability to among other things, achieve a clarification of design goals, needs formulation (co-design of problematic areas), etc. among between the designer and the beneficiaries (Simonsen and Hertzum, 2012). The contribution of PD towards enhancing mutual learning and co-production of relevant knowledge between designers and design beneficiaries, hence bridging the hitherto existing disconnect. This refers to the dual principles of reciprocity and mutuality as unique selling points of the PD approach during systems design. Suffice to say that the integration of PD and user-centric design holds significant potentials in the case of SMART Campus design.

The involvement of users in the design, development and subsequent implementation of the SMART campus initiative has been deemed imperative for different reasons. Of significance is the need to ensure that the adoption of democratic and collegial platforms during the design, development and implementation of the initiative. Blomberg and Henderson (1990) reiterate the significance of user involvement in systems design based on their expertise of the work environment and the interaction of previously designed systems on workplace quality. Following from the foregoing, the adoption of such platforms will encourage the strengthening of the resource weak communities (Bjögvinsson et al., 2012) within the university community who often feel compelled to adopt and utilize new technological advancements in the execution of assigned roles. Such feelings inadvertently affect productivity, both at individual and organizational basis.

Having dwelt substantially on the advantages of users and user-perspectives in the design and development of actionable systems and programmes in organizations, this study will proceed to provide a narrative, in subsequent parts, on how user-centrism and PD were utilized during the design of a SMART Campus initiative at SAUoT.

### **2.3. Description of case study context**

The catch phrase of SAUoT Vision 2020 is “social and technological innovation”. Furthermore, “innovation” is one of the five SAUoT values. Innovation is an improved product, process or service that benefits society in a timely and, sometimes, transformational manner. It is a team activity at the intersection of different fields, bringing together diverse ideas, abilities and/ or methods to result in the creation of value (Patil et al., 2015). Innovation creates societal value (through an existing or new product, process or service) and one interesting aspect is internal innovation whereby an organization tweaks its processes to bring about efficiencies.

In the quest for digital transformation, one entity at SAUoT has taken several steps ranging from digital scholarship aimed mainly at enhancing student experience by placing all learning materials at a learning management system that is accessible anytime, anywhere; followed by comprehensive digital strategy aimed at bringing about operational integration and optimization through digital workflows and storage of information. However, these initiatives have been constrained by lack of their uptake by other entities across the campus. Recently, a project on digital transformation across the campus has been launched and it is expected that what has worked so far will be taken up by all entities.

Hence, to ensure that all initiatives towards digital transformation are integrated, a SAUoT strategy for SMART campus is being proposed. The SAUoT campus is an ideal environment and 'vehicle' through which to research, develop and evaluate a diversity of SMART Campus, and potentially SMART City concepts, being embedded within Bloemfontein as an existing city, and encircled by major facilities, including a psychiatric hospital, police station, high court, and churches. In addition to the obvious benefits of a more efficient, connected and responsive campus, such a campus would also enhance and reinforce the University's reputation as a progressive academic institution and a university of technology. Such potential benefits and support are also likely to strengthen the case for further funding e.g. from the Department of Higher Education and Training (DHET), Technology and Innovation Agency (TIA); Department of Science and Technology (DST) and other funders who would like to be associated with efficient and technologically connected working environment.

However, before the complexity of challenges that developing a SMART Campus poses can be addressed, a formalization of needs as opposed to abilities is crucial. Also, it is necessary to identify what has already been done, both internally and externally. Indeed, an awareness of the later, would not only help to avoid simply replicating the work of other Universities, but enable a refocusing of efforts on identified areas of strength. It is also imperative that a 'people' oriented approach be advocated rather than 'hardware-centered' and avoid simply finding uses for new technologies and data, rather than focusing on the actual needs of those that use and service the campus.

### **3. Research Method**

A brainstorming workshop session was convened by the lead author to elicit viewpoints from various stakeholder categories within the SAUoT concerning the design and implementation of the SMART campus initiative. Effort was made to identify and recruit discussants purposively from the different stakeholder groups present in campus. This was considered necessary because of the need to provide these groups with the opportunity to participate in the development of a protocol for the institution's SMART campus transition. In total, 19 participants were recruited apart from the lead author who acted as facilitator and the co-author. Stakeholder groups from which these participants were drawn included: non-academic personnel from the Academic planning, Registry, Finance/Accounts, Procurement, Facilities, and, Information and Communication Technology (ICT) departments respectively. Also, in attendance were members of academic staff representing different disciplines and a select number of students from the Student Representative Council (SRC). In summary, the workshop featured a truly representative audience comprising of the internal stakeholders of the university community.

To break the ice, the facilitator had requested for researchers in the audience to make presentations on the utility and application of the SMART ideology according to their different specialisms. These presentations lasted for 10 minutes each on the average. PowerPoint presentations on themes such as SMART Buildings, SMART Energy, SMART Water, SMART Mobility and the Internet of Things (IoT) was carried out. In the aftermath of these presentations, questions around salient issues were posed by the facilitator to achieve the objective of the workshop- the development of a common ontology among different stakeholder categories concerning a SMART Campus and identification of priority areas where the incorporation of SMART features were deemed imminent.

Questions posed to the audience during the deliberations were centered on the following thematic areas:

1. A context-specific definition of the SMART Campus,
2. Stakeholders' expectations of a SMART Campus environment;
3. An appraisal of the state-of-art SMART infrastructure at SAUoT.
4. The level of integration and optimization of available SMART Infrastructure on Campus,
5. A SWOT analysis concerning the transition towards a SMART Campus environment, and;
6. Finally, a consensus on the priority implementation areas.

Discussants were requested to write down their answers on a notepad once a question was posed. A round of discussion ensued upon receipt of the notepads and the facilitator tried to achieve a consensus among participants on key issues concerning that question. This process lasted for three hours with breaks in-between.

The authors thematically analyzed the texts provided by the participants during the workshop. A comprehensive document outlining the details of the workshop was compiled by the authors and subsequently shared with the participants at a later date. At this point, these participants were availed with a one-week window to either express their reservations on the information provided or make clarifications where necessary concerning the emerging implementation objectives included in the document. At the end of this period, all participants agreed that the content of the compilation was indeed, a valid reflection of their contributions and stance on the SMART Campus initiative.

Based on the foregoing, a set of strategic goals were formulated. These goals include:

1. Leveraging digital platforms to integrate and optimize operational activities,
2. Create user-friendly platforms for interaction with key stakeholders,
3. Optimize all utilities-energy, water, space-through reliance on Internet of Things (IoT),
4. Provide a secure and safe campus using SMART technologies
5. Leveraging digital platforms to enhance student life-both academic and social, and;
6. Optimize the functions of all SAUoT buildings using intelligent devices.

Accordingly, the development of these strategic goals informed the design of a user-led SMART Campus architecture at the institution. Yet, this paper only seeks to report on the utility of the processes applied towards enabling a consensus on these strategic goals.

#### **4. Reflections on the utility of the process**

In this section, the authors reflect on their experiences during the brainstorming workshop session as well as the utility of the process therein in engendering the development of a common ontology concerning SMART Campus and its design and implementation.

This study adopts the standpoint of Muller (2003) on the place of workshops in PD. In that study, workshops are referred to as providing a platform for bringing together, parties with divergent views, enabling robust exchange of ideas and information on a set of goals. A salient outcome from such platform will usually include a shared commitment towards enunciated goals by the parties. This was the essence of the brainstorming workshop convened by the first author. Studies into implementation failures in Higher Education institutions have identified stakeholder apathy, because of the top down approach to policy/strategy design, development and implementation, as major hindrance. In the case of the SMART Campus agenda at SAUoT, the authors sought to ensure that not only did the design remain congruent to the ideals and expectations of a significant cross-section of the university community but also to ensure that its implementation was driven by this population.

The need to create shared knowledge among this population was acknowledged and served as a guiding principle during the identification of discussants. An understanding of the disparity of knowledge concerning the SMART Environment episteme led to the selection of researchers engaged with research in this area to make simplistic presentations to the audience prior to the commencement of brainstorming session proper. Also, the facilitator sought to allay the fears of the participants concerning the centrality and overt dependence of the SMART Environment episteme on technology. This was achieved through an attempt to develop a context-specific definition of SMART Campus from the perspective of the discussants. This was necessitated by the notion that the transition towards smartness will engender a loss of jobs at the university through the transfer of hitherto information technology-based competencies to external solution providers as was the case in successful SMART campus exemplars. Besides arriving at a

context-specific definition of the SMART campus, the centrality of human engagement in the plan was reiterated to the cohort.

In furtherance to this, discussions availed discussants with the opportunity to critique the present level of smartness at the university and project the potentials of a SMART-enabled future therein. Regarding the former, discussants identified the various advances made concerning smartness at the university in their respective disciplines/departments and enumerated the available systems which could be leveraged upon to drive the initiative. Also, the cohort identified the challenges with the ability of available SMART infrastructure to boost the transformation. Significant among these challenges was poor integration of systems and platforms which resulted in a prevalence of information and knowledge silos. In envisioning the future, the discussants listed their expectations from the transition to SMART environments, especially as it concerned improved productivity in the workplace, security and usability of available networks. This encouraged consensus building on prioritization of different milestones in the design and implementation plan.

The brainstorming workshop boosted a multi-disciplinary user-led design of the SMART campus through the provision of an enabling platform for not just eliciting information about user preferences and expectations (user-centrism) but also allowing users to participate in the design of the SMART Campus initiative at the user. The advantages witnessed therein are like those professed elsewhere- see Muller (2003), Dalsgaard (2012), Kübler et al. (2014). Discussants were also apportioned roles in the implementation plan which evolved out of that workshop. These roles have subsequently culminated into the identification of capstone projects at the university which are meant to serve as harbingers of the SMART Campus. These projects include the SMART Farm, SMART Building, SMART Access/Mobility, etc. Yet, the absence of external stakeholders during the workshop was considered a major limitation of the session. The decision of the authors to confine participation to only internal stakeholders was described as faulty by discussants as the university's role in societal transformation implied the need for external stakeholders to be identified as users. This is not new as Bjögvinnsson et al. (2012) in their study, describe the tendency of PD facilitators to focus only on projects with identifiable users as a drawback of the process. They assert the need to move away from actual use to envisioned use during this process.

## 5. Conclusion

This study set out to understudy and report on the utility of a user-centric participatory design methodology in the design of a SMART campus at an SAUoT. The study was considered imperative as cases of user apathy towards Smart technologies on university campuses are increasingly being reported. Critical among the reasons deduced for this apathy was the non-incorporation of user perspectives during the design process. To avoid such issues at SAUoT-a university that is at the initial stages of transforming into a SMART campus, the authors attempted to explore the utility of a PD approach to eliciting their views and shaping the decision-making process for implementation with such views. Findings from the study indicate that whereas user-centric PD approaches served as a veritable platform for achieving consensus among various stakeholders, it also had its pitfalls. Despite some of the pitfalls elucidated in the study, the use of the user-centric PD in product design activities, such as the case in the SAUoT scenario, holds positive implications for stemming burgeoning levels of user apathy for digital solutions associated with the SMART campus initiative.

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## URBAN ECOLOGY



# AUSTRALIA'S URBAN BIODIVERSITY: HOW IS ADAPTIVE GOVERNANCE INFLUENCING LAND-USE POLICY?

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## Summary

Green space in cities is valuable for improving the quality of life of urban residents. This occurs through the provision of ecosystem services within areas of open space. Biodiversity plays an important role in enhancing the resilience of urban ecosystems, ensuring the continued supply of ecosystem services.

Urban changes in Australia are expected to result in significant changes in urban biodiversity. Climate change is one factor considered likely to exacerbate many existing urban threats to biodiversity. Where cities are located in areas of high conservation significance, such as Melbourne's temperate grassland communities, these rare and threatened habitats are particularly vulnerable.

Biodiversity planning policy in Australia largely focuses on the retention of existing areas of high native biodiversity. While a focus on retaining existing native biodiversity is important, a sole reliance on this approach likely results in inflexibility when dealing with uncertain urban changes. This paper questions whether land-use planning policy in Australia has due consideration in addressing the uncertain threat posed by urban changes such as climate change.

The paper investigates current biodiversity land-use planning policy in Melbourne and Sydney through the lens of contemporary sustainability and resilience theory. The paper uses an analytical framework to assess land-use planning policies' adoption of adaptive governance elements. We conclude that, while some policy measures provide for adaptability in the face of uncertainty, more needs to be done to better protect Australia's unique and valuable biodiversity from the unpredictability of urban threats such as climate change.

**Keywords:** Biodiversity, land-use planning, policy, adaptive governance, climate change, resilience

## **1. Introduction and Background**

In the face of urban change, the resilience of urban ecosystems underpins the ongoing provision of biodiversity habitat, as well as quality of life for urban residents. Adaptive governance provides a policy framework that is focused on increasing resilience in the face of uncertainties such as climate change. This research investigates to what extent recent urban biodiversity land-use planning within Australia has incorporated an adaptive governance approach. The paper investigates this question by constructing an assessment framework derived from the key elements of adaptive governance, as outlined in the literature, and applying this framework to the assessment of current land-use planning policies in Melbourne and Sydney.

### **1.1. Biodiversity and ecosystem services**

Throughout history, humanity's success has depended on the health of the environments in which we live. The management of biodiversity, the abundance and variety of genetic traits, species composition, and functional groups within an ecosystem (Müller et al. 2013) are important factors in the ongoing provision of ecosystem services, the benefits humans receive from the environment (Bolund & Hunhammar 1999). These services, whether providing resources, regulating and maintaining ecosystems, or providing cultural opportunities (Harrison et al. 2014; Langemeyer & Gómez-Baggethun 2018) are made more efficient, productive, and stable through enhancing biodiversity, in-turn supporting the humans who rely on them (Cardinale et al. 2012).

As the world increases in population and becomes more urbanised, it is likely that humanity's reliance on ecosystem services will continue to increase (Seto, Güneralp and Hutrya 2012; Bolund & Hunhammar 1999, Wiedmann et al. 2015). Unfortunately, urbanisation has to date occurred at the expense of biodiversity and consequently, the function of ecosystems globally (Seto, Güneralp and Hutrya 2012; Hoorneweg et al. 2016). For example, this has been seen in Australia, where Melbourne's urban expansion has resulted in significant loss of temperate grassland communities and the species that rely on them (Ives et al. 2013). However, cities are not 'unnatural' places, with urban environments providing many opportunities for the conservation and enhancement of biodiversity and ecosystem-services (Ives et al. 2016). To ensure an appropriate quality of life for the world's growing urban population, it is increasingly important that planning policy prioritises the provision of ecosystem services through policy that maximises biodiversity within cities (Guo et al. 2010).

### **1.2. The influence of urban changes and uncertainty**

Urban biodiversity faces significant challenges due to urban changes such as expansion and fragmentation processes (Borgström et al. 2006), and environmental changes. Climate change is one such change which is anticipated to have severe and uncertain impacts on urban biodiversity and the provision of ecosystem services (Coffey & Wescott 2010). This is largely through uncertain developments, such as increasing likelihood of extreme heat events and significant uncertainty regarding future rainfall patterns (Reisinger et al. 2014; Roggema 2016), where the conditions required to retain healthy ecosystems are being altered with a changing climate (Root et al. 2003; Kendal 2011). This has been compounded with a history of inappropriate urban growth and habitat loss, resulting in increasingly fragile urban ecosystems, as seen by the higher proportion of threatened species existing in cities compared to non-urban environments (Ives et al. 2013).

Biodiversity both provides resilience to the uncertainty of climate change through the increased stability of ecosystem service (Cardinale et al. 2012), while also becoming increasingly vulnerable to it (Root et al. 2003). As such, urban biodiversity both protects and needs to be protected in the face of a changing climate. In a climate change future, where social-ecological systems are expected to become less predictable (Roggema 2016), retaining biodiversity for the ongoing provision of ecosystem services is vital to assist in human and non-human adaptation (Green et al. 2016b).



### **1.3. Adaptive governance**

When managing the preservation and enhancement of urban biodiversity in an uncertain future, adaptive governance has been proposed as a policy framework for improving and adapting policy mechanisms to address uncertainty and changing conditions (Olsson et al. 2006). As it is impossible to fully predict future social-ecological changes due to the constant flux of social and ecological variables (Tyre and Michaels 2011), dynamic adaptive governance structures are designed to allow for and utilise disturbances to build knowledge and capacity for responding to future uncertainty (Roggema 2016; Folke et al. 2005). As such, this flexible approach has been shown to result in improved environmental outcomes for the management of biodiversity and the provision of ecosystem services in an unpredictable system (Kenward et al. 2011; Olsson et al. 2006; Gunderson et al. 2016; Chaffin et al. 2016).

A review of the literature has identified the core elements of adaptive governance. Firstly, adaptive governance encourages learning through innovation and experimentation, requiring the ongoing iteration of policy through monitoring and feedback cycles (Karkkainen 2008; Folke et al. 2005; Green et al. 2016a; Tyre and Michaels 2011). Secondly, adaptive governance encourages a nested governance hierarchy, with leadership coming from central government bodies that provide vision and meaning for action amongst the wider stakeholders. This in turn empowers local and non-government bodies to undertake management and monitoring activities with a level of autonomy (Folke et al. 2005; Green et al. 2016a; Evans 2011; Tyre and Michaels 2011; Roggema 2017). Additionally, adaptive governance requires an increased involvement of stakeholders in creating policy, requiring significant collaboration by non-government bodies (Green et al. 2016a; Heller & Zavaleta 2009; Roggema 2017). Thirdly, adaptive governance relies on institutional networks to be established, connecting all bodies involved in the governance of biodiversity assets, from national government bodies through to local and non-government entities. This is achieved through the use of bridging organisations, where an impartial actor, not directly related to implementing biodiversity policy, acts as a facilitator between different governance bodies (Green et al. 2015; Folke et al. 2005), sharing knowledge evenly throughout the network to build capacity of all governance bodies (Green et al. 2016a; Green et al. 2015; Folke et al. 2005). The existence of a modest overlap in the responsibilities of governance bodies prevents management duties being unfulfilled and allows for the shifting of governance responsibilities and spreading of risk should alternative actions be required (Folke et al. 2005).

### **1.4. The Australian and international context**

While methods of biodiversity land-use planning in Australia have to date largely not followed an adaptive governance framework, biodiversity management globally is increasingly adopting alternative planning approaches. In Australia, biodiversity policies have largely focused on the protection of native and threatened flora and fauna within a defined protection area, aiming to retain existing environmental conditions and preventing further degradation and loss of native species (Borgström 2018; Erixon, Borgström & Andersson 2013; Barr et al. 2016). This demonstrates a static governance approach, which seeks to fix a disturbance event and return a system to its pre-disturbed state (Roggema 2017). This approach fails to build resilience in the face of a dynamic environmental context, where the underlying ecological conditions required for the persistence of an ecosystem change (Folke et al. 2004). While a static governance approach has dominated biodiversity policy-making approaches, there is a growing trend of alternative planning approaches, such as the rise of eco-urbanism and nature-based solutions (Duvall, Lennon & Scott 2017). There is growing research interest as to the extent that biodiversity planning within Australia has adopted these changes (Byrne, Sipe & Dodson 2014). As such, this paper seeks to determine whether recent biodiversity land-use planning policy within Australia has incorporated a more dynamic approach such as the adaptive governance approach.

## 2. Method

We used a case study approach to assess how current biodiversity land-use planning within Australia incorporates adaptive governance elements. We selected two policy case-studies: The Greater Sydney Commission's Regional and District Plans (GSC), and the Melbourne Strategic Assessment Program (MSA). The GSC and MSA were selected as they are significant planning policies which guide land-use planning and urban development within Sydney and Melbourne, the two fastest growing cities in Australia (ABS 2018). The policies provide the overarching definitions for the structure and design of management activities. The substantial growth and urbanisation within these cities is likely to significantly impact biodiversity outcomes (Ives et al. 2013; McDonald, Marcotullio and Güneralp 2013). As such, evaluating the measures taken by these cities to address these issues was considered valuable.

The documents analysed for the GSC case study included the Regional Plan, which set the overarching policy direction, and the four District Plans, which applied the policy direction to locally relevant information (GSC 2018). The MSA policy documents included the Program Report, which outlines the MSA and details how it will be implemented (DPCD 2009), and the Biodiversity Conservation Strategy (BCS), which provides further detail on the management of important biodiversity areas (DEPI 2013). While there are many documents within the MSA, these two most thoroughly outline the objectives and actions of the program.

To investigate how the case study policies utilise adaptive governance in responding to future climate uncertainties, an assessment framework was developed. It brings together the key elements of adaptive governance identified in the previous section (shown in Table 1). The analysis did not focus on each policy's biodiversity planning merit, instead focusing on how the policies address adaptive governance.

*Table 1 Policy analysis framework – adaptive governance (adapted from Folke et al. 2005 and others as noted in previous section).*

1. A focus on learning through experimentation and feeding lessons back into policy	<ul style="list-style-type: none"> <li>a. Experimentation and innovation encouraged in policy</li> <li>b. Models and initial understandings are treated as provisional and to be replaced by learned knowledge</li> <li>c. Provision for careful monitoring included</li> <li>d. Findings feed back into policy</li> </ul>
2. A reliance on non-government and local government actors, and networks to undertake implementation	<ul style="list-style-type: none"> <li>a. Hierarchy of governance responsibility: <ul style="list-style-type: none"> <li>i. State provides vision and meaning for action</li> <li>ii. On-ground management and monitoring undertaken by local government</li> </ul> </li> <li>b. Policy builds capacity for management and monitoring to be undertaken by non-government bodies</li> <li>c. Provision for local and non-government bodies to act autonomously in designing implementation activities</li> <li>d. All stakeholders are significantly involved in creation and review of policy</li> </ul>
3. Vertically and horizontally interconnected systems of governance	<ul style="list-style-type: none"> <li>a. Use of bridging organisations</li> <li>b. Mechanisms for sharing knowledge between all levels of governance</li> <li>c. Modest overlap in policy and responsibility</li> </ul>

We used the adaptive governance analysis framework to assess elements that directly related to the biodiversity policy domain of each document. Content was selected due to its use of biodiversity-related terms (biodiversity, ecosystem, habitat, flora, fauna). Policy areas that weren't directly related to biodiversity planning were outside the scope of this analysis. For example, the provision of public open space for recreational purposes or the social impacts of climate change detailed in the GSC plans were excluded from the assessment, as they were considered insufficiently linked to biodiversity planning.

### **3. Results**

This section presents the findings of our analysis of how adaptive governance is addressed within the MSA and the GSC policies. The three key elements of the analysis framework are presented separately. The extent to which the two case studies address each of the elements are presented, and findings summarised in the following tables. The results will then be further discussed in the following section to explore how biodiversity land-use planning within each policy reflects or adopts adaptive governance principles.

#### **3.1. Element 1 – Learning through experimentation and feeding learning back into policy**

Both policies demonstrated elements of experimentation, though these were limited to revising existing actions (Table 2). The MSA's Adaptive Management component provided an elaborate process of experimentation, learning, and feedback, leading to changes in the way conservation outcomes were achieved. The GSC policy included strategic content relating to monitoring and feedback; however, this was not followed with operational content such as actions indicating how policy will be refined. The elements of experimentation didn't extend to iterations of the policy itself, with objectives and conservation outcomes largely unable to be modified. One exception of this is within the MSA program where conservation outcomes were able to be amended if "*...the outcomes are agreed to be technically improbable*" (pg. 47 DPCD 2009).

#### **3.2. Element 2: Non-government and local government actors and networks for implementation**

The policies demonstrated marginal involvement of non-government bodies. The GSC policy provided several examples of building capacity and autonomy for local government bodies to undertake actions outlined in the policy, predominantly within the Green Grid project where local governments were identified as the lead agency to operationalise the project (Table 2). The MSA program provided little capacity and autonomy to local governments. Both policies demonstrated a submission and feedback process in-line with traditional consultation practices (Table 2). There was no evidence found of a more robust collaborative involvement of stakeholders during the creation and review of the policies.

*Table 2 Element 1 Results*

Framework Section	Melbourne Strategic Assessment	Greater Sydney Commission
1.a – Experimentation and innovation encouraged in policy?	Adaptive management process outlined in the policy addressed through the inclusion of progressive iteration and experimentation.	Establishment of a Green Grid includes elements of progressive iteration.
1.b – Models and initial understandings are treated as provisional and to be replaced by learned knowledge?	Multiple examples of incomplete information, at times utilising formal models, being replaced by learned knowledge.	Objective 40 of the Regional Plan states: “Plans refined by monitoring and reporting” (GSC 2018). Actions relating to the refinement of the plans were not found.
1.c – Provision for careful monitoring included?	Monitoring processes are widely detailed throughout both MSA policy documents. Monitoring is divided into two parts. Firstly, monitoring is intended to “ensure compliance with the endorsed program” (DPCD 2009). Secondly, adaptive management component of the policy is intended to “... monitor whether the outcomes envisaged for each matter of national environmental significance is being effectively achieved...” in the face of “... changing circumstances and procedures and/or new information relating to matters of national environmental significance” (DPCD 2009).	Monitoring is often referenced within the GSC policy with the principal intention to identify abnormalities in the implementation of the policy and to assist future decision making to ensure the initial objectives and actions of the policy are achieved. Actions relating to this include the development of performance indicators relevant to each Council’s context to assess the implementation of the policy.
1.d – Findings feed back into policy?	The MSA’s focus on adaptive management creates many avenues to feed learnings back into policy. Firstly, through changes to management practices to achieve the stated conservation outcomes. Secondly, to amend these outcomes if they are deemed “...not achieved or are unlikely to be achieved” (DPCD 2009).	Learnings not fed back into policy but intended to be used to influence future decision making to achieve policy objectives. Actions relating to the delivery of the Green Grid are intended to be progressively refined from learnings gained through the delivery of past Green Grid projects.
2.a – Hierarchy of governance responsibility i. State provides vision and meaning for action ii. Operationalization of actions undertaken by local government	i. The Program Report, through outlining outcomes and activities to achieve outcomes, provides a detailed vision and meaning for action. ii. Local government bodies are included in a marginal number of conservation actions compared to state government bodies.	i. The GSC policies provide significant vision and meaning for action to be undertaken. ii. Local government plays a significant role in undertaking actions outlined in the policy. Local council is the lead organisation for certain actions such as the delivery of the Green Grid.
2.b – Policy builds capacity for operationalization of actions to be undertaken by non-government bodies	Minimal involvement of non-government bodies in undertaking actions outlined in the policy. Land-owners wanting to maintain land ownership after urban development need to enter into an agreement with the Victorian government requiring them to undertake management activities.	Minimal involvement of non-government bodies in undertaking actions outlined in policy. Regional Plan sets a vision for incorporating non-government action to build ecological resilience. This was largely absent in the policy’s actions. A single action strategically incentivises land-owners within rural areas to protect and manage biodiversity assets through the offset market.
2.c – Provision for local and non-government bodies to act autonomously	Local government has limited autonomy. Most actions undertaken by local government involve implementing plans and statutory requirements prepared by state government bodies.	Local Government is provided autonomy as the lead actor in delivering the Green Grid action. Local Governments also have autonomy in reviewing local environmental plans to incorporate the actions outlined in the District Plans.
3.a – Use of bridging organisations	No evidence of bridging organisations.	No evidence of bridging organisations.
3.b – Mechanisms for sharing knowledge between all levels of governance	Monitoring and reporting obligations were the only mechanism for sharing knowledge between different governance bodies.	Monitoring and reporting obligations were the only mechanisms for sharing knowledge between different governance bodies.
3.c – Modest overlap in policy and responsibility	Federal government has delegated authority to the Victorian government. Victorian and local government bodies have some overlap through collaborating on preparation of documents associated with greenfield planning. No overlap between government and non-government bodies.	The delivery of the Green Grid demonstrates overlap between State and local government bodies

### 3.3. Element 3 – Vertically and horizontally interconnected systems of governance

Both the MSA and GSC demonstrated limited vertical and horizontal interconnections between governance bodies. The GSC demonstrated slightly higher levels of interconnectedness through the Green Grid implementation, a series of interconnected but independent projects, able to be implemented by all levels of government (Table 2). While the GSC demonstrates some capacity to act as a bridging organisation between different levels of government, this is heavily constrained as the GSC exercises authority over local government authorities through its role in overseeing their planning scheme amendments.

## 4. 4. Discussion

The analysis of the two strategies demonstrates limited adaptive governance capacity. While both strategies included some elements, there is significant potential to increase the involvement of local and non-government bodies in decision making, and increase incorporation of feedback loops and policy learning to improve implementation and outcomes. The results of analysis highlight key opportunities for increasing adaptive governance in biodiversity planning approaches. The discussion concludes by reflecting on the analysis framework and its efficacy for policy analysis.

### 4.1. Learning and feedbacks

Neither strategy demonstrated substantial elements of policy experimentation to influence key policy objectives, limiting the adaptability of both policies to future climate uncertainties. Within the MSA and GSC, capacity for iteration was only found to extend to actions already under the policies' objectives. This is either through rectifying mistargeted policy application, or, as seen in the MSA, undertaking experimentation of management actions to better achieve the stated objectives. The MSA's approach exhibits some adaptive governance elements which enhance the policy's ability to dynamically respond to uncertain disturbances (Karkkainen 2008; Folke et al. 2005). However, as experimentation only applies to modifying management actions within rigid objectives ('Feedback loop A', Figure 1) rather than revising the underlying policy objectives ('Feedback loop B', Figure 1), this possibly limits the use of adaptive and innovative policy solutions in the face of future and uncertain disturbances. Even when the MSA includes details regarding the ability to amend core objectives, this only applies to objectives that are considered unachieved or unachievable (DPCD 2009). This approach focuses on reducing failure instead of looking at opportunities for innovation and improvement through establishing new objectives or amending objectives in a lateral direction (Green et al. 2016a). As such, the ability for either policy to fully respond to a significant and unpredictable disturbance is reduced (Tyre & Michaels 2011; Green et al. 2016a).

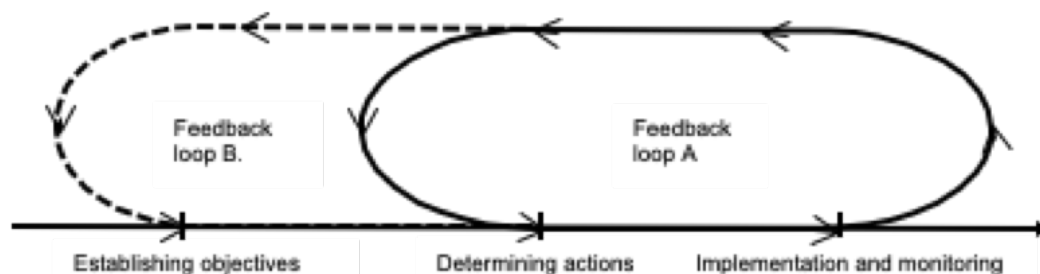


Figure 1 Policy feedback loops



## **4.2. Reliance on local and non-government actors**

Under-reliance on local and non-government bodies demonstrates a missed opportunity for both the GSC and MSA policies, by not incorporating a dynamic biodiversity land-use planning approach to the extent possible. While both policies demonstrate a significant level of strategic content, creating a vision and meaning for action critical in guiding other governance bodies (Folke et al. 2005), the operational components of both policies demonstrate an overreliance on state agencies either directly undertaking actions, or heavily influencing actions to be undertaken by local bodies. Neither policy takes a robust approach towards collaborating or building capacity with non-government groups to undertake actions or create and review the policy. Consultation processes are limited to standard submission and feedback processes and do not sufficiently incorporate more meaningful forms of engagement (Green et al. 2015). These findings are consistent with research on public participation with climate change adaptation policy (Sarzynski 2015; Green et al. 2015). These factors limit ownership and buy-in from local communities, potentially impacting long-term political and public support, while restricting the flow of information critical for generating improved ideas and decision making (Green et al. 2015; Bodin & Crona 2009; Tyre & Michaels 2011).

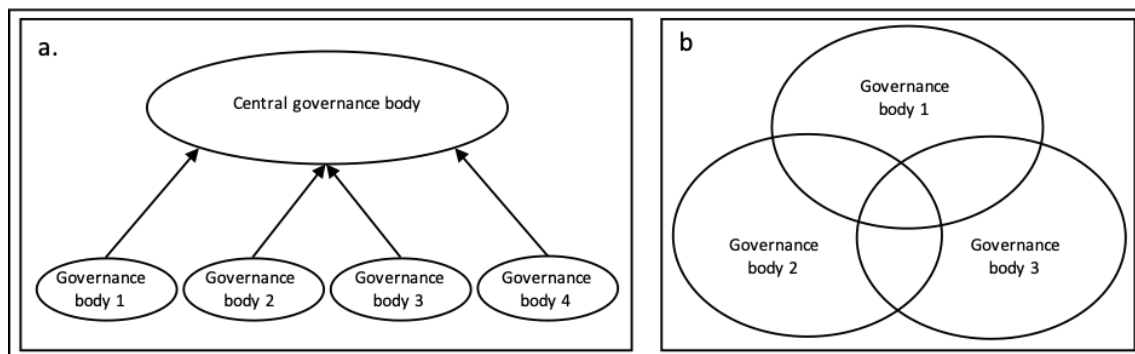
## **4.3. Interconnected governance**

Limited vertical and horizontal interconnectedness reduces each policy's adaptability in the face of uncertainty. The omission of an external bridging organisation, independent from the implementation of the policy, limits the capacity for coordination and information flow between different levels of governance. This in turn impacts the generation of new and innovative ideas to enhance decision making (Green et al. 2015). As there are no mechanisms for knowledge sharing other than highly vertical and structured monitoring and reporting processes, elaborate horizontal and vertical interconnections are not able to develop, impacting the ability for the policies to respond to uncertain disturbances (Green et al. 2016a; Green et al. 2015; Folke et al. 2005).

The MSA demonstrates policy and responsibility overlap through delegated authority from federal government to the Department of Planning and Community Development (now DELWP). While there is collaboration with local government and external state agencies, this is limited in scope and characterised by an unbalanced and centrally concentrated power relationship (Figure 2a). The resulting lack of horizontal overlap between responsibilities of governance bodies as defined within the policy, likely results in a reduced ability for governance structures to re-organise and respond meaningfully in the face of short-term and long-term disturbances (Folke et al. 2005). The Green Grid program within the GSC policy demonstrated an alternative model of integration and is discussed further below.

## **4.4. The Green Grid: innovation in governance and green space?**

The GSC's Green Grid program demonstrates the greatest potential for adaptive governance within the two policies, including the possibility of improved vertical and horizontal interconnectedness and greater reliance of local and non-government bodies. The delivery of the Green Grid demonstrates overlap between responsibilities and power relationships of the multiple governance bodies (Figure 2b), as individual groups are tasked with implementing independent projects which together contribute to a broader network of green spaces. This arrangement builds capacity and provides autonomy for both state and local bodies, contributing to the Green Grid, in turn generating buy-in from local government and opening up opportunities to access the institutional knowledge held within local Councils (Green et al. 2016a; Roggema 2017). The overlap enhances the ability for individual bodies to change their field of focus to absorb unexpected disturbances, while ensuring the broader green network is maintained through the implementations of different government bodies (Folke et al. 2005). Together these factors may underpin an enhanced ability to respond to uncertainty.



*Figure 2 Responsibility overlap and power relationships: the MSA (a) and GSC's Green Grid program (b)*

While the Green Grid program includes multiple beneficial adaptive governance attributes, there are areas where its adaptive capacity can be further enhanced. Greater involvement of non-government bodies would further enhance on-going public support for biodiversity management (Green et al. 2015). This could be achieved through the inclusion of incentive-based policy tools for private land, an important but underutilised land tenure type within the green network (Goddard, Dougill & Benton 2010; Miller 2008; Feinberg et al. 2015). Additionally, including provision for knowledge sharing through bridging organisations would enhance the collective knowledge pool, improving decision making (Green et al. 2015). Finally, including experimentation of the policy management actions (as demonstrated within the MSA) would allow feedback learning and policy iterations to better adapt to unforeseen disturbances (Folke et al. 2005; Green et al. 2016a).

#### **4.5. Future research directions in adaptive governance**

The method used to assess the MSA and GSC was an appropriate way to assess each policies' consistency with adaptive governance theory. We consider the analysis framework suitable for use in a broad range of policy assessments outside the field of biodiversity planning and climate change. The methodology used was best suited for analysing a small number of policies in a high level of detail. To analyse and compare a broader number and range of policies, a scoring mechanism could be incorporated, quantifying and standardising the assessment results. Incorporating additional elements within the assessment framework, such as key policy attributes: strategic, tactical, operational, and reflexive elements (Bush and Hes 2018; Frantzeskaki and Tilie 2014), would provide greater insights into the transformative areas of each policy and where adaptive governance is most significantly reflected. This would allow for a wider scale assessment of biodiversity land-use policies to determine whether this research's findings are reflected in other Australian jurisdictions' policies.

Additionally, given biodiversity's central role in the provision of ecosystem services, it is vital that policy mechanisms are developed to enhance urban biodiversity. As such, further work should be undertaken to investigate various policy mechanisms and their potential impact on urban biodiversity outcomes.

This research has focused on policy content elements and is predicated on the premise that, in practice, adaptive governance provides a better capacity to respond to uncertainty. While there has been some research in this field (for example Kenward et al. 2011), this area requires further investigation into the practicality of adopting a more dynamic policy framework in a policy making context (Chaffin et al. 2016; Karpouzoglou et al 2016; Orach & Schlüter 2016).

## 5. Conclusion

Urban changes, such as those expected as a result of climate change, are anticipated to have uncertain and severe impacts on biodiversity in cities, likely impacting provision of ecosystem services and the quality of life for those living in urban environments. Adaptive governance provides a useful policy framework to enhance a system's ability to respond to uncertain disturbances and would benefit the resilience of biodiversity planning in the face of climate change. This paper has investigated two Australian land-use policies to determine to what extent Australian urban biodiversity planning adopts an adaptive governance approach. The research found that, while the two policies demonstrated some elements of adaptive governance, the overall inclusion of adaptive governance elements is limited. This likely leads to an increased vulnerability of Melbourne and Sydney's biodiversity values in the face of unpredictable disturbances associated with climate change. This paper contributes to the understanding of Australian biodiversity policies' adaptive capacity and presents an analysis framework suitable for assessing the adoption of adaptive governance within and beyond biodiversity land-use policy.

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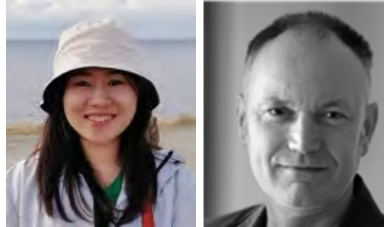
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# MAPPING THE PERMEABILITY OF URBAN LANDSCAPES AS STEPPING STONES FOR FOREST MIGRATION

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## Summary

Large-scale urbanisation has become a significant barrier to the migration of trees, which is being exacerbated by accelerated climate change. Maintaining and increasing landscape permeability is expected to be an effective strategy to facilitate the process of forest migration through the city. This study develops a new methodology to map the permeability of urban landscapes as stepping stones from the perspective of seed dispersal. Since seed dispersal agents experience their landscapes as hierarchical mosaics of patches, two spatial scales—habitat and home-range scales—are simultaneously considered in the study. The proposed method combines a least-cost path model and a graph theory-based approach. The least-cost path model is applied to map the potential movements of dispersal agents, based on which two graph theory-based indices—the probability of connectivity index and the integral index of connectivity—are used to quantify the accessibility of the landscape at habitat and home-range scales, respectively. This method is demonstrated by a case study in the Greater Manchester area, UK. Eurasian jay, Eurasian siskin, coal tit and grey squirrel are selected as the main dispersal agents in the study area. The results provide a comparison of the landscape permeability maps generated from different dispersal agents and identify key areas likely to facilitate the process of forest migration through Greater Manchester. Recommendations regarding landscape design and management for improving permeability are also discussed.

**Keywords:** forest migration, permeability, stepping stones, seed dispersal, climate change

## 1. Introduction

As a response to global climate change, many tree species are moving to higher latitudes or elevations with more suitable climate conditions (Hampe, 2011). However, increased urbanisation means that they will have to overcome substantial anthropogenic barriers (e.g., agricultural land, buildings, and highways), which may impede their ability to keep pace with the rapidly changing climate or even modify their migration patterns (Tomiolo and Ward, 2018). Within this context, assessing and increasing the permeability of urban landscapes is expected to be an effective strategy to facilitate this ecological process. Here, “permeability” refers to the capacity of a landscape to support species’ movements.

Several methods have been proposed for assessing landscape permeability to species movements. Most of them focused on specific landscape features related to habitat quality or human modification, for example, land cover type, road density, and housing density (e.g., Gray et al., 2016, Littlefield et al., 2017). Other studies estimated permeability by modelling or experiments (Shimazaki et al., 2016, Gastón et al., 2016, Cline et al., 2014, Caryl et al., 2013). Additionally, Anderson et al. (2015) utilised genetic data to infer the permeability of landscape features to the movement of chipmunks.

Although these methods provide spatially explicit estimates of landscape permeability, they may be less useful for the study of forest migration. On one hand, they focus on the movements of active dispersers (animals) and may be inadequate for tree species that depend on passive seed dispersal. Successful forest migration depends on effective seed dispersal between forest fragments, which is affected by the ways in which seed dispersal agents move and interact with the landscape (Clobert et al., 2012). Therefore, the movement of dispersal agents should be considered in the efforts to assess landscape permeability. Moreover, since different dispersal agents may respond very differently to the landscape (Saunders et al., 1991), a sound understanding of their dispersal abilities is also required. On the other hand, in human-dominated environments where landscape patches are small and highly isolated, the dominant function of the landscape is acting as a series of stepping stones (functional connections) that form dispersal paths and transmit ecological flows, rather than providing habitats (Boscolo and Metzger, 2011). In this respect, the spatial pattern of a landscape might be of great importance to the migration of trees because it directly influences the accessibility of the landscape for dispersal agents, whereas landscape features related to habitat quality or human modification might be of limited value.

Accordingly, this study proposes a new method for mapping landscape permeability based on a measure of landscape accessibility for dispersal agents, assuming that landscapes with higher accessibility might have a higher probability of seed dispersal and therefore are more permeable to the migration of trees. Since the focus of this study is on seed dispersal, the behaviour of dispersal agents is mainly considered; other biotic or abiotic factors such as soil type, habitat quality, plant diversity, or interspecific competition are excluded. In addition, to account for the movements of animals at multiple scales, the habitat and home-range scales of dispersal agents are simultaneously considered in this study. The proposed method combines a least-cost path (LCP) model and a graph theory-based approach. The LCP model is applied to map potential movement pathways of dispersal agents, based on which graph theory-based indices are used to quantify landscape accessibility. The Greater Manchester area, UK, is used as a case study to demonstrate this mapping method.

## 2. Method

### 2.1. Data

We use the 2010 topography layer in the Ordnance Survey Master Map as the land-cover data, which gives a comprehensive view of 13 land-cover types in the study area (<http://digimap.edina>).

ac.uk/). At the same time, to compare the degree of permeability with the intensity of human modification of the landscape, the greenspace layer (with detailed land use categories which captures the major aspects of human modification) in the Ordnance Survey Master Map is used to classify urban landscapes as (1) natural, with a low intensity of human modification (e.g. natural woodland); (2) semi-natural, with an intermediate intensity of human modification (e.g. camping park, cemetery, golf course, public park or garden); and (3) manmade, with a high intensity of human modification (e.g. transport, bowling green, sports facility).

According to a research by the Forestry Commission (<https://www.forestry.gov.uk/fr/infd-837f9j>), there are a number of tree species that need to migrate through Greater Manchester in this century, including European larch (*Larix decidua*), Sitka spruce (*Picea sitchensis*), sweet chestnut (*Castanea sativa*), lodgepole pine (*Pinus contorta*), Scots pine (*Pinus sylvestris*), sessile oak (*Quercus petraea*), and beech (*Fagus*). Most of them are dispersed by frugivorous birds. The acorns and nuts of lodgepole pine, sweet chestnut, sessile oak, beech, and Scots pine are moved by Eurasian jay (*Garrulus glandarius*), while Eurasian siskin (*Spinus spinus*) and coal tit (*Periparus ater*) are the principal dispersal agents for European larch and Sitka spruce. Besides, the grey squirrel (*Sciurus carolinensis*) is also considered as a main dispersal agent in the study area, given that this small mammal is highly mobile and can disperse chestnut and acorn readily through fragmented urban landscapes (Rushton et al., 1997).

*Table 1 The key parameters of seed dispersal agents (Conway and Fuller, 2011, Go'mez, 2003, Dyer, 1995, De Montis et al., 2016, Rolando, 1998, Nupp and Swihart, 2000, Pascual et al., 2014, Senar et al., 1992, Sellers, 2011).*

Dispersal Agent	Habitat Size	Home-range Size	Daily dispersal Distance	Long-distance Dispersal	Body Mass
Eurasian Jay	≥ 4 ha	≥ 10.7 ha	≤ 1 km	1 km -5 km	161.7 g
Eurasian Siskin	≥ 4 ha	≥ 8 ha	≤ 0.5 km	0.5 km - 3 km	13.8 g
Coal Tit	≥ 1 ha	≥ 3 ha	≤ 0.4 km	0.4 km - 5 km	9.25 g
Grey Squirrel	≥ 0.0625 ha	≥ 0.5 ha	≤ 0.15 km	0.15 km - 2 km	510 g

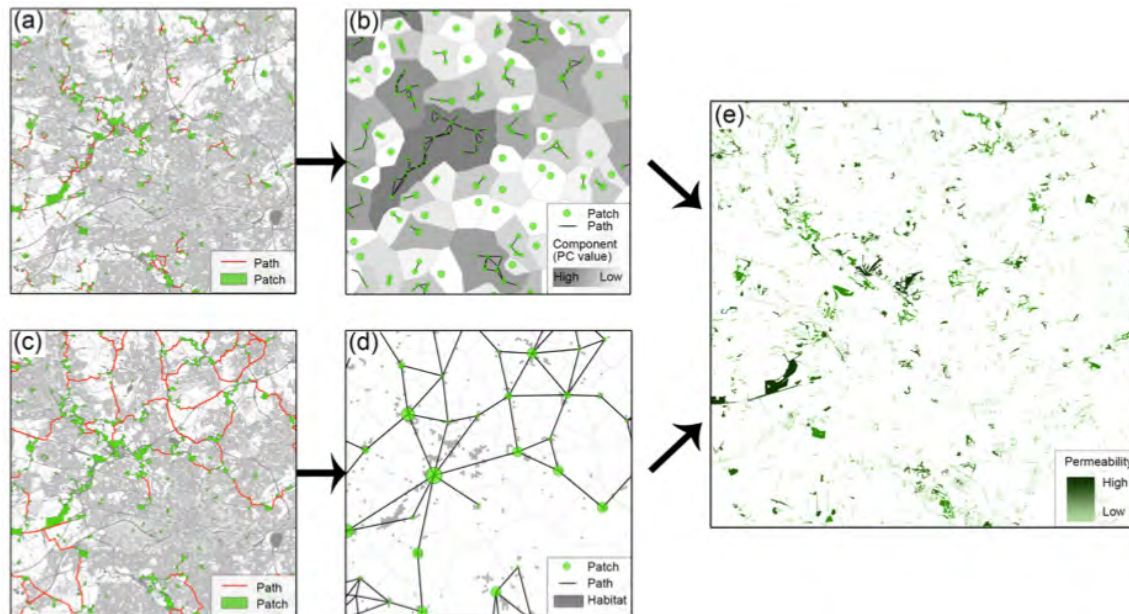
The spatial records of the four dispersal agents are obtained from the UK's NBN Atlas. For Eurasian jay and grey squirrel, their dispersal distances, are obtained from the literature, as well as other key parameters (see Table 1). However, for the remaining two species, a direct observation of their daily dispersal is not available. In this study, we use the model developed by Sutherland et al. (2000) to estimate their daily dispersal distances based on their body masses. The minimum home-range sizes of these species are then derived from the estimate of dispersal distances (Jenkins et al., 2007).

## 2.2. Landscape Accessibility at Habitat Scale

The assessment of landscape accessibility starts from an identification of landscape networks for dispersal agents. Land-cover types are reclassified as either habitat or non-habitat area for dispersal agents. For the aim of this study, broadleaved, coniferous and mixed forests are selected as suitable for habitat. After that, we use the minimum habitat size (see Table 1) as grain size to change the resolution of the habitat map for each dispersal agent, aggregating small, scattered habitat fragments into large, contiguous habitat patches.

Since the dispersal probability between habitats is inversely related to the least-cost distance between them (de la Pena-Domene et al., 2016), a least-cost path (LCP) model is applied to map the paths between habitats (as shown in Figure 1a). The LCP model uses a raster-based optimisation algorithm to identify the optimum path between patches, in terms of cumulative land-cover resistance (Watts et al., 2010). In the study of Greater Manchester, the resistance values of individual land-cover types are obtained by habitat suitability modelling using the MaxEnt software (Phillips et al., 2017). The spatial records of each species and the land-cover map are

used as input data. For the following analysis of accessibility, each set of interconnected patches is defined as a component (an isolated patch makes up a component itself).



*Figure 1 Illustration of The Mapping Method. (a) Identify Habitat Networks, (b) Evaluate Landscape Accessibility at Habitat Scale, (c) Identify Home-range Network, (d) Evaluate Landscape Accessibility at Home-range Scale, and (e) Assess Landscape Permeability.*

A graph theory-based index, probability of connectivity (PC) (Saura and Pascual-Hortal, 2007) is used to transform the habitat network into a node-link graph and calculate the accessibility of each habitat (Figure 1b). The PC index is a probabilistic index that integrates both patch area and inter-patch distance in one measure. It has been shown to relate well to actual species movement and occurrence patterns (Awade et al., 2011). We evaluate the accessibility of each habitat patch based on a quantification of its contribution to the overall PC value of the component that the patch belongs to, using the Graphab software.

### 2.3. Landscape Accessibility at Home-range Scale

The home range of an animal is composed of a cluster of connected habitat patches, which could support its minimum resource requirement. Different home ranges are connected by the paths of long-distance dispersal, using the LCP model (Figure 1c). The distance threshold of the paths is determined by the maximum distance that the animal could move in its search for new home ranges.

At home-range scale, the integral index of connectivity (IIC) (Pascual-Hortal and Saura, 2006) is applied for the assessment of landscape accessibility rather than the PC index, because IIC has been shown to better relate to the functional connectivity among home ranges (Decout et al., 2012). The accessibility of each home range is evaluated by a measurement of its contribution to the overall connectivity (IIC value) of the landscape, using the Graphab software (Figure 1d).

### 2.4. Landscape Permeability to Forest Migration

We calculate the permeability of each habitat area by multiplying the accessibility results of section 2.2 and 2.3, given the interactions between landscapes at different scales (Figure 1e). Habitat areas are then classified into three categories, high-, medium-, and low-permeable, using



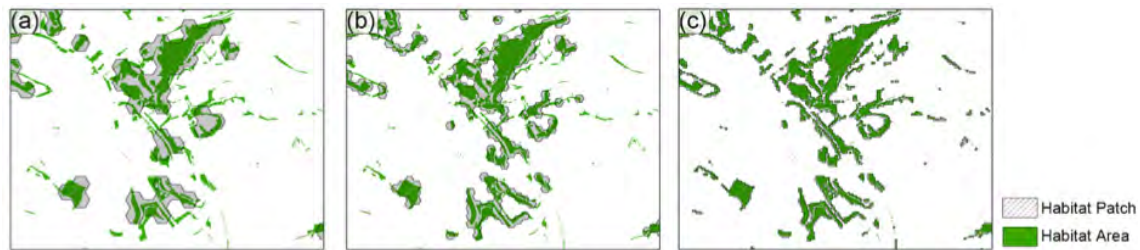
the method of natural breaks in ArcGIS. Finally, we combine the resulting permeability map with the map of human modification to identify areas for improvement.

### 3. Results

As shown in Table 2 and Figure 2, the aggregation of habitat areas yields 498, 498, 1677, and 7240 habitat patches for Eurasian jays, Eurasian siskins, coal tits, and grey squirrels, respectively. After that, the potential paths between habitats are identified using the LCP model, based on the land-cover resistances values derived from the habitat suitability modelling (Table 3). The connected habitats are then divided into 91, 171, 248, and 1255 home ranges for the four dispersal agents, respectively.

*Table 2 Landscape Elements for Dispersal Agents*

Scale	Number	Eurasian Jay	Eurasian Siskin	Coal Tit	Grey Squirrel
Habitat	Patch	498	498	1677	7240
	Path	423	192	1726	6546
	Component	192	347	533	2609
Home-range	Patch	91	171	248	1255
	Path	182	273	1900	7938



*Figure 2 Example of Habitat Patches Identified for Different Dispersal Agents: (a) Eurasian Jays and Siskins, (b) Coal Tits, and (c) Grey Squirrels.*

*Table 3 HIS Scores Obtained from The MaxEnt Software and the Land-cover Resistance Values for The Four Dispersal Agents*

Land Cover Type	Eurasian Jay		Eurasian Siskin		Coal Tit		Grey Squirrel	
	HIS	Resistance	HIS	Resistance	HIS	Resistance	HIS	Resistance
Buildings	0.46	54	0.45	55	0.51	49	N/A	1000
Health	0.43	57	0.45	55	0.43	57	0.2	80
Marsh	0.43	57	0.45	55	0.43	57	0.2	80
Residential	0.47	53	0.58	42	0.61	39	0.71	29
Agricultural	0.4	60	0.45	55	0.39	61	0.3	70
Orchard	0.43	57	0.45	55	0.43	57	0.2	80
Roads	0.69	31	0.45	55	0.43	57	0.63	37
Rock	0.5	50	0.45	55	0.43	57	N/A	1000
Grassland	0.41	59	0.58	42	0.43	57	0.2	80
Scrub	0.67	33	0.57	43	0.57	43	0.37	63
Urban	0.43	57	0.45	55	0.43	57	0.28	72
Water	0.85	15	0.78	22	0.86	14	0.35	65
Woodland	N/A	1	N/A	1	N/A	1	N/A	1

Figure 3 illustrates the relative accessibility of individual habitat and home-range patches. Patches with high values are critical for maintaining landscape connectivity and therefore can be regarded as key stepping stones for seed dispersal. As shown in the figure, for all the four dispersal agents, only a handful of home-range patches are responsible for a disproportionate share of seed dispersal events in the landscape network.

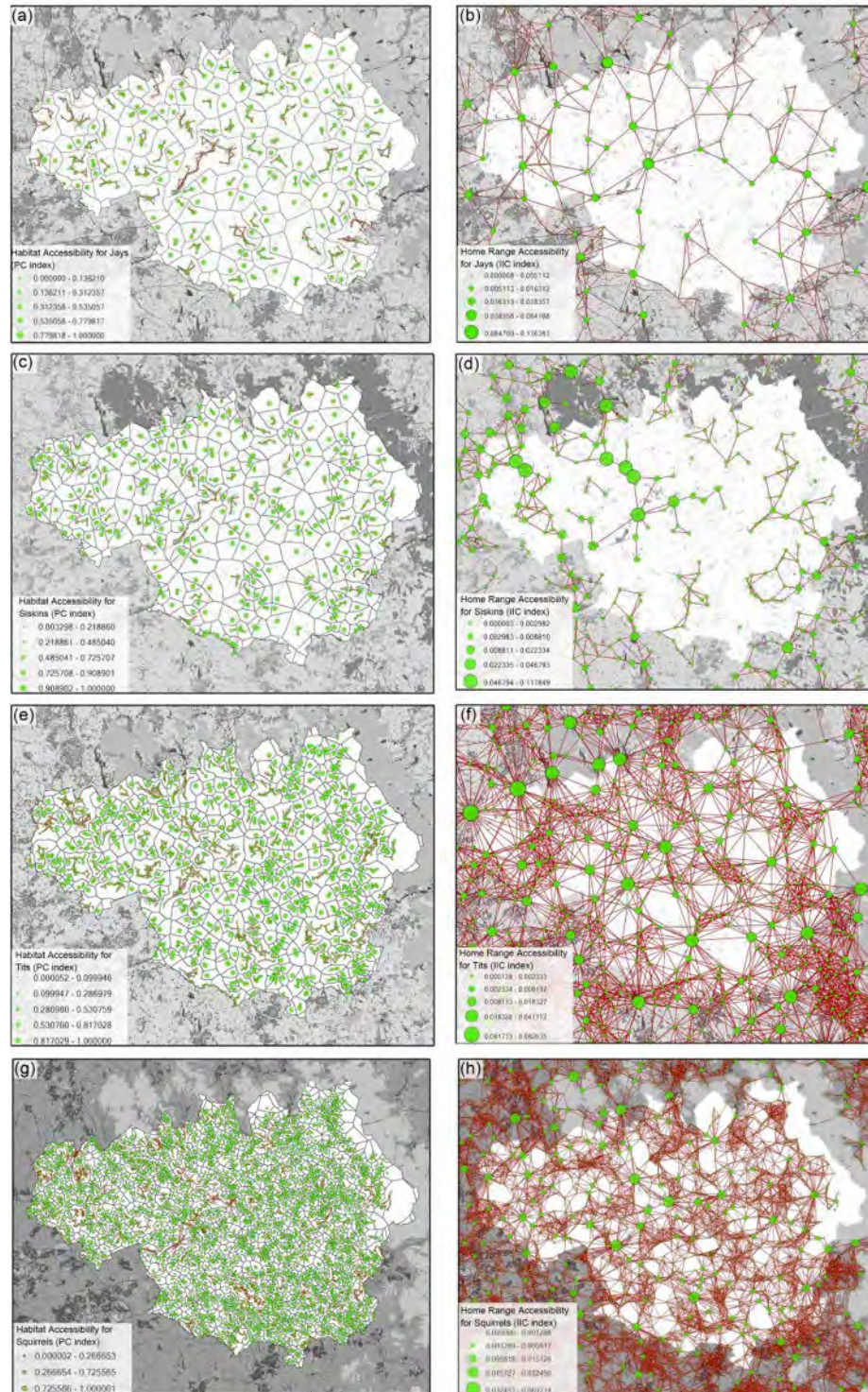


Figure 3 Landscape Accessibility for Dispersal Agents



Table 4 Classification of Landscape Permeability

Permeability	Eurasian Jay	Eurasian Siskin	Coal Tit	Grey Squirrel
High-permeable	0 - 0.0039	0 - 0.0047	0 - 0.0017	0 - 0.0024
Medium-permeable	0.0040 - 0.0135	0.0048 - 0.0212	0.0018 - 0.0081	0.0025 - 0.0108
Low-permeable	0.0136 - 0.0364	0.0213 - 0.0617	0.0082 - 0.0265	0.0109 - 0.0231
Impermeable	N/A	N/A	N/A	N/A

After the calculation of permeability in section 2.4, each habitat area is assigned a value representing its permeability to forest migration, with higher values indicating greater ease of movement. The permeability values are categorised into four classes: high-permeable, medium-permeable, low-permeable, and impermeable. The impermeable class is the areas that are suitable for habitat but cannot be identified as patches for dispersal agents. Table 4 shows the range of permeability values for each class. The percentage of each class regarding both patch number and habitat area is presented in Figure 4. The percentage of habitat patches with high or medium permeability is higher for Eurasian jays and siskins than for the other two dispersal agents. Nevertheless, the total percentage of the high and medium class between the four dispersal agents is not very different, in terms of habitat area. This is because most of the low-permeable and impermeable areas are small patches. Figure 5 shows the spatial distribution of the four permeability classes for different dispersal agents. The differences in spatical distribution indicating that landscape permeability to forest migration is influenced by the dispersal capabilities of local species.



Figure 4 Percentages of the Four Permeability Classes

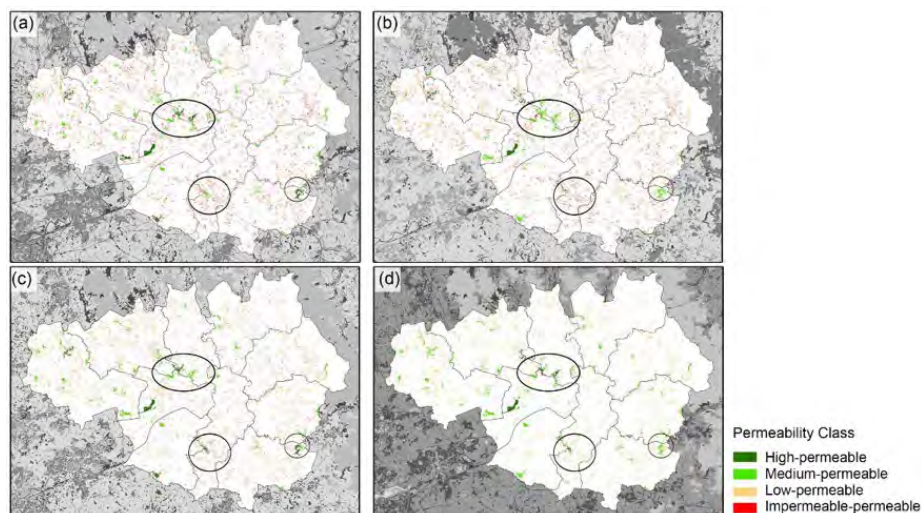


Figure 5 Spatial Distribution of The Four Permeability Classes for (a) Eurasian Jays, (b) Eurasian Siskins, (c) Coal Tits, and (d) Grey Squirrels

We integrate the results from the four dispersal agents to obtain a permeability map of Greater Manchester (Figure 6a). In summary, around 13% of the total habitat area are very permeable to forest migration when all the four dispersal agents are considered, while the areas corresponding to the medium-permeable class account for 24%. Those low-permeable and impermeable areas cover more than 60% of the total habitat area, although most of them (95%) are smaller than 1 ha.

Figure 6 (b) describes the percentages of permeable areas in natural, semi-natural and manmade greenspaces in Greater Manchester. Landscapes showing high- or medium- permeability occupy 30% of natural, 34% of semi-natural, and 19% of manmade greenspaces. These relatively permeable natural and semi-natural greenspaces are very important for forest migration because they can support both seed dispersal and plant establishment, whereas the manmade greenspaces are potential locations where habitat quality should be improved to increase their contributions to forest migration. At the same time, 69% of natural and 65% of semi-natural greenspaces appear low permeable to forest migration, indicating that they are isolated habitats where the permeability could be improved by adding new stepping stones to increase their accessibility.

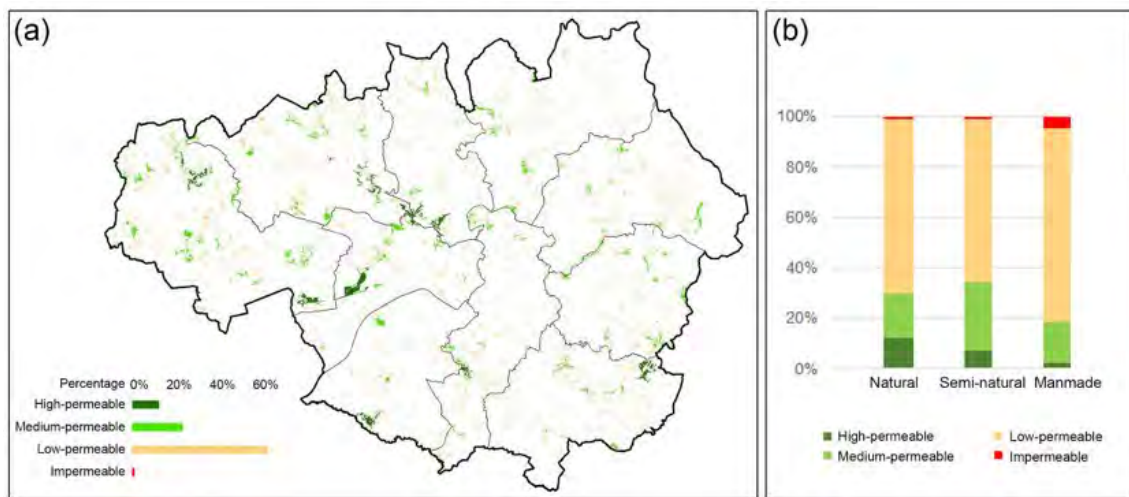


Figure 6 (a) Permeability Map of Greater Manchester Considering Four Dispersal Agents, (b) Percentages of Areas of Each Permeability class in Natural, Semi-natural and Manmade Greenspaces.

#### 4. Conclusion

This study develops a novel method to map the permeability of urban landscapes to forest migration. It combines an LCP model that identifies landscape networks for dispersal agents, and a graph theory-based approach which evaluates landscape accessibility at multiple scales. This allows designers to re-visualise highly modified and fragmented urban landscapes as stepping stones for seed dispersal, which in turn allows for a more piecemeal form of landscape design to have strategic benefit by engaging as part of a larger system.

The proposed method is applied to the case study of the Greater Manchester area, UK. The results identify urban green spaces with the potential to facilitate the climate-driven migration of trees through the city and provide a comparison of the permeability maps generated from different dispersal agents. Moreover, this study combines the map of permeability with the map of human modification to illustrate the application of the proposed method to incorporate other considerations and analytical possibilities. It is believed that this method would be especially important for landscapes where human activity in intense and implementing large continuous reserves is not possible. Future research should explore how to add new patches (through

forestation or restoration programs) in the landscape matrix to favour the movements of dispersal agents and thereby to increase the permeability of urban landscapes to forest migration.

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# POTENTIAL OF TREES TO MITIGATE CLIMATE CHANGE IMPACTS IN A RAILWAY CORRIDOR CASE STUDY IN SYDNEY

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## Summary

Railway corridors as transportation networks cover significant land areas in Sydney Metropolitan region. Many sections contain trees, shrubs and vacant land areas along the railway tracks. Trees are protected in these locations due to restricted access conditions and could act as urban forest banks located close to developments to mitigate climate change impacts. Trees as useful green infrastructure could provide significant environmental, ecological and economic benefits. Limited research has been carried out to measure the contributions of trees in the grey infrastructure facilities such as motorways, landfill sites and railway corridors in cities. Recognising immense prospects of greening these grey infrastructure spaces to provide climate change adaptation is essential.

A railway corridor case study through residential suburbs of Western Sydney and approximately of 11 km long was selected for this project. The objectives of this paper were to determine the existing land use distribution and to measure climate change mitigation potential of trees as carbon storage and sequestration capacities; air pollution reduction capabilities and associated economic benefits in this corridor. This paper modelled tree growth using a scenario-based approach to determine the impacts of increasing tree canopy cover in the case study site.

In this paper, existing land use distribution; potential of carbon storage and sequestration and air pollution reduction capacity and economic costs of current tree canopy cover in the rail corridor case study were measured. These aspects were analysed using Geographic Information Systems (GIS) methods and i-Tree software developed by US Forest Service. Results established that trees provide positive ecosystem services. Revegetating vacant lands with trees on the corridor case study could enhance carbon storage and sequestration and air pollution reduction potential and associated economic values significantly.

Keywords: trees; carbon sequestration; carbon storage; air pollution; green infrastructure

## 1. Introduction and context

Trees can provide multiple benefits in social, environmental, ecological and economic domains. Trees can contribute positively to carbon storage and sequestration, air pollution reduction potential, biodiversity protection, rainfall interception, urban heat island mitigation and building energy savings through shading (USDA Forest Service, 2003; Nowak Greenfield, Hoehn and Lapoint 2013; Donovan and Butry 2010; McPherson and Simpson, 2003). Trees can improve quality of the urban environments, public health including mental health; increasing property values; provide social benefits and support cultural heritage and identity of communities (Jones, Davis, and Bradford 2012; Akbari, 2002). Urban trees in grey infrastructure locations such as motorways, railway corridors and in landfill sites have immense potential to provide positive ecosystem services for human environments. A limited work has been conducted to utilize these benefits of the trees. Railway corridors as transportation networks cover significant land areas in Sydney Metropolitan region. Many sections contain trees, shrubs and vacant land areas along the railway tracks. Trees are protected in these locations due to restricted access conditions and could act as urban forest banks located close to developments to mitigate climate change impacts. Some examples of collaborative efforts to greening the grey infrastructure show interesting outcomes. Two and half kilometres of railway corridor located between Wandsworth Common to Clapham Junction, London, UK were revegetated with woodland planting in a joint project by the forestry organisation, railway department and community organisations (National Urban Forestry Unit, Rail Track, AMEC rail and English Partnerships. 2000). Department of Planning, Transport and Infrastructure (DPTI) in the City of Marion in Adelaide, Australia had conducted a revegetation project to create a biodiversity corridor along the entire Adelaide to Seaford rail line to provide better environmental and ecological performance (City of Marion 2013). Trees as vegetation could enhance the visual and experiential qualities of the rail corridors for the daily train commuters, rail users and communities living in close to these transport lines.

Metropolitan Sydney is networked by rail infrastructure which covers almost 400 kilometres and the corridor vary in width allowing land areas to be integrated at varied locations within the corridor (Blair, Roldan, Ghosh and Yung 2017). A pilot study funded by Transport for NSW (TfNSW) was conducted on a kilometre long north side of the railway corridor between Belmore Station and Lakemba Station on the T3 Bankstown Line in Sydney in 2016 (Blair et al. 2017). This study measured carbon storage, carbon sequestration, and air pollution reduction capacities of existing trees in the case study site using i-Tree Eco methodology. A field survey estimated a total of 158 trees with a tree canopy cover area of 2827m<sup>2</sup>. These trees stored 8488 kg carbon and sequestered 979 kg annually (Blair et al. 2017). A total of 16 different species of trees identified in the corridor and each species provided different carbon storage and sequestration benefits shaped by tree characteristics, growing conditions and tree health. *Casuarina glauca* was the dominant species on the project site, *Acacia parramattensis* had the highest carbon sequestration potential per tree, equal to 21 kg/year. *Cinnamomum camphora* had the highest annual carbon storage potential per tree equal to 340 kg (Blair et al. 2017). Highest benefits of air pollution removal were in Ozone removal (9178 grams per year) and Particulate matter greater than 2.5 microns less than 10 microns in diameter (PM<sub>10</sub>) removed was equal to 5589 kg per year (Blair et al. 2017). A part of approximately 9500m<sup>2</sup> existing grassed area in the project site could be successfully converted for planting which could enhance further the carbon benefits of the corridor (Blair et al. 2017). This study established notable contributions of the existing trees and the future planting potential of the available vacant land.

## 2. Aim and objectives

This research focuses on a railway corridor case study through residential suburbs of Western Sydney and approximately 11 km in length. The main aims of this project are to estimate climate change mitigation potential of existing trees in this railway corridor as environmental and economic benefits and to determine how these benefits change with the increase in the tree canopy cover.

The objectives of this paper follow.

- To determine the existing land use distribution in this rail corridor case study;
- To measure as carbon storage and carbon sequestration capacities and associated economic benefits provided by the existing trees;
- To estimate air pollution reduction capabilities and associated economic benefits provided by the existing trees;
- To model a tree canopy growth scenario to estimate the variation in the future potential of carbon and air pollution reduction capabilities and economic benefits of trees.

### 3. Research Methodology

#### 3.1. Selection of a railway corridor case study

The case study corridor of approximately 11km length is located in the Western Sydney on the T1 western line. It included railway stations, tracks, adjoining land and buildings which were located within the railway properties as defined by spatial property boundary data from Land and Property Information of New South Wales. The rail corridor case study stretches between an overpass of Carlsie Avenue in Mount Druitt suburb to a location close to Emperor Circuit in Penrith. The site includes three stations, Kingston, Werrington and St Marys. Although Mount Druitt and Penrith stations were not included within the site, these stations lie close to the case study boundary. This site was selected as this corridor is further away from the city; is located in suburban areas and had a combination of vacant land areas, trees and buildings on either side of the railway track. Fig 1 presents the extent of the case study site along the railway corridor in the Western Sydney.

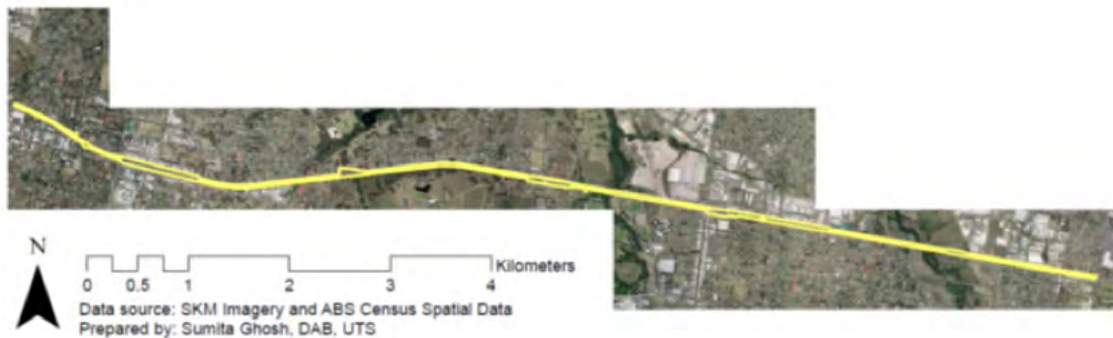


Figure 1 The case study rail corridor on the T1 western line

#### 3.2. Research method

'i-Tree Canopy' was developed by the United States Department of Agriculture (USDA) Forest Service, Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture and Casey Trees (USDA Forest Service et al., 2018a and 2018b). Using 'i-Tree Canopy' method and Geographic Information Systems (GIS) and latest aerial imagery data from Google Imagery, a spatial distribution of different land covers, carbon sequestration and storage and air pollution removal benefits and associated economic values were calculated. A total of eight suitable land cover classes or categories were formulated for the case study after a visual examination of existing land covers from the aerial photograph of the site. 'Tree canopy cover' (T) represented only the trees on the site while 'Shrubs' (SH) included comparatively smaller plants and bushes. 'Rail' (RL) represented the railway tracks while 'Building' (B) and Impervious Surfaces (IS) are impervious covers including houses and impervious surfaces other than buildings respectively. 'Grass' (GR) had a permeable surface covered mainly with a grass cover. Tree planting in the corridor depends on availability open spaces, heights of overhead electrical wires and distances from the rail track. Bare Ground (BG) was characterised by vacant land



without any grass cover. 'Grass' (GR) and Bare Ground (BG) provided future planting potential areas considering the distances from the railway track and suitability of planting locations. Trees should be planted six meters away from rail track and should be less than 4 meters tall to avoid the overhead wires (NSW Transport NSW Trains). Also trees in the corridor help to improve the microclimate of the surrounding neighbourhoods.

'i-Tree Canopy' assessment methodology and protocols for calculation were followed systematically and appropriately for the data collection and result preparation. Application of 1000 points for the case study site analysis, provided more accurate results for the spatial and cover distribution (areas and percentages), carbon sequestration and storage and air pollution reduction capacity and associated economic values of the trees with the minimal standard errors. Air pollution removal include removals of ozone (O<sub>3</sub>), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), particulate matter less than 10 microns (PM<sub>10</sub>), particulate matter less than 2.5 microns (PM<sub>2.5</sub>), and sulphur dioxide (SO<sub>2</sub>) (USDA Forest Service et al., 2013, p.1). Mainly one scenario (Scenario 1) for tree growth modelling in the railway case study corridor was formulated. Scenario 1 included an increase from the existing tree canopy cover in the case study corridor to 20% by transforming suitable 'Bare Ground' cover locations into tree canopy cover. Care had been taken in this scenario to transform only those locations or points that were suitable for tree plantation based on aerial imagery information. Locations on unsealed roads and close to railway tracks were avoided.

The existing tree canopy cover analysis and one future growth modelling scenario were analysed to estimate spatial distributions of different land covers, carbon sequestration and storage and air pollution removal benefits and associated economic values for the case study. An additional scenario was briefly examined where the tree canopy cover increased to 50% coverage by transforming three different land cover categories: 'Bare Ground', 'Grass' and 'Shrubs'.

## 4. Analysis and results

### 4.1. Existing spatial distribution of land cover and tree canopy cover analysis

The total site area was 54 hectares (ha). Spatial distribution of land covers (Table 1 and Fig 2) showed rail track covered 24 ha (37.1%) and tree canopy was only 4 ha (7.71%). Grass cover was 14 ha (25.3 %) while bare ground covered 12 ha (21.5%) of the site. The grass cover and bare ground are the land bank where future tree planting could be progressed to enhance the carbon benefits, and air pollution reduction to mitigate further impacts of climate change.

*Table 1: Spatial distribution of land covers on the case study site for existing trees*

Land use/ Land cover	Description	Area (hectares (ha))	Area Standard Error (ha)
Tree	Tree, non-shrub	4	±0.00
Shrubs	Shrub	1	±0.00
Grass	Grass	14	±0.01
Bare Ground	Bare ground (pervious)	12	±0.01
Impervious Surfaces	Impervious surfaces other than buildings	2	±0.00
Building	Buildings and built forms	1	±0.00
Rail	Rail tracks	20	±0.01

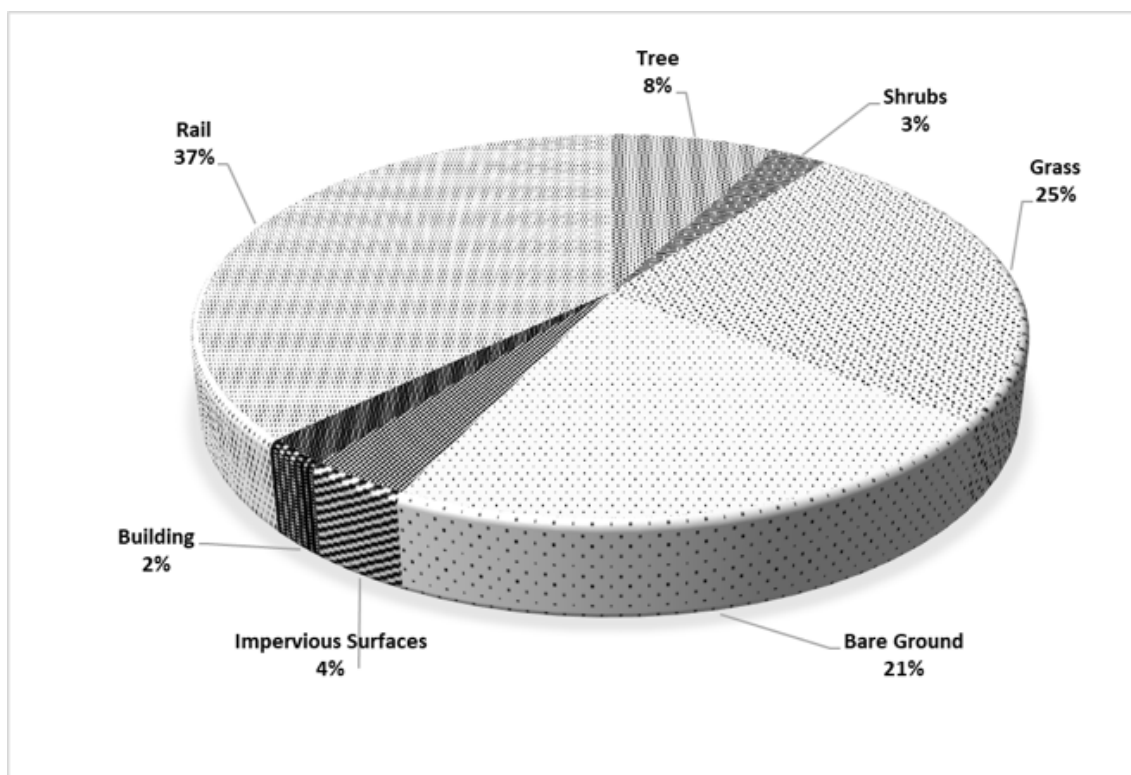


Figure 2 Percentage land cover area distributions on the case study site (existing)

The existing trees assessment on the case study site showed that the existing trees could store a total of 1.17 kilotons of CO<sub>2</sub> with an economic value AUD\$35,993.67. The existing trees could sequester up to 53.71 metric tons of CO<sub>2</sub> annually with an economic value of AUD\$3,087.37. The 'i-Tree Canopy' analysis of air pollution reduction potential for PM<sub>10</sub> was 72.96kg and 250.06kg of ozone removed annually and altogether (CO, NO<sub>2</sub>, O<sub>3</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, PM<sub>10</sub>) the economic value of was calculated to be equal to AUD \$263.77. Table 2 presents the benefits of existing tree canopy cover from 'i-Tree' analysis.

Table 2 Benefits of existing tree canopy cover

Benefit Description	Environmental Value (metric value)	Standard Error (SE)	Total Economic Value (AUD/dollar value)	Standard Error (SE) (AUD)
Total CO <sub>2</sub> Storage (not an annual rate)	1.17 kilotons	±0.13	AUD\$35,993.67	± \$3,940.61
Total annual CO <sub>2</sub> sequestration in trees	53.71 metric tons	±5.88	AUD\$3,087.37	± \$338.01
Total air pollution removal per year	CO: 5.01kg NO <sub>2</sub> : 25.03kg O <sub>3</sub> : 250.06kg PM 2.5: 14.91kg SO <sub>2</sub> : 13.76kg PM <sub>10</sub> : 72.96kg		AUD \$263.77	

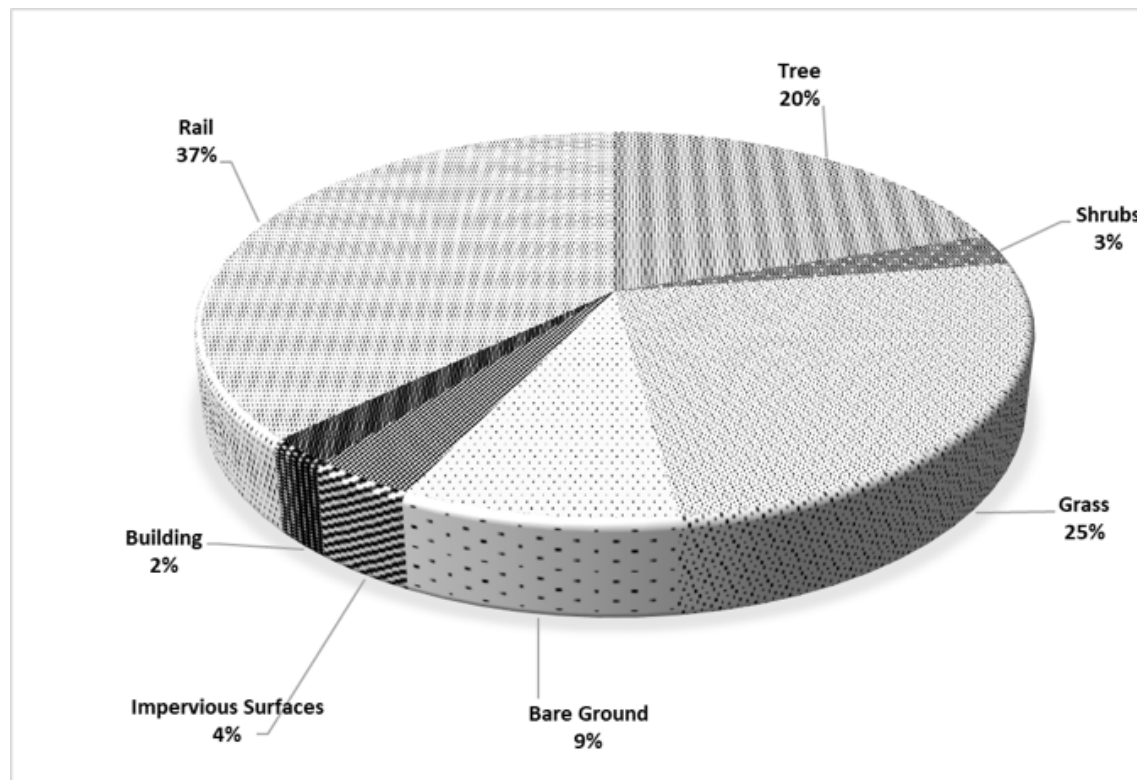
i-Tree Canopy Annual Tree Benefit Estimates based on these values in g/m<sup>2</sup>/yr and \$/t/yr: CO 0.121 @ \$204.85 | NO<sub>2</sub> 0.603 @ \$61.40 | O<sub>3</sub> 6.021 @ \$251.52 | PM<sub>2.5</sub> 0.359 @ \$9,763.21 | SO<sub>2</sub> 0.331 @ \$18.88 | PM<sub>10</sub>\* 1.745 @ \$725.26 | CO<sub>2</sub>seq 1,293.459 @ \$57.48 | CO<sub>2</sub>stor is a total biomass amount of 28,177.630 @ \$30.76 Note: Currency is in AUD, Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points. 1 kiloton = 1000 metric tons; 1 metric ton= 1000 kg

## 4.2. Scenario 1 tree canopy cover analysis

In Scenario 1 the existing tree canopy cover in the case study corridor was increased to 20%. This is done by converting by transforming suitable 'Bare Ground' cover locations into tree canopy cover. This scenario represented a future tree planting option when the existing tree canopy cover of 7.71 % was increased to 20% tree canopy cover within the railway corridor. The spatial distribution analysis of existing conditions demonstrated that there were reasonable areas of vacant land on the case study site which could be revegetated with trees. In this scenario, 'Bare Ground' decreased to 9% from 21% in the existing tree canopy situation. Table 3 presents spatial distribution of land covers on the case study site for the Scenario 1. Fig 3 presents the percentage land cover area distribution on the case study site for the Scenario 1.

*Table 3 Spatial distribution of land covers on the case study site for Scenario 1*

Land use/ Land cover	Description	Area (hectares (ha))	Area Standard Error (ha)
Tree	Tree, non-shrub	11	±0.01
Shrubs	Shrub	1	±0.00
Grass	Grass	14	±0.01
Bare Ground	Bare ground (pervious)	5	±0.00
Impervious Surfaces	Impervious surfaces other than buildings	2	±0.00
Building	Buildings and built forms	1	±0.01
Rail	Rail tracks	20	±0.00



*Figure 3 Percentage land cover area distribution on the case study site (Scenario 1)*

The Scenario 1 assessment on the case study site showed that the increased tree canopy cover could store a total of 3.05 kilotons of CO<sub>2</sub> with an economic value AUD\$93,957.51. The amount of carbon storage in trees had increased by 161% with an increase an area of tree canopy to 7

ha. The trees in this scenario could sequester up to 140.22 metric tons of CO<sub>2</sub> annually with an economic value of AUD\$8,059.24 with this increase in tree canopy cover. The 'i-Tree Canopy' analysis of the economic value of air pollution reduction potential together was calculated to be equal to AUD \$688.66 which was higher than the AUD\$283.77 in the existing trees analysis. Table 3 presents the benefits of Scenario 1 assessment from 'i-Tree Canopy' analysis.

*Table 3 Benefits of tree canopy cover in the Scenario 1*

Benefit Description	Environmental Value (metric value)	Standard Error (SE)	Economic Value (AUD/dollar value)	Standard Error (SE) (AUD)
Total CO <sub>2</sub> Storage (not an annual rate)	3.05 kilotons	±0.19	AUD\$93,957.51	± \$5,923.14
Total annual CO <sub>2</sub> sequestration in trees	140.22 metric tons	±8.84	AUD\$8,059.24	± \$508.06
Total air pollution removal per year	CO: 13.09kg NO <sub>2</sub> : 65.33kg O <sub>3</sub> : 652.75 kg PM2.5: 38.9kg SO <sub>2</sub> : 35.92kg PM10:189.15 kg		AUD \$688.66	

Following this Scenario 1, the tree canopy cover in the rail corridor case study site was further increased to 50% in an additional scenario considering tree planting options in the 'Bare Ground', 'Grass' and 'Shrubs' land cover categories and was assessed using 'iTree Canopy' method. The carbon storage amount increased to 7.61 kilotons (Std. Error: ±0.24) with an associated economic value of AUD \$304,468.35 (Std. Error: ±9,608.90). The annual carbon sequestration potential was increased to 349.14 metric tons (Std. Error: ±11.02) from 53.71 tons and the economic value would rise to \$20,067.86 (Std. Error: ±633.33) from AUD\$3,087.37 in the existing trees assessment.

## 5. Discussion and conclusion

This research estimated carbon storage and sequestration benefits, and air pollution reduction capacity of urban trees using the 'i-Tree Canopy' method and GIS for the selected case study in the Western Sydney. Total permeable and impermeable land covers and spaces for tree plantations to increase the overall tree canopy cover to enhance tree benefits could be determined from the spatial distributions of land cover classes in the case study site. The selected site had a significant area for future tree plantations which could be used effectively to address and adapt to climate change impacts and develop mitigation policies. The scenarios showcased that it is possible to enhance carbon benefit contributions of trees to a significant extent by changing the overall tree canopy cover. This also established that the grey infrastructure areas of cities and towns are also very useful in contributing positively towards better urban performance. Specially in railway corridors due to restrictions of access, the trees are likely to grow well; provide meaningful ecosystem services; preserve tree species and at the same time could provide better environmental quality and microclimate for the surrounding neighbourhoods. In addition, the bare ground area if revegetated with trees would prevent soil erosion and rainfall interception. Urban forests created along the railway corridor could also act as urban forest banks and a wildlife corridor protecting biodiversity.

One of the limitations of this study was that i-Tree Canopy could only assess based on the tree canopy cover data from aerial imagery. This aerial imagery analysis although saves a lot of time compared to conducting a field survey but individual tree species and tree characteristics cannot be identified from this aerial imagery based analysis. Fieldwork based analysis would be required for creating a tree inventory database and identifying tree species in the rail corridor. Tree planting in the rail corridor is strictly guided by regulations for safety. Following the guidelines, the plantable

spaces could be determined within the corridor. Selection of suitable types of trees is significantly important to achieve an effective result. For example, smaller trees with comparatively lower heights would more suitable for planting in the corridor depending on availability open spaces, heights of overhead electrical wires and distances from the rail track. One of the advantages is that the land ownership by a single organisation could be managed systematically at the organisational level and also maintaining all the requirements essential for the rail transport. A tree canopy goal could be formulated considering a time period for implementation.

This paper provides a snapshot of carbon and economic values provided by the urban trees located on a grey infrastructure. Future research should focus on exploring roles of trees in grey infrastructure facilities to harness their potential. Trees could contribute positively towards developing sustainable solutions for the human environments.

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# URBAN AGRICULTURAL PRACTICES IN THE MEGACITIES OF DHAKA AND MUMBAI

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## Summary

Dhaka city in Bangladesh with a population density of approximately 27,700 people per square kilometres is one of the densest city in the world. The urban morphological characteristics and urban design and planning provisions in the high density city restrict land availability for growing food locally, in the city. As a result the foods especially vegetables and fruits available in the local market of Dhaka are transported from the rural regions of the country, with high food miles, mostly adulterated with preservatives for longer shelf life. Evidence shows that this megacity is adopting useful pathways to integrate safer local food production or urban agriculture within the built environments. Not only unsafe available food is the only problem of this city, in more than thirty years Dhaka city has lost enormous amount of open spaces from 44.8% to 24.1%. As a result the city has lost its agricultural land, other food producing spaces such as home and community gardens, small vegetable farms and recreational spaces such as neighbourhood park to urban development. Local food production of rooftop can be a gateway for safer food production as well can add extra green spaces to the city.

The aim of this research is to review existing and emerging urban agricultural practices and current planning policies in the city of Dhaka and a selected high density cities of the world using an exploratory literature review and analysis two case studies from these cities. One innovative case study from Dhaka would be analysed and compared it to one relevant case study from Mumbai, India considering productive spaces, current performance, potential to grow local food and ability of making social awareness which would cause other people of the city to adopt urban agriculture as a part of their urban life.

The outcome of this research would provide a realistic view of the status of Dhaka's urban agricultural system and practice in compared to another high density city's food production practices. This will give a clear idea about current research and planning, urban design policy if that includes urban agriculture, mainly it will identify the research gap this practices create, and this research would provide some recommendations for integrating local food production within the city to improve and to build a resilient future.

Keywords: urban agriculture; rooftop garden; Dhaka; Mumbai; food security

## 1. Introduction and Context

Dhaka is one of the major cities and the capital of Bangladesh has a population of 12 million and a population density of approximately 27,700 people per square kilometres. It is predicted that the population of Bangladesh will be over 20 million people by the year 2020. Although this population is contributing to the economy of the country but simultaneously it is causing unbearable pressure on the city's infrastructure. Due to land scarcity and topography, the land price of Dhaka is very high even compared to other developed countries (Baker 2007). Fig 1 presents photos from Dhaka and Mumbai.



*Figure 1 Two high density cities (Photos by M. Islam and K. Faiz)*

On the other hand, Mumbai is situated almost 2300 kilometer away from Dhaka and is regarded as the economic capital of India. Similar to Dhaka, this city is highly populated with a population of 23.5 million people, which is almost the double as Dhaka's current population. The population density of Mumbai is about 20,482 person per square kilometer, making it the ninth most crowded city of the world.

This paper focuses on the urban agriculture practices in these two dense cities, which are located in the same region of the world. Although agriculture is not one of the principal activities of most of the cities in the world, in a number of specific countries there are many urban dwellers who rely solely on urban agriculture for food and livestock production for their supply to nutrition and food security (Zezza and Tasciotti 2010). Urban agriculture can play a major role in making these cities self-sufficient through local food production. Many cities in the world are currently practicing urban agriculture within city limits. Cuba showcases a good example of how urban agriculture practices can flourish in a country to tackle food supply crisis. In 1989 when Cuba was cut off from the Soviet Bloc and was also under US embargos, food crisis began to take place on that small island nation. Hunger became a part of Cubans' daily life. Not only the food import stopped, but also importing of other agricultural materials such as animal feed, fertiliser, and industrial equipment were also stopped. This crisis led the government to take initiate urban organic farming in Cuban cities such as Havana. (Clouse 2014) Among South East Asian countries, Dhaka and Mumbai are the two very high-density cities that have been impacted by rapid urbanisation. But when it comes to formal urban agriculture, both the cities have a culture of growing food within the city as a hobby, but not as a strong urban component. Compared to Bangladesh, India has more numbers of major cities and urban agriculture is slowly getting its position in the urban fabric in a few cities. For example, urban agriculture is a new concept in the city of Hyderabad in India. More than four hundred households of this city practice urban agriculture and horticulture department of the government has a subsidy system for the citizens who want to initiate farming of their own. Despite having this promising initiative from the government, there is hardly any noticeable urban agriculture in the core areas of the city. This is because the city is very dense and tenants do not

have access to the spaces where they could grow food. Some of the residents have received this subsidy from the government and applied to practices of growing food in the outskirts of the city (Awasthi 2013).

## **2. A Review of urban agricultural practices in Dhaka and Mumbai**

Islam's (2002) research established that almost 78% of rooftops of Dhaka had already incorporated some forms of gardens. This city has not introduced any formal 'Urban Agriculture' (UA) system and there is very limited literature available on this specific topic (Das 2017; Sajjaduzzaman, Koike, and Muhammed 2005; Shariful Islam 2002). Although approaches to UA practices in Mumbai are different from Dhaka, a limited work has been conducted on UA research for this city. Only notable urban agriculture typology that exists in the Dhaka city is a rooftop garden. The community garden concept did not progress because communities could not afford to invest in a land area for community garden due to high land price in Dhaka and also this is not a common cultural practice (Zinia and McShane 2018). But in Mumbai, three typologies of UA system are widely practised such as 1) farming along the railway tracks, 2) community garden, 3) rooftop garden (Satterlee 2015).

Historically UA in Mumbai was informal and had only existed in the form of a terrace or balcony garden (Satterlee 2015). These are popular as part of a food production system in Mumbai, especially to meet one's personal recreational need (Vazhacharickal 2014). Simultaneously, Mumbai's community gardens are run by a group of people or non-government organisation with various goals such as creating awareness on local food production in local people and to teach gardening techniques to people so that they get inspired to start gardening themselves. Produces from these community gardens are usually distributed between the garden members and sometimes get donated to nearby church and hospital (Satterlee 2015).

Indian Railway plays a major role in Mumbai to implement a government-initiated food production system in the city. This organisation has allocated their unoccupied land to the employees with lower socio-economic profiles of their organisation to farm and grow vegetables. The project is named "Grow more food" has protected Indian Railway's unoccupied lands from illegal encroachment. The huge farming culture in the city is also linked to cultural practices of many agricultural migrants from the adjacent rural areas (Vazhacharickal 2014). Produces from these farms are usually consumed by the farmers and they sell the extra vegetables to the local markets (Satterlee 2015). Sadly, this innovative approach towards urban agriculture farming is threatened by the overuse of fertilisers and pesticides by the poor farmers who lack in formal training and knowledge about organic farming and motivated to increase only the production. Lack of knowledge on organic farming and its benefits have led to the high chemical contamination in the vegetables that farmers grew in this project (Vazhacharickal 2014). But nevertheless, this is the only formal approach from the government's side to encourage urban farming for food production in this city (Satterlee 2015).

Similar to Mumbai, there is nil or a minimal involvement from government's side to promote urban agriculture in Dhaka. As discussed earlier, community garden or gardening on land is difficult in the city due to the unaffordable land price and unavailability of land. But rooftop gardening has significant potential in the city. The dense built environment of the city provides a larger roof space area available and a huge opportunity for city dwellers to grow their own food on the rooftop gardens. Also among the many green adaptation methods, rooftop gardening is one of the most affordable methods for the Dhaka dwellers to increase the number of green spaces in the city (Zinia and McShane 2018). When Shariful (2000) interviewed the current food growers of Dhaka, he found out that usually homeowners prefer to have gardens on the rooftop but they are not very willing to let their tenants practice gardening on the rooftops of their houses. Each rooftop gardener in Dhaka spends around \$50-\$80 Canadian dollars annually as an expense on the garden and half of the gardeners have prior experiences of gardening and in agriculture (Shariful Islam 2002).

Different types of planters are used in Dhaka's rooftop gardens and are made out of permanent to temporary materials. Permanent structures such as cemented platforms are seen very less (approximately 5%) and these are most popular medium to hold the plants. Up to 83% of these planters are clay pots, and the rest of the planters are plastic drums (Sajjaduzzaman, Koike, and Muhammed 2005). Unlike Dhaka, Mumbai's UA farmers mostly upcycle on-biodegradable waste by using them as planters and other gardening materials (Satterlee 2015). When Dhaka's UA is hobby-driven, Mumbai's urban agriculture aims to help improving waste management practices within the city. Every community garden or rooftop garden has a provision for using waste as compost for the plants (Satterlee 2015).

Economic conditions of 75% gardeners who grow food on their rooftop gardens in Dhaka's context are usually from middle-class backgrounds. Rich and poor both classes are less involved in rooftop gardening in Dhaka (Sajjaduzzaman, Koike, and Muhammed 2005). Economic conditions of Mumbai's urban farmers present variations of social and economic statuses who participate in urban food production. While rooftop and community gardeners are usually the upper middle class, railway farmers fall directly below the poverty line in Mumbai (Satterlee 2015).

## **2.1. Rooftop Gardening Project in Dhaka**

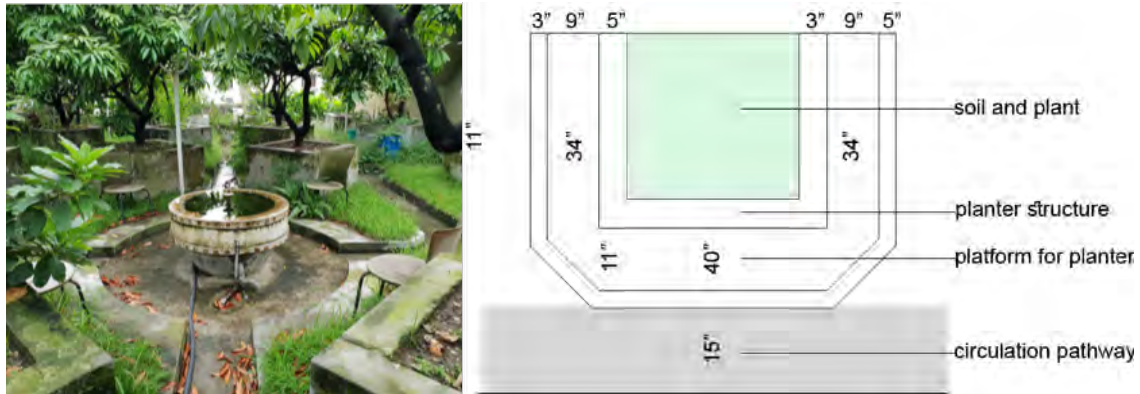
Food and Agriculture Organization of United Nations (FAO) in collaboration with Department of Agricultural Extension (DAE), Ministry of Agriculture, Bangladesh had funded a rooftop gardening project in two major cities of Bangladesh, Dhaka and Chittagong. The project was implemented for two years from 2015 to 2017. On record, this is the only formal urban agricultural project in Bangladesh where a global organisation worked solely on food production in a rooftop garden. The main objective of this project was to increase awareness about rooftop gardens as a medium to achieve food security and nutrition in growing agricultural produces; reducing air pollution and if possible to generate income strengthening the local economy. In this project, in two cities, around 250 demonstration rooftop gardens were established and the same number of house owners received training and knowledge on latest rooftop garden technologies from the experts from three non-government organisations, one public university and a research institute. Although compared to the total population of the city, the share of householders included was very minimal. But still under this project, almost 800 people received basic training on the rooftop gardens and 45 young people with limited educational backgrounds received training to be an aspiring gardener (Das 2017). Apart from this personal training provision, this project also took an initiative to educate school children. The result of this project commenced an incentive from the government and two city corporations declared 10% rebate on holding tax for any building which has a green roof on it (Das 2017).

## **3. Analysis of roof garden case Studies from Dhaka and Mumbai**

### **3.1. A rooftop garden case study in Dhaka**

A rooftop garden selected as a case study for Dhaka is situated in Uttara, Sector 06, at the fringe of Dhaka. The area is comparatively new, so it is more planned and organised than other parts of the City. From Uttara's sector 6 map, it is observed that the road layout is in gridiron pattern and the residential plots are systematically placed. This area has mixed-use pattern with school, university, supermarket and shops, although dominant land use is residential, This rooftop garden attracted significant media coverage as a TV Show entitled 'Rooftop farming' and was hosted by one of the celebrity agriculture enthusiasts, Shykh Seraj. Fig 2 presents a photograph of the rooftop garden case study in Dhaka and a plan of the planter box placed on the rooftop garden.





*Figure 2 A rooftop garden case study in Dhaka (Photo by the author) and the plan of a planter box (Source: Drawn by the author)*

The selected rooftop garden is set upon the roof of a five-storied privately owned house. The total area of the house is about 229.9 m<sup>2</sup>; 50% of the total rooftop is dedicated to growing food and includes mainly fruit trees planted in concrete boxes. It has permanent structures to accommodate trees on the rooftop. Structures of the garden are planned and constructed accordingly to sustain the extra loads of the trees in the garden. The garden is a notable example; not common in the city of Dhaka and also compared to other urban agricultural practices of Dhaka. Preplanning of this garden at the design stage before construction began and the owner's enthusiasm for gardening and recreating a green space in a dense urban area, make this garden an outstanding example in Dhaka. The built-up areas, roads and green spaces on the three adjacent blocks of the selected case study show that all the plots are almost of the same size; have a good road connection with each other, but the setback between buildings are very narrow. Satellite imagery of this planned part of this dense city indicates that this city lacks in green or open spaces. From this image, it is also noticeable that, the rooftop garden on the building of the selected case study contributes a reasonable amount of green space in the neighbourhood. An aesthetically designed artificial fountain and seating areas to relax on the rooftop garden indicate that the garden functions as a socialising space for family and friends.

This garden has two sizes of planters to grow trees. The larger planter is 101 cmX101 cm with a depth of 50cm. The smaller planter is a permanent structure and is 66 cm X 53 cm with a depth of 50 cm. There are altogether twenty-five planters on the rooftop, out of which nineteen are of large size and rest six are of smaller size. But on this rooftop garden, the owner has comparatively larger size trees such as mango or star fruit trees which generally grow on the ground. On the site visit to the rooftop garden case study, twelve types of fruit trees such as mango, star fruit, lemon, guava, lychee, tamarind etc. and exotic fruit trees such as avocado and Thailongan were recorded. There were some vegetables such as spinach, mint, pumpkin and others were growing in the garden.

They have created a visible drainage system for the garden. Two types of drainage system exist in this garden. The first type of drainage is linked to the planter to drain out excess water after watering the plants- from the planter to the rooftop garden. The second type of drainage system is to drain the water draining out of the planters and rainwater from the rooftop garden to the ground level.

One of the main problems was that the movement paths were narrow and were only 38 cm wide although pre-designed. The spreads of the large trees at lower heights at some points make it difficult to walk through these paths and this also poses a problem for regular maintenance of the garden. During site visit, it was observed that drainage was blocked at several points making these paths waterlogged and slippery.

### 3.2. A rooftop garden case study in Mumbai

Mumbai Port Trust's central kitchen rooftop garden is selected as the case study. It is a celebrated institutional garden in Mumbai and is different from a private residential rooftop garden case study in Dhaka. It was founded by the catering officer, Preeti Patil as a way of recycling enormous food waste created by the thousands of people's meal prepared in this kitchen (Satterlee 2015).



*Figure 3 Sketch of a rooftop garden case study in Mumbai (drawn by the author), source: <http://cityfarmer.info/mumbai-port-trust%E2%80%99s-%E2%80%98wild%E2%80%99-kitchen-garden-india/>*

The rooftop of the central kitchen of Mumbai Port Trust Authority building is about 229.9 m<sup>2</sup> in size (Marielle Dubbeling 2012). In 2002, this garden started with only five plants, now contains about 150 different types of plants in the garden (Marielle Dubbeling 2012; Pendharkar 2008). The garden not only has fruits and vegetables, it has a separate section for growing medicinal plants and herbs (Pendharkar 2008). The photos and research studies indicate that the garden was not pre-designed, rather it was designed organically at the post-construction phase when the building was already operating. Similarly, the materials used as planters, are mostly recycled waste. 90% of the waste generated by 30,000 employee's meal preparation are recycled in this garden (Marielle Dubbeling 2012). Fig 3 shows the sketch of the organic organisation of the garden, use of different types of material as planter and plants of different types and sizes.

This garden had started as a small initiative and just to solve an immediate problem but over time has become a model garden for many urban gardeners in Mumbai and in India. After the success of this garden, Preeti Patil founded one of the most successful organisations named 'Urban Leaves' to inspire and help people with farming knowledge and techniques ('MbPT Terrace Garden and the philosophical and practical base of Urban Leaves').

Both the rooftop gardens in Dhaka and Mumbai in two different settings have similarities as they are creating food forests in two high-density megacities. Table 1 compares the two selected rooftop garden case studies in Dhaka and Mumbai.

*Table 1 A comparison of rooftop garden case studies in in Dhaka and Mumbai*

Category	Rooftop garden, Dhaka	Rooftop garden, Mumbai
Land use	Residential	Institutional
Area	278.7 m <sup>2</sup>	229.9 m <sup>2</sup>
Concept	Pre-planned	Organic
Purpose	Hobby garden	Waste management
Produce type	Mainly fruits, partially vegetables	Mainly vegetables, partially fruits and herbs
Planter type	Permanent, cemented	Recycled waste, temporary

#### 4. Discussion

A literature review of urban agricultural practices in two megacities, Dhaka and Mumbai from the same geographical region has been conducted in this paper. An important comparison of two selected roof garden case studies has also been completed. Dhaka and Mumbai have very similar urban conditions and are considered as comparatively very dense cities of the world. Although the scarcity of the available land areas exists, these cities are still putting efforts to grow their own food locally. Balcony and rooftop gardens are popular forms of urban agriculture in both the cities. Community garden plays a huge role as small-scale urban agricultural typology for Mumbai whereas in Dhaka community garden typology is absent in the local food growing scenario. In Dhaka, the majority of urban farmers in rooftop gardens are from middle-class backgrounds, but in Mumbai members of upper middle-class society are more involved in growing food in community and rooftop gardens within the city.

The literature on quantitative data and core aspects of the garden such as the amount and types of produce, growing seasons, expenditure, quality of food produced and how much food distributed at the outlets are not available for both Mumbai and Dhaka. Limited and almost no planning or food policies are available that aim to improve the uptake of urban agriculture in that region. Urban agriculture is appreciated for its potential to grow food for the city dwellers worldwide. But the potential of urban agriculture in this specific region yet to be explored. Future research should explore and compare how cultural practices, affordability and people's behaviour impact climate and other issues and provide varied urban performance linked to food for moving towards a resilient food future.

From both the case studies, apart from their differences, one aspect is common that a fully functioning food producing rooftop garden is a possibility in both Dhaka and Mumbai. In both the case studies in Dhaka and Mumbai, one individual and a private group respectively dedicated themselves to grow food voluntarily. But their small initiatives have contributed towards increasing two small green spaces and providing access to nutritious food in the city. If the governments of these two cities are able to implement intervention techniques and planning and food policies for urban agriculture, it could have broader and more effective benefits to offer. Building capacities in people to use efficient farming techniques; developing guidelines on the types of suitable plants that could be grown on the rooftop gardens and measuring how rooftop local food production could improve micro-climate of cities would be very useful. All these benefits collectively could make a positive difference in the overall performance of cities.

#### 5. Conclusion

This paper analysed literature references from two selected cities from neighbouring countries, Dhaka and Mumbai to study the urban agriculture practice in both the places. Analysis of two case studies of rooftop gardens were also conducted to comprehend their similarities and differences in practice methods and to portray these urban agricultural practices as examples of functioning food production systems on the rooftops of these dense cities. Literature and case studies both indicate possibilities of implementing successful urban agriculture practices in these cities but

more research needed on this field along with efficient and effective policies from government's side to promote urban agriculture in Dhaka and Mumbai.

## Acknowledgements

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# CONTEMPORARY URBAN BIOTOPES: LESSONS LEARNED FROM FOUR RECENT EUROPEAN URBAN DESIGN PLANS

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## Summary

The increased number of people living in urban areas requires rethinking what liveable cities are about. Within the next decade both climate change and the shortage of resources on water, energy and nutrients will have strong effects on the urban environment. The big challenge is to create 'healthy cities'. Bringing landscape to the cities can strongly contribute to make cities healthier, resilient, and more vibrant to accommodate all its citizens. Though key to provide this new perspective is how to create healthy cities in densely built areas, and strengthen the urban metabolism, while also addressing externalities, such as urban heat island effects, increased storm events, and sea level rise.

The objective of this paper is to gain insight in the new complexity that arises from the increasing relevance of landscape and planting in dense urban environments in order to set a contemporary agenda for urban green space design. The increasing need to develop healthy, circular and climate adaptive cities leads to new demands on urban green spaces. A journey along recent urban plans for Rotterdam, Athens, London and Utrecht demonstrates that by rebalancing traffic in cities, a vibrant and green public realm can be realised. Re-balancing transportation and the shift to multimodal mobility have a large impact on spatial qualities of cities and provides creating access for all. Public realm can be transformed into a green and blue network and will set the scene to activate public realm for vibrant city centres.

The complexity that arises from the new demands on green space in dense urban environments is explained through the analyses of four case studies in Rotterdam, Athens, London and Utrecht and literature reviews. These four 'research by design' projects are discussed and evaluated to reveal the increasing (societal) relevance of urban green space.

These projects offer new perspectives on the integration of climate adaptive design and circularity. Toolboxes for heat mitigation and for water sensitive design are developed and applied in the designs. Today's complexity to increase the degree of self-sufficiency within city limits and regions as well as climate adaptation requires continuous monitoring of the level of incorporation of the different aspects of 'healthy living' into the realized development and assessment of the standards each year. Adding today's aspirations on including biodiversity calls for the idea of 'urban biotopes', turning the green into an urban ecosystem that can evolve over time. Creating circular economy within the dense urban development plus climate adaptive design and aspirations on creating an urban biotope make urban development complex. It requires careful considerations about how to balance energy production and green, and how to integrate underground infrastructure, to make sure that the proper conditions for urban green are set.

**Keywords:** urbanisation, healthy cities, resiliency, climate adaptation, circular economy, biodiversity



## 1. Introduction

Increasingly, a higher number of people are living within city limits; the world is becoming rapidly urbanized and adjacent natural resources are being exhausted at an unsustainable rate. The quality of our lakes, rivers and streams is decreasing due to run-off. Ecological and agricultural areas are being developed to accommodate the population shift, resulting in a loss of 'green.' At the same time, we are facing climate change due to which contemporary cities are faced with the task of providing fresh water and access to restorative naturalized areas, while protecting citizens from natural disasters like flash floods, coastal storm surges, heatwaves and droughts.

In the European densely built mega polis and metropolitan areas there are urgent questions on how to develop healthy (peri-)urban environments with integrated water and drought management and heat island effect mitigation solutions. Within the cities the fundament for change lies in creating efficient transportation systems, connected to the urban network of spaces. A decade ago the agenda for improving the quality of the public was set. Successful transformations of infrastructure into green structures, such as the Cheonggyecheon River in Seoul (Kodukula, 2011) and urban transformations of the industrial to post industry cities in Bilbao (Areso, 2009) and Melbourne (Adams, 2009), have shown that large scale transformations are possible.

The big challenge is to create 'healthy cities'. Following up to the change towards a direction of creating green landscape cities our contemporary challenge is to incorporate the 'metabolism of the city' within the context of the densely built urban environment. The challenge is to manage the exchanges of energy, material and population in a responsible and sustainable way—considering and strengthening the urban metabolism. Being aware of the growth of the world's population and the ongoing increase of percentage of people living within city limits it will be imperative to find answers to unhealthy living conditions and to increase the degree of self-sufficiency within city limits and regions.

Creating a healthy living environment requires reducing distances between working and living plus rebalancing traffic into a shift towards public transport and slow movement. Furthermore, it includes climate proof cities and landscapes, addressing the issues of storm water management and other topics can be related to strategies for energy transition the shift from fossil fuels to sustainable energy management and for re-thinking waste, nutrients and food production within the city limits. The increasing need to develop healthy, circular and climate adaptive cities leads to new demands for urban plans. In that context the role of green spaces in the development of cities will change and will become more relevant. To gain insight in the new complexity regarding urban green space design, four recent urban plans for Rotterdam, Athens, London and Utrecht were analysed on how different increasing demands on green space were integrated in the designs. This paper describes lessons learned from these four urban design projects in order to set a contemporary agenda for dense urban environments as 'urban biotopes'.

## 2. Methodology

The new perspective on creating healthy cities can strongly contribute to make cities healthier, resilient, and more vibrant to accommodate all of its citizens. Via 'research by design projects' new perspectives arise on integrating climate sensitive design and circularity and insights are developed how to achieve substantial improvements in public realm. Three recent urban design projects in Rotterdam, Athens and London are discussed and evaluated for the way in which these designs offer integrated solutions for urban challenges regarding climate change, circular economy and mobility. The contribution of these three case studies to these challenges is evaluated through assessment of the design projects' output and through literature reviews. Moreover, a currently ongoing urban design project in the Dutch city of Utrecht is reviewed as a pilot project for the application of the concept 'urban biotope'.

### **3. Results**

#### **3.1. Rotterdam, the connected city centre**

The first step to the transformation of cities is to change mobility. The strategy for urban change in Rotterdam, and later for London and Athens was based on three pillars: creating access for all and rebalance transportation, transforming the public realm into a green and blue network and activate the public realm to create vibrant city centres.

Re-balancing transportation has a large impact on spatial qualities of cities. With increased mobility, the quality of life of our cities is under pressure. Mobility is an issue in contemporary metropolitan regions and in rapidly growing cities. In many cities, auto-centric city planning has led to vehicular movement exceeding maximum capacity of road space, resulting in congestion and low-quality anonymous space, lacking identity. Prioritizing automobile transportation results in a lack of safe pedestrian and cyclist networks. It has a negative impact on quality of life; air pollution takes a heavy toll on our health. Being aware that about a third of the total amount of air pollution comes from motorized traffic, development of clean transport to improve air quality will help to increase liveability of cities.

The shift from vehicular mobility to multimodal is part of the strategy for Rotterdam city centre, focusing on expansion of pedestrian networks, public transit, and cycling. The idea of space needed to change, not by simply removing lanes of traffic on the main boulevards and roads avenue, but by shifting from vehicular orientated space to pedestrian orientated space. For the city centre, an area of four times four kilometre, the switch from hard traffic (car-oriented) space to 'soft traffic' (pedestrian, cyclist and public transport oriented) space allows the centre to become accessible in a different way—the public realm itself to become a catalyst for urban revitalization. Focal points in the city were connected, and the old pre-World War II streets were activated such that pleasant and attractive networks for slow traffic could be regenerated. Resulting into a connected city the ground is set for greening the space, and to create inviting places to stay (Knuijt, 2008).

#### **3.2. Re-Think Athens and a toolbox for heat mitigation**

Creating space for pedestrians and cyclists sets the ground for resilient and climate proof public realm (Bulleri, 2018). The proposed transformation of Athens' city centre, interlinked infrastructural change with the built environment, and created a basic framework for a blue-green network. Changing the heart of Athens into a true contemporary metropolitan city centre required transformation of the city triangle into a lively part of the city. Newly gained space, as a result of the major step towards a walkable city by reducing car traffic in this area, will transform it into a vibrant, green and accessible heart of the city (Knuijt, 2013). The combination of water solutions was key to make the city more resilient, adaptable, and dynamic. The blue-green network served a multifunction purpose—stormwater and drought management and heat island effect mitigation.



Figure 1 Heat mitigation toolbox Athens – measures and spatial distribution (Knuijt, 2013)

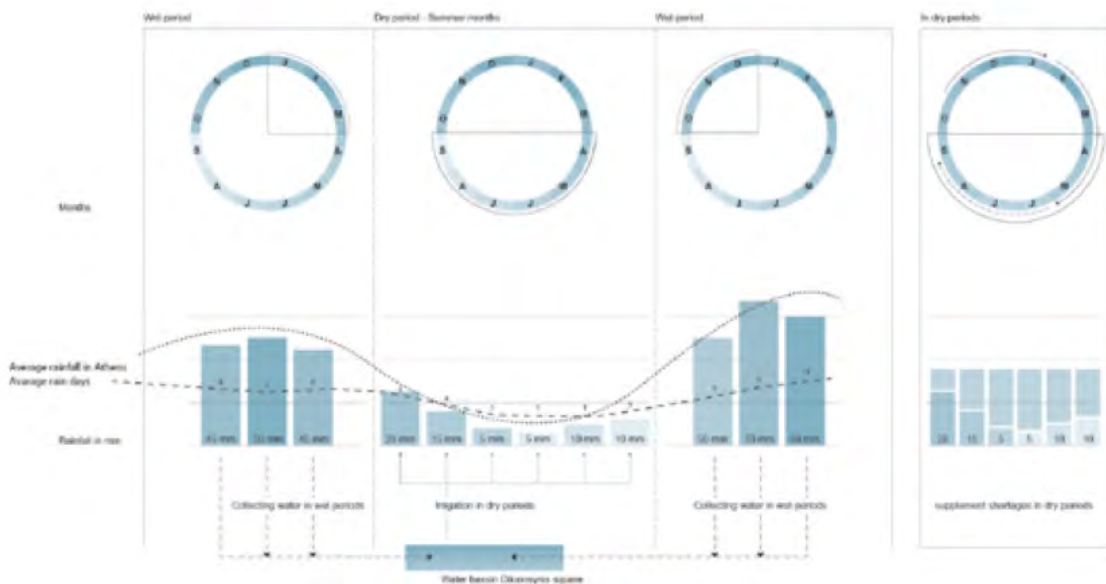


Figure 2 Rainfall in Athens, seasonal change (Knuijt, 2013)

To mitigate urban heat island effects urban measures to improve the urban microclimate, energy consumption and thermal comfort of citizens are required and integrated into the design principles of the public realm. A heat mitigation design toolkit was part of the proposal of OKRA landscape architects: the addition of greenery, use of light materials and integration of open water helps reduce the urban heat island effect. A contextual approach defines where the tools for different categories can be applied. Trees and other vegetation provide shade and allow

of evapotranspiration, both having a cooling effect. Providing water for the trees stimulates transpiration and contribute to cooling as well. Europe's largest rainwater retention system allows the area to be self-sufficient on water for irrigating green areas.

Parallel to the design process monitoring of the results has taken place. Similar to technical aspects, such as traffic modelling, also aspects of climate adaptive design can be calculated (Santamouris, 2013). It is not quantities indicating the amount of green and water of the design; it is the performance that can be indicated in figures. The broad notion 'sustainability' gets precision. For the Re-Think Athens project, the heat mitigation toolbox was evaluated and translated into the design for public realm. Measurements on site were executed (University of Athens, 2013) and during the design stages the outcome on heat reduction of the proposals were calculated via using ENVI-met simulations. A cooling of 1.5 degrees Celcius plus 20% of the thermal comfort index on a typical summer day was the aim. Results of 1.5 up till 3.0 degrees was; the outcome. (Werner Sobek GT, 2013).

### 3.3. London Meridian Water and a toolbox for water sensitive urban design

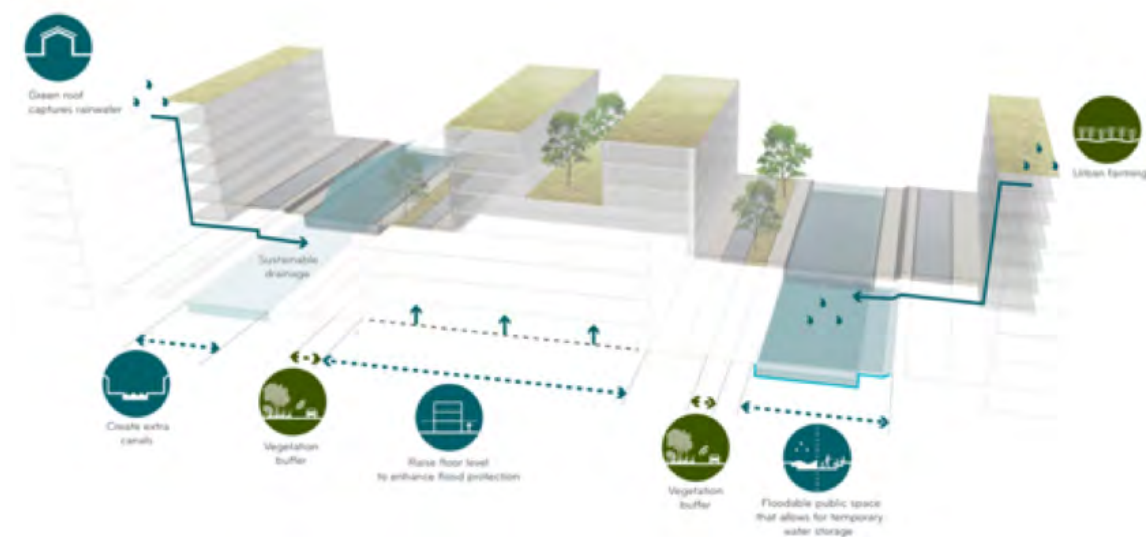
To adapt to climate change and prevent urban areas from the negative effects of flooding and drought, thinking of these aspects need to be integrated already at an early stage of the plans for urban developments. Regenerating the water system is key to a contemporary and healthy relationship between nature and culture (Hoyer, 2011).

For London's largest building development, Meridian Water, situated on a brownfield area, OKRA landscape architects developed a water sensitive urban design toolbox. As a result of considering that water solutions and green in public realm in the River Lee valley could work as an 'urban water machine'. A coherent set of tools was developed, contributing to healthy cities by integrating water into the public realm by storing, filtering and infiltrating (Knuijt, 2016).



Figure 3 Toolbox for water sensitive urban design, London Meridian Water (Knuijt, 2016)





*Figure 4 Toolbox for water sensitive urban design translated into typical section for one of the waterways, London Meridian Water (Knuijt, 2016)*

The first category of tools is about how to prevent areas from flooding. The second category is about to ensure integrated water management capturing and reuse is of essence. The green areas are designed to act as flood storage system within the built environment. Additional water storage can be designed into parks and squares serving dual purposes—leisure, recreation and sport most of the year, and stormwater storage during intense storm events. Stormwater can be stored in above or below ground containers used as an alternative for irrigation. Stormwater ponds can be seen as attractive naturalize elements that also serve as habitat to urban flora and fauna. Canals and pools within the public realm can hold and convey water while not only providing something beautiful to look at, but also allowing for evapotranspiration to occur, thus lowering the urban temperature. Capturing as much rainwater on site as possible is one way in which we can ensure climate proof cities. The third category related to sound water management includes tools to filter, to infiltrate and to recharge. The last category of tools is about the educational aspect of water. In addition to rain gardens, swales, ponds, streams, and channels, other water elements within public areas such as water-squares, fountains and interactive play elements can serve as protection by providing additional temporary storage and or reuse. Moreover, creating hydro-centric recreational opportunities is a way to bring people into contact with water; providing these opportunities is essential for education and awareness. Within the design of public realm, water and green can be integrated in multiple scales, resulting in attractive public realm.

### **3.4. Merwedekanaalzone, Utrecht: A new horizon**

Improving biodiversity in the urban context and preventing planting from diseases brings nature close to people living in the city. In the most recent urban design project of OKRA landscape architects, the Merwede area in Utrecht, a large brownfield development along the Merwedekanaal, 'urban biotopes' are designed in the public realm and on innercourts plus rooftops. The concept of urban biotope in this case means to design a resilient urban planting plan with a balanced nutrient and water supply system for planting. Based on the existing trees in the area, a selection of additional species is made to create variety in size of trees, understory planting, groundcover and perennials. Part of the planting is edible green, providing nuts and fruits for birds and insects.

Within the context high density urban development improved water sensitive solutions, waste management, and energy neutral developments are included. Creating circular economy within the dense urban development plus climate adaptive design and aspirations on creating an urban biotope make the situation complex. It is that complex that choices have to be made where



energy production can take place and at what place green on roofs has priority. It even requires re-thinking and integrating underground infrastructure, to avoid that at a late design stage it becomes clear that part of the green can't be realized.

The project as itself is regarded as a 1:1 design lab and requires monitoring of the results, executed by research institutes. Most likely today's highest standards will be normal standards in a few years, and might be outdated standards within ten years. That requires continuous monitoring of the level of incorporation of the different aspects of 'healthy living' into the realized development and assessment of the standards each year. Results during construction will be set against today's baseline, and include achievements during the next 10 years, thus being able to evaluate the different aspects on water sensitive solutions, heat mitigation, carbon reduction, energy circles and waste management for a longer period.

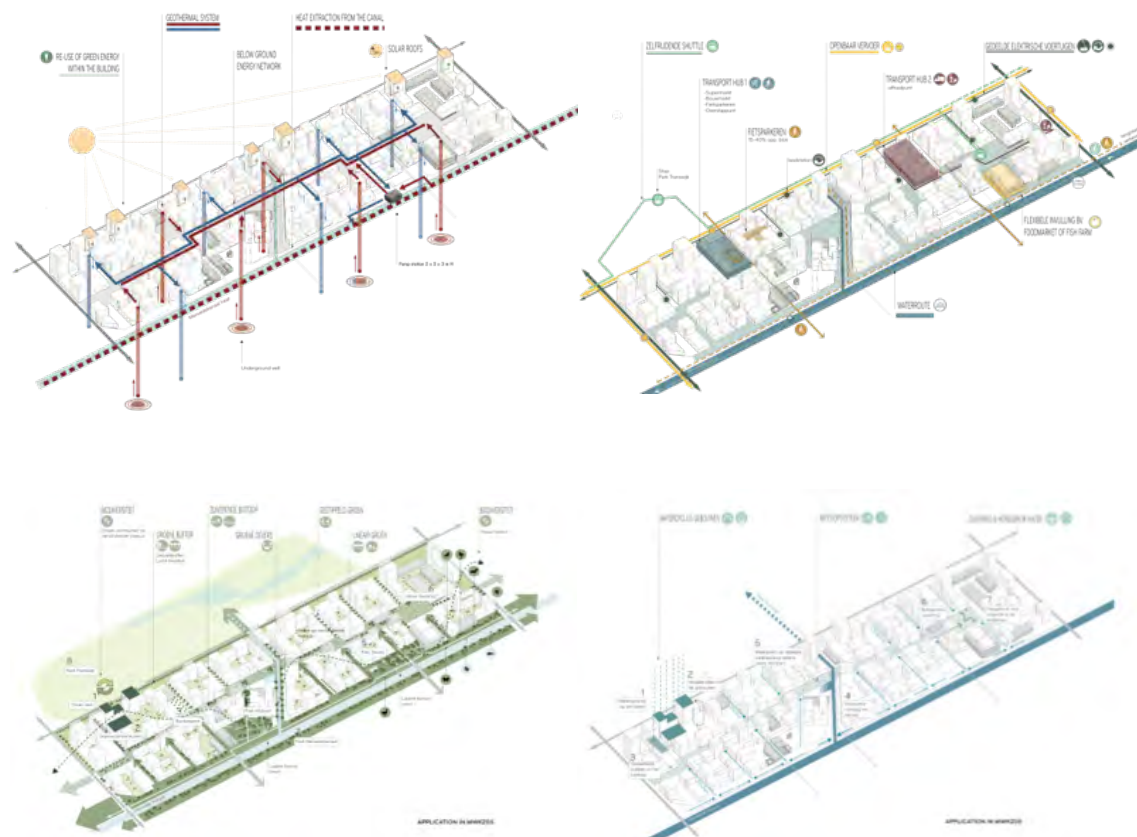


Figure 5 Climate adaptive solutions and circular integrated in the plans for Merwede (OKRA, 2018)

#### 4. Towards healthy cities

The base of the above mentioned urban strategies is to enhance green and connected cities. Firstly, fundamental change is possible via rebalancing a city's mobility system, creating access for all, transforming public realm into a green-blue network and activating public realm to create vibrant city centres.

Secondly, the role of planting in this green-blue network is beyond aesthetics and has increased societal relevance. Planting is becoming increasingly important to tackle big societal, urban challenges such as climate adaptation, biodiversity and heat mitigation. Whereas traditionally

cities can be regarded as petrified landscapes, the integration of landscape and city can result in the creation of holistic cities.

Moreover, increasing urban densification and increasing complexity caused by the need to design and organise cities in a circular way, demands holistic green strategies. In fact, the city should be regarded as a system, connecting places with multi-modal and multi-functional corridors. Cities, like organisms, require inputs, such as water, energy, people and produce outputs, such as waste. The continuous exchange of energy, material, and population is essential to the way a city functions and can be regarded as a metabolism.

Finally, today's aspirations on including biodiversity in highly urban environments calls for the concept of 'urban biotopes'. The concept of urban biotopes regards a holistic approach in which planting, nutrients and water together form new urban ecosystems. Urban biotopes seem promising for designing cities in such a way that a balanced and holistic green system can evolve over time. Although urban biotopes require careful considerations about how to integrate energy production, underground infrastructure and mobility in such a way that proper conditions for urban green are set, the concept is very promising for the necessary development of long lasting green networks and resilient cities.

The design task today is to manage those exchanges in a responsible and sustainable way—considering and strengthening the urban metabolism and creating healthy cities. Entering a new era will require that once more the interaction to other fields of expertise will be key to find strategic solutions to new challenges. Mixing up and integrating all disciplines seems a fairly logic approach when working in this context. To find answers to today's complex challenges a clear vision and a strong collaboration between dedicated people on different fields of expertise is required.

Universal are the qualities that emerge from the landscape and that do connect us with mother earth, of change are the new programs that will be drivers for spatial adaptation. The creation of landscape cities today, being healthy and sustainable leads to interesting cities of tomorrow. It goes beyond blue-green networks: creating green that enhances urban biodiversity and brings nature to cities even in the densely built urban environment will be the next step in ensuring that cities are resilient enough to be a good place for working and living tomorrow.

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## **SPACE AND PLACE**



# A MULTI-CRITERIA DECISION ANALYSIS BASED FRAMEWORK TO EVALUATE PUBLIC SPACE QUALITY

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## Summary

Good public space are an inherent part of liveable cities. However, due to the complexity and ambiguity of the concept of public space quality, capturing essential characteristics to assess the quality of public space in a quantitative framework is not straightforward. In this paper, we introduce the Public Space Quality Index (PSQI), a Multi-Criteria Decision Analysis (MCDA) based framework to measure the quality of public space in a systematic manner. This paper discusses the development of our research methodology, which includes four key phases: criteria selection, criteria ranking and weighting, criteria quantification and criteria aggregation. We also present the results of the first phase, and discuss the main findings from an expert workshop we conducted with Singapore-based urban design professionals, as a validation and learning moment for our past and future work, respectively.

Keywords: public space quality, MCDA, urban design, evidence-based design



## 1. Introduction

Public spaces are essential in the creation of vibrant and sustainable cities: they are our platforms for social interaction, social mixing and social inclusion, facilitate the exchange of ideas, culture, and skills, support trade, leisure and tourist activities, and many other functions. As they define the fabric of urban life, there has been continuous interest in studying public space use and the design of qualitative public space, from various perspectives, in many different disciplines.

However, evaluating public space quality is not straightforward. A wide range of characteristics contribute to how humans perceive open spaces, from diverse dimensional properties such as geometry, topology and other physical attributes of the place, over the number and profiles of users of the space, the flexibility and multi-functionality of the space and its boundaries, and so on. Moreover, as is often the case in design, some of these characteristics are inherently and intricately interrelated, making it difficult to assess the contributions of each individual part to the quality of the whole.

Despite these difficulties, scholars in the field have always tried to inform design by means of guidelines and heuristics, requiring them to qualitatively and quantitatively describe and measure properties of public space. Canonical works of urban design, such as Jacobs (1962), Whyte (1980) or Gehl (1987), describe systematic examinations of (the reasons behind) different levels of liveliness in urban public spaces from a social use perspective, and how these relate to particular characteristics and design features of these spaces. In order to evaluate public spaces and inform design practice, the findings - or, if lacking, narratives - of urban design studies are often distilled into guidelines and principles, ranging from straightforward qualitative checklists (e.g. Gehl Institute, 2017; Carr et al., 1992), over multi-spectral frameworks (e.g. Montgomery, 1998; Gehl Institute, 2018), to comprehensive manuals (e.g. Llewelyn-Davies, 2000). In recent years, more comprehensive models to quantify, assess and score public space qualities have been proposed. Ewing and Handy (2009) developed operational definitions to measure five urban design qualities related to walkability (imageability, enclosure, human scale, transparency, and complexity), applied to (commercial) streets in the United States. Mehta (2014) developed a public space index based on 45 different variables to evaluate the quality of public space from five dimensions including inclusiveness, meaningful activities, comfort, safety and pleasurability. Varna and Tiesdell (2010) utilized various descriptors/indicators to evaluate public space based on the concept of publicness such as ownership status, walking opportunities, means of control and others. Other studies focus on the impact of a limited set of easily measurable criteria on human activity in public space; Beirao and Koltsova (2015), for example, put forward that a street's liveliness potential can be expressed in terms of the number of entrances in a street, the street length, and the territorial depth of building entrances. For a comprehensive overview of public space quality guidelines, measures and evaluations, consult Koltsova Jenne (2017).

While literature shows an increased interest in evidence-based, measurable guidelines and criteria for “good” public space design, there are still important research gaps to be bridged in our road towards informed urban design approaches and tools. We put forward four important limitations. Firstly, the level of validity is often unclear (in part due to the necessary reliance on case study research) and the range of applicability is often limited (because validation studies, due to their time-consuming nature, are restricted along public space types, locales, times, etcetera). As both limitations could be considered inherent to the topic, this implies that a robust methodology to evaluate public space quality ought to include extensive validation and cater towards extendibility, respectively. Secondly, while most public space design guidelines and evaluation methods aim towards the same goal (i.e., “better public space”), and there is a high degree of overlap between the criteria, characteristics or design ambitions they prescribe, the wide range and variety of used terms, descriptions and structuring categories makes it difficult to compare different methods and combine lessons or evidence provided by each individually. Together, point one and two have led to a fragmented landscape of results. Thirdly, the majority of evaluations and guidelines only qualitatively mention the important aspects for assessing public space quality, but seldom illustrate how to quantitatively measure each aspect in detail. Fourthly,

although some researchers may have attempted to quantify each characteristic of public space, they lack a systematic way to combine all important features into a score that can measure public space quality in a more objective manner. Evaluation methods that do propose a single score (e.g., Mehta, 2014) apply a simple weighted sum approach; for a complex topic like public space quality, relative weights can be easily criticised and should not be considered robust (Narula and Reddy, 2015). Moreover, a single score will not manage to capture the diverse differences in opinions and appreciations different users will have about the same public space. Carmona (2015) argued that one of the defining characteristics of the public spaces in a global city is the sheer diversity of spaces and overlapping typologies, and that more and more urban design professionals acknowledge that there is no such thing as an “ideal public space” that suits all users, implying a paradigm shift from a “public realm that is equally appealing to all” towards “an acceptance that users are diverse and will seek different things from their spaces”.

With these limitations in mind, we are developing the Public Space Quality Index (PSQI), a Multi-Criteria Decision Analysis (MCDA) based framework to quantitatively measure the quality of public space. It is a systematic attempt to integrate a comprehensive list of criteria of public space into scores that can be used to compare and rank different public spaces. Our ambition is to create a methodological framework that is:

1. **Incremental**, so a sub-set of criteria and related design guidelines can be developed at a time;
2. **Extendible**, so more criteria can be added at a later stage;
3. **Adaptable**, so others can use it in their contexts, using their particular design guidelines;
4. **Coherent under change**, so it will be possible to compare scores for different user groups or expert types, but at the same time provide a single, robust score for per public space, based on criteria that are crucial for everyone, including a degree of uncertainty.

Figure 1 illustrates the goal we are working towards. Each entry in the top-right chart shows the range of scores of public spaces in the neighborhood below, under various assessment and weighting scenarios that represent the preferences of particular user groups. In this example, we highlighted two user groups, school children (A) and seniors (B), but any group could be included in the scoring model, be it climate comfort experts, government agencies, or parents.). Because each group rates values criteria differently, they score each space differently. Assessing many user groups (or many individuals) will allow us to plot all public space quality scores; if a score is consistently high among different users, it is likely that this public space has a high general quality – this is indicated by the yellow dots of the box plot graph in the illustration. What we end up with is both an indication of how well a space supports diverse user needs, as well as a robust, general score that indicates if a space does well for many. This can in turn inform the design of networks of diverse public spaces, some with general appeal, others catering to particular users. Note that, although the general framework we are developing can be expanded to different countries, we are focusing on the PSQI for use in Singapore in this work.

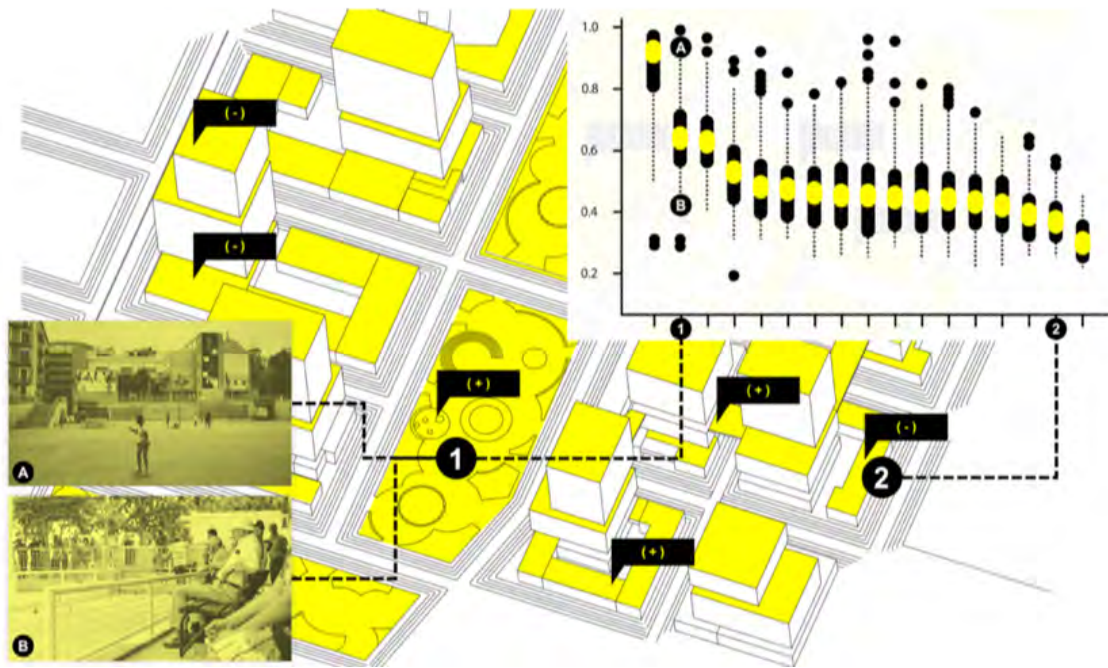


Figure 1. Illustration of the goal we are working towards: a framework that can demonstrate of how well a space supports diverse user needs, as well as a robust, general score that indicates if a space does well for many.

In this paper, we present the results of the first phase of the development of the PSQI. We start by describing the four phases of our methodology to build this systematic MCDA framework (i.e. criteria selection, ranking and weighting elicitation, criteria quantification, and criteria aggregation). We continue by discussing the selection of our initial list of criteria and our first test: an expert workshop to both get feedback on our set of selected criteria, and try out a number of rank and weight elicitation methods in preparation for phase two. Concluding remarks and possible future directions are given and discussed in the last section.

## 2. A Methodology to Derive a Public Space Quality Index

Multi-Criteria Decision Analysis (MCDA) represents a collection of instruments and methods to understand the structure of a decision-making problem and the multitude of dimensions that characterise it. MCDA helps the decision makers investigate complex problems with qualitative-quantitative attributes, using open and explicit judgement criteria to obtain better informed and justifiable choices. It has been widely employed to solve problems in different areas, such as environment (Soltani et al., 2015), sustainability (Zavadskas et al., 2015), and urban planning (Curwell, 2005a). Our proposed MCDA-based framework to evaluate public space quality has four consecutive phases, each of which will be explained in more detail in the following subsections.

### 2.1. Phase 1: Selecting Public Space Quality Criteria

In the first phase, researchers decide which characteristics of a public space (such as the shape, the number of trees and benches, ...) are relevant in describing its quality. Defining and selecting which public space characteristics will be quantified as criteria is done based on a literature review and discussions with urban design experts. The aim is to get a clear understanding of the problem that needs to be assessed using MCDA, the interrelations between its multiple criteria, and how these criteria are perceived (by experts, users, or other stakeholders).

Effective problem structuring and criteria selection are fundamental steps of the MCDA framework. We followed a set of guidelines for MCDA criteria selection developed by Akadiri and Olomolaiy (2012) and Akadiri (2013):

- **Comprehensiveness:** all the possible aspects of public space should be covered in order to assure a comprehensive evaluation list, i.e. criteria should be ideally selected based on what is desirable to measure not on which criteria is available;
- **Applicability:** the criteria should be generally applicable to assess public space quality as precisely as possible;
- **Transparency:** the criteria have to be easily understandable and selected in a traceable manner, so as to avoid misunderstandings and misinterpretations;
- **Practicability:** the criteria must be implementable and operational.

After developing an initial set of chosen criteria that together could define public space quality, this initial set of criteria is discussed by a panel of urban design and public space experts. It also enables testing a number of ranking and weighting elicitation methods in preparation for phase two. Section 3 discusses the development of our criteria list and the expert panel (under the form of a workshop).

## 2.2. Phase 2: Ranking and Weighting Criteria

When the criteria that determine public space quality have been selected, the next thing to determine is how much each one contributes to the overall quality, i.e. determining their rank and the relative distance between each rank (which reflects their weighting). This is commonly done based on a large sample survey. In our study, we plan to survey several different expert and user groups, in order to map out their different of the relative importance of particular public space characteristics.

As long as the rankings are obtained, there are various methods to elicit the weights, for instance, the rank sum weight method, rank exponent weight method, reciprocal method, rank-order centroid weight method and etcetera. Moreover, the original ordinal ranks can also be used as weight by simple normalization. In this work, we use multiple weighting methods to build different weighting scenarios based on the results from, as we aim to explore the impact of different weightings on the overall public space quality score.

## 2.3. Phase 3: Quantifying the public space characteristics

This phase determines how to translate each criterion into a 0 to 1 score (i.e. how to quantitatively measure them). In addition, the value function of each criterion is determined, which is a mathematical presentation of people's judgement on the criterion. For example, a measured score of 0.5 for a criterion might already represent 90% of the value that criterion adds to the total score. This value function elicitation is again based on a survey of the same groups surveyed in phase two (and could be part of the same survey).

There are several common approaches in building the value function, such as direct rating technique, curve fitting, bisection techniques and many others (Stewart, 2005). However, the construction of a value function for every evaluation criterion in the framework is not an easy task. On one hand, finding a value function (monotonic or not, continuous or discrete, linear or convex, etc.) to correctly describe the essential property of one criterion is demanding, especially for those criteria that are hardly measurable (e.g., human scale). On the other hand, different user groups or experts can have different perceptions of the same criterion and thus it is possible to have multiple value functions per criterion - though this is not commonly done in MCDA, it is necessary to explore variations in user group appreciation of public space.

To tackle the first difficulty, we will not only tailor the value function for each criterion based on a thorough understanding of its property using traditional methods such as direct rating technique,

but also plan to embrace new technologies to create and represent different virtual public spaces as a parametric 3D model. In this way, survey participants can change criteria and directly see how it is represented in a virtual representation. For example, suppose we want to obtain the value function of criterion *Secure*, we can check the participants' perception of "feeling safe" by showing them with different numbers of cameras, asking the question: "to what extent do you feel protected against harm, not all – could be better – good enough – good?"

To tackle the second challenge, we will obtain different value functions from different user profiles to understand the various needs and requirements among different groups of people. Moreover, it is possible that even the participants in the same user group will provide different values functions, thus we adopt a similar strategy as the Stochastic Multiobjective Acceptability Analysis (SMAA) developed by Tervonen & Figueira (2008) to explore the whole space of parameters (and related criteria and valuation).

## 2.4. Phase 4: Criteria Aggregation and Public Space Quality Index

The final step aggregates all the criteria into a public space quality score using their respective weights and value functions obtained from surveys. We will use a weighted-sum aggregation method in this work, commonly used in MCDA literature. Unlike most methods, because we will elicit criteria weights and value functions from many different user groups, we will also be able to map how public spaces score for different user groups, and determine a single, robust score representing the "general appeal" of these spaces.

There are a range of alternative aggregation methods in MCDA, but the simplest and most used one is the additive model, as shown in Equation (1):

$$V_{k,j}(p) = \sum_{i=1}^m w_{ik} v_{ij}(p) \quad (1)$$

where  $V_{k,j}(p)$  is the quality score of public space  $p$ ,  $k$  is the  $j$ -th weighting scenario of criterion  $i$ , and  $v_{ij}(p)$  is the  $i$ -th value function of criterion  $i$  which reflects experts' preference of public space  $p$ 's performance on criterion  $i$ .

However, when using multiple criteria to model the quality of a complex subject, such as public spaces, the criteria will likely have some interdependency, i.e. some might positively or negatively reinforce others. Interactions between criteria (Stewart, 2005) is an important issue in MCDA and will be factored in to obtain a more accurate quality score. In order to do this, we revise Eqn. (1) as follows:

$$V_{k,j}(p) = \sum_{i=1}^m w_{ik} v_{ij}(p) - \frac{1}{2} \sum_{i=1}^m \sum_{t=1, t \neq i}^m \beta_{ti} \sigma_{ti}(p) \quad (2)$$

where  $\beta_{ti}$  represents the interaction between  $i$ -th and  $t$ -th criterion with a value of  $\beta_{ti}$ , meaning no interaction, positive interaction and negative interaction respectively;  $\sigma_{ti}(p)$  demonstrates the extend of such interaction which can be measured qualitatively, e.g. a "weak-mild-medium-strong-very strong" scale has corresponding value of 0.1, 0.3, 0.5, 0.7, 1.

## 3. Results and Discussion

### 3.1. Initial Set of Public Space Quality Criteria

Following the guidelines discussed in Section 2.2, we have done an extensive literature review of topics on public space, public space quality, public space assessment and related sources (in part reflected in the introduction). We developed an initial list of 19 public space criteria in



a first attempt to develop a comprehensive set (with comprehensive implying it should capture the factors commonly influencing quality). Part of this 19-criteria list and their corresponding description are shown in Table 1, per illustration.

*Table 1. Public Space Quality Criteria*

ID	Criteria	Description
1	Flexible use	The space use is not strictly predefined or regulated what activities can take place, or if users can improvise uses or rearrange urban furniture.
2	Interactive boundaries	Interactive boundaries support active, passive, and social engagement (e.g. facade transparency, shopfronts, visually interesting boundaries, ...).
3	Maintenance and cleanliness level	The maintenance and cleanliness level of the space. Also refers to surface materials, finishes, correct choice of materials, ease of maintenance, accessibility for maintenance
16	Supports active engagement	The space can invite people for physical activities which may include: areas for active activities (sports, exercise, play); interactive water features; interactive green features (grass, sand, climbing trees, ...)
17	Supports passive engagement	The space can invite people to observe the space which may include: presence of water feature; trees; green feature; interesting views; opportunities for "people watching"
18	Supports social engagement	The space can invite people to interact socially which may include: grouping of seating that allows conversations; opportunities for communal/group activities, opportunities to eat/drink in group; opportunities for the exchange of goods (e.g., market)

### 3.2. The Expert Workshop

The expert panel to assess our initial list of criteria and prepare for the second phase of the PSQI development took the form of a 90 minute expert workshop. We selected and invited several Singapore-based experts in urban design and public space use, resulting in a group of 14 experts (practitioners and academics) with various backgrounds (small and large offices, specialists in mobility, thermal comfort, human cognition, ...) and a balanced gender and (non-)Singaporean ratio.

The goals of this workshop were: firstly, to discuss the soundness and completeness of the list of criteria we proposed; secondly, to get an initial set of results that rank and weight this list; thirdly, to understand the extent to which different experts differ in opinion on public space quality, and how comfortable they are quantifying something of a complex and qualitative nature. Note that while we obtained ranks and weights for our criteria list, these results are only used to inform the development of Phase Two of this study.

**Part 1: discussing and extending the criteria list.** After a short introductory presentation of our research goals, we introduced our criteria list to the experts, describing and explaining each criterion individually. We then opened the floor for discussion. The experts generally agreed on the proposed list, but suggested adding two more criteria to the list – "Inclusion and Social Justice" and "Visual Attractiveness". With these added, there was general consensus on the resulting list of 21 criteria (with the caveat that the phrasing would need more clarity).

**Part 2: individual direct scoring of the list of 21.** In the first exercise, we asked experts to directly score each criterion in our extended list, using a pre-made electronic survey. Experts

answered the question “How important do you think the criteria are for good public space design?” on a 0-6 scale, where 0 meant “not important at all” and 6 meant “extremely important”. This short task gave them time to familiarise themselves further with our list of criteria, and put an initial - individual - value on the importance of each criterion in terms of its contribution to public space quality. The survey results were then aggregated, and the criteria list ranked by descending average score (see Figure 2, right panel). The three most highly rated criteria were “Human Scale and Reference”, “Pedestrian Accessibility” and “Supports Social Engagement”; perhaps surprisingly, rated least important to public space quality were “Smell”, “Supports Active Engagement”, and “Flexible Use”. Aside from testing a direct scoring method to elicit ranks and weights, done individually as if it were an online survey, this part of the workshop also gave us an average rank of importance for our list of 21 criteria.



Figure 2. Left pane: workshop participants voting on criteria in the co-creative Swing method. Right pane: ranked average scores for 21 public space quality criteria (direct scoring).

**Part 3: co-creative Swing method.** The second, most important and final exercise of the 90-minute workshop required the experts, now split into two representative groups with a moderator each, to rank and weight criteria together, reaching consensus for each decision. This co-creative exercise can also enable the researchers to observe and analyze the differences in opinion between experts. The format is an adapted version of the traditional Swing method (e.g. Montibeller and Franco, 2007), which is an individual weight elicitation method. For the exercise, the experts were required to follow the following steps:

1. Consider the first four criteria on the ranked list resulting from the previous exercise. Now imagine a very bad public space, one that performs poorly on all these four criteria. (The moderator would put the four considered criteria in the center of the table and ask the questions.)
2. Decide which of the four criteria you would like to change from their worst to their best condition in order to make this a better public space. This first, most important criterion gets 100 points as a score.
3. Add the next highest criterion from the ranked list to the table, to again have four criteria to compare. Choose the next most important criterion to be improved, assuming all the criteria are at their worst. This criterion needs to be scored (0-99), but always lower than the previously selected criterion. The participants are asked to first write their score on a post-it note and paste it under the criterion they think is most important; this brings forward their individual opinions before having to reach consensus (see Figure 2, left pane). They are then asked to debate their choices, and reach consensus on which of the four criteria to select, and how to score it. The recorded difference between individual and group opinions can shed light on group dynamics in decision making.
4. Repeat Step 3) until all the criteria have been scored.

The ranked list of 21 criteria resulting from the previous exercise allowed us to develop a much shorter Swing method exercise (required due to time constraints): firstly, we limited this exercise to the top 12 criteria from the list; secondly, we introduced a moving bracket of 4 criteria to choose from (as explained above), rather than all criteria as per the standard Swing method - this is only possible because we start from a pre-ranked list. In addition, at any time an expert could nominate an additional criterion into the selection bracket if they thought it was equally important than the current four.

The experts were divided into two groups in order to compare differences between groups. Table 2 shows final ranking results of group A and B, the scores per criterion, and the rank differences (A to B). As can be seen, the experts in both groups emphasized the importance of Inclusion and Social justice, Human Scale and Reference, Pedestrian Accessibility, and Supports Passive Engagement, which almost aligns with the Top 5 criteria from the first exercise. This may reflect the preference of the experts for more human-oriented criteria. Low priorities for Lighting, Security and Safety, and difficult debates, may be related to the context of Singapore, which is highly secure by default. The rank difference (last column) shows a relatively similar ranking between both groups. Surprisingly, Thermal Comfort has the largest rank difference. This is likely because it was only the 12th and last criterion in the initial list (despite its importance in a tropical city), but Group B (which included a thermal comfort expert) decided to nominate “thermal comfort” into the selection bracket early on. The large difference in the range of scores given by both groups is due to a (spontaneous) decision by group B to scale their allocated scores over a wider range after finishing their exercise.

The differences in ranks and scores demonstrate that different experts have quite varying preferences when it comes to public space quality. Nevertheless, we also observe that the rank difference between the groups is not that big, with strong outliers more likely caused by the exercise format than anything else. Moreover, the relatively small difference in score between many criteria, and the discussions they emerged from, seems to suggest that the criteria on the list of 21 are indeed deemed crucial to public space quality.

*Table 2. Results of the Co-create Swing Method.*

Group A Result		Group B Result		Rank Difference
Rank. Criteria	Score	Criteria	Score	[A-B]
1. Inclusion and Social Justice	100	1. Human Scale and Reference	100	2
2. Human Scale and Reference	99	2. Pedestrian Accessibility	95	1
3. Supports Social Engagement	89	3. Inclusion and Social Justice	80	3
4. Pedestrian Activity	84	4. Thermal Comfort	79	2
5. Supports Passive Engagement	83	5. Supports Passive Engagement	75	0
6. Visual Attractiveness	82	6. Supports Social Engagement	72	4
7. Proximity to Diverse and Vibrant City Life	79	7. Proximity to Diverse and Vibrant City Life	71	0
8. Pollution	78	8. Pollution	60	0
9. Thermal Comfort	77	9. Security	55	5
10. Lighting	74	10. Visual Attractiveness	52	2
11. Security	71	11. Safety	50	2
12. Safety	69	12. Lighting	35	1

#### 4. Conclusion and Future Work

In this paper, we presented a systematic Multi-Criteria Decision Analysis framework to evaluate the quality of public spaces. We discussed the essential steps of our methodology in detail and illustrated the first steps of the methodology: a set of public space quality criteria, and the results

from an expert workshop. The workshop serves as an important linkage between the first phase of the research and second phase; some relevant lessons learnt were:

- Our list of 21 criteria was deemed comprehensive by these 14 experts; within the list, there were clearly more and less important criteria.
- While expert opinion varied strongly in individual scoring exercises, consensus (and changes in opinion) were not difficult to reach; this is something to take into account when eliciting weights and values from individual surveys.
- It is difficult to rate the importance of very qualitative, context based criteria, let alone quantify them or elicit a value function. Hence, we decided to develop a better, context based survey using a parametric 3D model for easier value function elicitation.
- Clear language is crucial when describing criteria. Nevertheless, even clear language is open to fuzzy interpretation. It is also strongly tied to particular (urban design) ambitions a criteria describes. In order to reduce the risk of interpretation, we are exploring a criteria list that only uses design guidelines to inform, but directly generates total scores from individual indicators.
- The participants lauded the workshop format, and the majority spontaneously asked to remain updated on the work, which illustrates interest in the topic of quantifying public space quality.

Integrating the lessons learnt, we are now in the process of finalising the criteria list and the ranking method to build our survey for the final case study, in which will be the scoring of a set of public spaces in Singapore. We have already gathered different types of data such as temperature, humidity, people's count and etc. from the sensors deployed in Jurong East in Singapore. We are also designing methods to collect data for the other public space design characteristics in our framework. All of this data actually capture the unique Singapore-based context and culture, and hence it would be important to collect and use different data when applying our framework to other countries with different cultures.

Our proposed methodology could eventually serve as a tool for various stakeholder groups, such as the urban designers and policy makers, to evaluate and compare public spaces designs in a more quantitative way. It will enable them to explore expected qualities and user appreciations of public space, both in terms of a diverse range of needs, and in terms of general quality. Nevertheless, it is important to stress that the PSQI is not an attempt at developing a "perfect recipe" for public space design; our ambition is to inform design by exploring how a comprehensive set of relevant criteria influences the appreciation (and behavior) of different user groups. We believe this tool cannot be exhaustive in its quantification, or in its influence on design or materialization.

Finally, note that while the PSQI is developed as an independent tool to assess public space quality in this work, it has also been designed to be incorporated into an integrated model to simulate the potential presence of people in public spaces. We refer interested readers to Herthogs et al. (2018) for details on this model.

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# FACTORS INFLUENCING URBAN OPEN SPACE ENCROACHMENT: THE CASE OF BLOEMFONTEIN, SOUTH AFRICA

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## Summary

Rapid changes in land use and occupancy patterns on urban open spaces have led to value conflicts in terms of the quest for sustainable neighbourhoods. Urban open spaces are becoming extinct due to rapid urbanization hence affecting the spatial patterns of urban land use. Such gradual disappearance has resulted from intensity of land use for residential, business, community facilities, etc. This has created challenges in terms of the value and sustainability of open spaces, land use management and preservation. The study seeks to explore, in its entirety, the incidence of open space encroachment in Mangaung Township, Free State Province of South Africa. Adopting a case study approach, this study deploys a variety of techniques like focus group discussions, face-to-face semi-structured interviews and personal observation for data elicitation at different intervals. Individual semi-structured interviews were conducted with purposively recruited town planning, land invasion and environmental management professionals from local and provincial levels of government. Discussants for the focus group discussions consisted of community members who have encroached upon open spaces and those occupying properties around open spaces. Happenings within the study area were observed at intervals and memos drawn therefrom. The accruing data was analyzed thematically, relying on qualitative content analysis (QCA). The study's findings, besides the provision of an insight into the drivers of this malaise, chronicles the plethora of strategies which have been adopted and implemented to curtail its continued occurrence, highlight the strengths and weaknesses of these strategies and proffer recommendations on how to optimally surmount this imbroglio. Findings indicate that the high cost of the available land for housing, poor sustenance and management of the available housing stock by municipality officials, non-participation of community members in planning processes, and poor enforcement of land use regimes remain salient contributors to the preponderance of open space encroachment. This study's findings hold immense implications for planning practitioners as well as other professionals and policy makers working within the urban planning and socio-economic development praxes both within the province and beyond.

Keywords: participation, South Africa, strategy, sustainability, urban open spaces,

## **1. Introduction**

Urban open spaces form integral aspects of land use planning. From a sustainability perspective, they are viewed as critical to the environment and quality of life. Campbell (2001) states that open spaces make cities attractive and viable places where people live, work and play. Accordingly, town planning guidelines dictate that developments must comprise of open spaces even though no criteria on the number, location and usage of these spaces is provided. During land use planning, different land uses are allocated to built-up and non-built up environments. According to Maruani and Amit-Cohen (2006), built-up environments include residential, industrial, commercial areas whereas the non-built environments comprise of open spaces. Turner (1992) reiterates the importance of the usage of the term “open space” which was employed for the first time by the London 1833 Select Committee on Public Walks. The Open Space Act 1906 (1906:11) defines an open space as “any land, whether enclosed or not, on which there are no buildings or of which not more than one-twentieth part is covered with buildings, and the whole or the remainder of which is laid out as a garden or is used for purposes of recreation or lies waste and unoccupied”. Mashalaba (2013:40) defines an urban open space as “a piece of land, either developed or pristine, that is either existing or planned to maximize the ecological integrity of an urban area by sustaining both urban and natural ecosystems; while improving the quality of human life in both social and economic terms”. Accordingly, parks, gardens, wetlands, allotments, trees and forests or grasslands in urban areas can be described as urban open spaces.

Rapid changes in land use and occupancy patterns on urban open spaces have led to value conflicts in terms of the quest for sustainable neighbourhoods. Urban open spaces are becoming extinct due to rapid urbanization hence affecting the spatial patterns of urban land use. The gradual disappearance of urban open spaces is evident in the increasing emergence of informal settlements and urban sprawl. Also, intensity of land use for residential, business, community facilities, etc. have contributed to this situation. Mensha (2014) states that African countries such as Kenya, Nigeria, Ghana, Sierra Leone, Senegal have lost urban open spaces due to rapid urbanization and urban sprawl. This has created challenges in terms of the value and sustainability of open spaces and land use management. Urban open spaces, as part of urban planning process, need to be controlled by the urban planning regulations yet planning jurisdictions in different countries still utilize outdated documents for this purpose. For instance, Mangaung Metropolitan Municipality in Free State, South Africa still relies on the Town Planning Scheme of 1969 in regulating land uses. Decision-making processes also take long, and this affects the development negatively and contributes to the encroachment of open spaces.

To achieve its objective, the rest of the paper is structured accordingly: theoretical perspectives; a review of literature on the following aspects: urban open spaces and sustainable neighbourhoods; encroachment of open spaces as a societal malaise; and the incidence of open space encroachment in Mangaung; justification of research methodology deployed; presentation and discussion of findings section, and; conclusion.

## **2. Theoretical Perspective**

The contents of this section emphasize the significance of open spaces in urban areas and its contribution thereof to the concept of sustainable neighbourhoods.

### **2.1. Sustainable neighbourhoods and open space planning**

Urban open spaces form an integral component of sustainable neighbourhoods. Socially, a neighborhood is seen as a “community” whereas the ecological stance focuses on the unique qualities of a target property. According to Al-Hagla (2008:2), the social perspective states that sustainable neighborhoods are communities that “meet the diverse needs of existing and future residents, their children and other users, contribute to a high quality of life and provide opportunity and choice”. From this definition, Campbell (2001) highlight different components,

namely, governance, transport and connectivity, services, environment, economy, housing and built environment, sociology and culture. In terms of ecological perspective, a neighborhood refers to an ecosystem created for humans and entails the microclimatic conditions. This area must provide comfort and sustenance to the target populace.

UN-Habitat (2001) identified principles for planning sustainable neighborhoods. These include (i) adequate space for streets and an efficient street network; (ii) high density; (iii) mixed land use; (iv) social mix; and (v) limited land use specialization. All these main principles of planning play a key role in fostering sustainable neighborhoods as they draw three key features, namely, vibrant street life which provides safe and vibrant neighborhood life, encourage walkability and affordability (Dehghanmongabadi, 2014). Urban open spaces play a significant role in achieving sustainable neighborhoods. In achieving sustainable neighborhoods, the key issues to be considered include space management, space function and landscape. Space management refers the sustainable lifestyle, community participation, sense of space and resource management. The space function focuses on car reliance and the need to travel, while sustainable landscape promotes self-sustaining and regulatory systems (Al-Hagal, 2008).

## **2.2. Encroachment of Open Spaces as a Societal Malaise**

### **Causal factors of urban open space encroachment**

Urban open spaces are faced with challenges that include rapid urbanization, poor enforcement of land use regimes, poor sustenance and management and low prioritization. These challenges have led to gradual disappearance of urban open spaces and have threatened sustainable planning of urban areas. Rapid urbanization is a major contributor towards urban open space extinction and a human rights-based approach to this can have a major impact to environmental sustainability policies (UN-Habitat, 2016). In planning, the implementation of land use regimes has been lacking especially in land earmarked for urban open spaces. Outdated land use schemes and delays in approval of land use change application hinders effective implementation for planning and development. Personnel (shortage and unskilled), financial constraints and political interference also contribute to poor enforcement. Poor sustenance and management of urban open space is another causal factor for encroachment. Arguably, this has resulted from the lack of involvement and education of the community about the value of open spaces. Mismanagement of these spaces have also led to underwhelming functionality performance thus resulting in environmental degradation. In addition, proper planning for open spaces is not highly prioritized hence encroachment. Evidence indicates a neglect of these spaces by the relevant authorities whilst focusing mostly on other social amenities (Mensha, 2014).

### **Measures to curb the incidence of encroachment**

Effective planning for urban open spaces contributes towards curbing the incidence of encroachment. Strategic and holistic plans as well as legal frameworks need to be formulated and implemented by authorities. Planners need to integrate urban open space infrastructure needs to their urban frameworks. Involvement of different stakeholders and community participation have also played a crucial role in planning for urban open spaces thus managing encroachment in that it increases the sense of place and ownership among the residents (Haaland and van den Bosch, 2015; World Health Organisation, 2017). When planning for urban open spaces, the social dimension of sustainability must be considered. This can be achieved by linking neighbourhoods, urban open spaces and the community assets to address accessibility issues/challenges. The community members must be educated about protection and conservation of urban open spaces in order to address the ecological dimension of sustainability. Urban open spaces must fulfil the goal for environmental sustainability and create opportunities for recreation and health and thus indirectly achieving the economic dimension of sustainability (Lindsey, 2003). In this instance, planners play a critical role in evaluation of the environmental and social impact on the environment. The plans done by planners during the planning process must support the principles

of sustainability and must be shared with the community during the community participation process with the aim of promoting community sustainability (Berke and Conroy, 2000).

Other countries like China have a variety of policies for the management of urban spaces. This includes policies like “Afforestation Project for the Plains of Beijing” and the “Urban Green System Planning of Beijing (2004- 2020)”. These policies failed to achieve the goal of controlling urbanization. Other policies used for the use and management of open spaces include the Urban Green Space Work Plan. This was also used in Beijing to increase urban open space area through implementation of the 2016 Urban Greening Work Plan. Beijing also uses the “Green Line Management System” to control the changing of urban open space into other land uses (Li et al., 2016).

### 2.3. Understanding the Incidence of Open Space Encroachment in Mangaung

Mangaung is one of the metropolitan municipalities in South Africa with the population of approximately 747 431. It covers 9 887 km<sup>2</sup> and comprises three prominent urban centres, which are surrounded by an extensive rural area. It consists of Bloemfontein, Botshabelo, Thaba Nchu, Soutpan, Dewetsdorp, Wepener and Vanstadensrus (Figure 1.1). It is centrally located within the Free State and is accessible via National infrastructure including the N1 (which links Gauteng with the Southern and Western Cape), the N6 (which links Bloemfontein to the Eastern Cape), and the N8 (which links Lesotho in the east and with the Northern Cape in the west via Bloemfontein) (MMM Reviewed Integrated Development Plan 2015-16:65, Mangaung Metropolitan Municipality Integrated Development Plan, 2017/18).

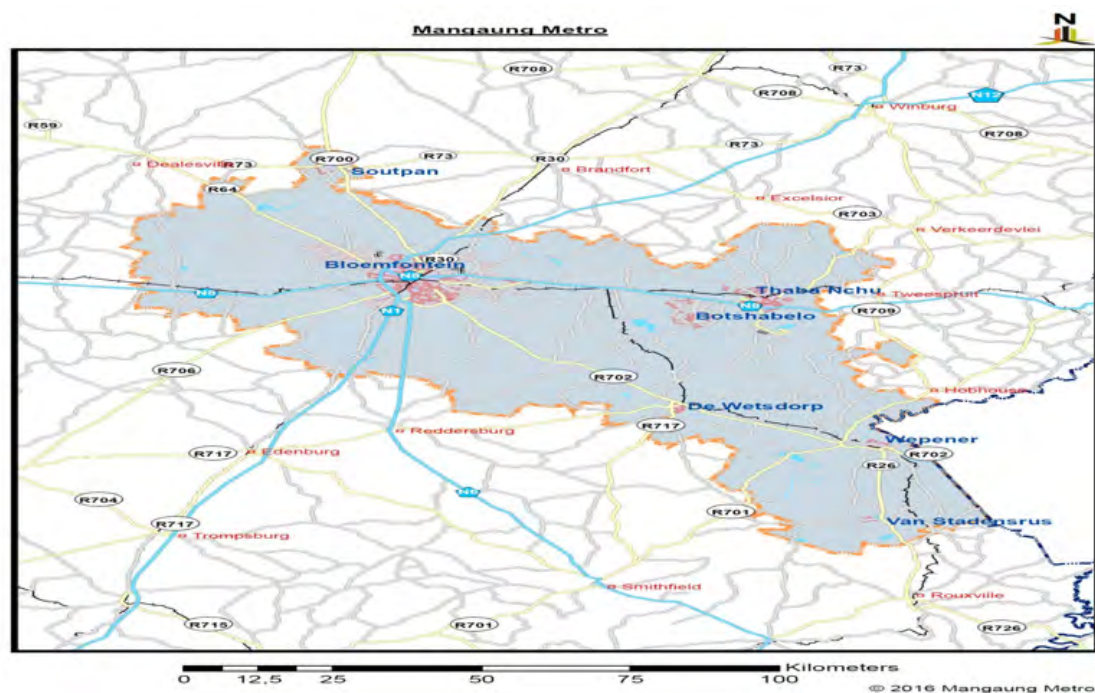


Figure 1.1 Map of Mangaung Metropolitan Municipality, Free State, South Africa

Mangaung is experiencing a high rate of urban open space encroachment which is mostly caused, among other factors, rapid urbanization. UN-Habitat (2016) states that urbanization plays a key role in eradicating poverty when it is planned properly and managed. Highly urbanized countries are always associated with low levels of poverty as a lot of people have escaped from poverty due of urbanization. This is due to higher levels of productivity, employment opportunities, improved quality of life and access to improved infrastructure and services (UN-Habitat, 2016). The municipality took a resolution in August 1998 in one of its Council Meetings that families



illegally residing on erven (properties) with the land uses other than “Residential” in areas for which the town planning has already been finalized as well as other existing or future townships areas, will not be accommodated in terms of town planning, surveying and the provision of services. However, this is now not the case because an exception is made on each land use application lodged for informal settlement upgrading on urban open spaces. Urban open space encroachment on municipal land has become very common in Mangaung. In such instances, both the Planning and Human Settlements Directorates will follow all the planning processes to formalize those areas

### **3. Methodology**

The main objective of the study is to explore, in its entirety, the incidence of open spaces encroachment in Mangaung Townships, Free State Province of South Africa. The study took a qualitative stance and adopted a case study approach with a variety of techniques like focus group discussions, face-to-face semi-structured interviews and personal observation for data elicitation at different intervals. Creswell and Poth (2018) state that a case study approach explores a contemporary bounded system through detailed, in-depth data collection through the deployment of a coterie of techniques like observations, interviews, documents, etc. The selected cases are subsequently described, understudied and analyzed. Individual semi-structured interviews were conducted with purposively recruited town planning, human settlements, land invasion and environmental management professionals from local and provincial levels of government. Discussants for the focus group discussions included community members who have encroached upon open spaces and, those occupying properties around open spaces. The selected members form part of the ward committees governing the study area. Personal observations were conducted around the study area to get first-hand information on the state of urban open spaces in Mangaung. The observations were also undertaken from memos drawn thereof. Due to personnel constraints at local government, 10 individual semi-structured interviewees were involved in the study. The accruing data was analyzed thematically relying on a set of pre-set themes that evolved from literature.

### **4. Presentation and Discussion of Findings**

The findings from the study will be discussed concurrently according to the thematic areas. These themes form part of the causal factors influencing urban open space encroachment. Two themes were selected for discussion: rapid urbanization and poor enforcement of land use regimes.

#### **4.1. Rapid urbanization**

Rapid urbanization has resulted in extinction of these open spaces. Urbanization is caused by a variety of factors that include rural-urban migration, natural population increase, expansion of the metropolitan periphery and illegal occupation of land (Cohen, 2006). Rapid urbanization has refocused attention on planning. This has led to different perceptions or value conflicts by different urban stakeholders regarding urban open spaces. These perceptions include categories such as the economic, recreational, environmental and housing values. These value conflicts around urban open space make it extremely difficult for planners to achieve the objectives of planning. Literature highlight that some West African countries like Nigeria, Ghana, Senegal, Sierra Leone have lost urban open spaces due to rapid urbanization. Beijing, for instance, has experienced a similar challenge in 2014 where it lost some urban open spaces due to rapid urbanization (Mensah, 2014; Li, et al, 2016). This is also evident in Mangaung as the interviewees and the discussants (people residing around the urban open spaces) support the notion that their townships are losing urban open spaces due to rapid urbanization. The residents and municipal officials indicated that most people encroaching urban open spaces are non-South African citizens and people from all over the country in search for better quality of life. Some of the discussants indicated that they

have lost the urban open spaces surrounding their properties because they have not been used for the initial land use. This is affecting the spatial patterns of urban land use.

The actual perpetrators of the encroachment indicated that they understand that there is value for urban open spaces, but their major concern is *shelter*, that is, proper housing with basic services. Solution to their challenge is encroachment on urban open spaces with the perception that local government will provide adequate or formal housing for them with basic services. Speak and Tipple (2006) argue that people living in informal settlements where there are no proper basic services may be included on the category of homelessness. Homelessness can also be classified as rooflessness, houselessness, insecure accommodation and inferior or substandard housing. Speak (2004) states that homelessness manifests itself as destitution which is mostly due to extreme poverty, isolation and shortage of societal resources. Homelessness can be defined in terms of categorisation, that is, supplementation, survival and crisis management. Some of the people who encroached these urban open spaces are family men who left their rural homes in search for better job opportunities. They stay in informal settlements and send their income to their families. This is referred to as supplementing rural livelihood. Some fall under the survival strategy of homelessness which originate from the supplementation strategy in that the survival homeless people also migrate from rural to urban areas in search for jobs. Most of these people left their homes with the intent to work for their families but they are often unable to send enough money to their families for better survival. Due to the lifestyle of staying in informal settlements, it becomes impossible for them to go back to rural areas and connect with their families (Speak, 2004). During the discussion, some of them indicated that they have more than 20 years staying in shacks without water and electricity. They are promised proper housing with basic services on yearly basis but are unsuccessful.

Another argument of the encroachers on urban open spaces is inability to afford proper housing hence choosing informal settlements. Goal 11 of Sustainable Development Goals (SDGs) is to "Make cities inclusive, safe, resilient and sustainable" (United Nations, 2016). This goal includes ensuring access for all to adequate, safe and affordable housing (SDG11.1). This is fundamental to inhibiting and addressing the problem of homelessness or residing in informal settlement. Homelessness is part of inadequate housing that remains a global sustainability challenge. Provision of adequate and affordable housing to citizens is a major challenge of urbanization and can result into homelessness. People who have encroached urban open spaces also lack access to basic services, which is a constraint and a cause for homelessness. Homelessness represents one of the extreme forms of deprivation and exclusion. It is a critical factor for persistent poverty and exclusion globally. This is a challenge for sustainable and inclusive urbanization (UN-Habitat, 2016 (a), (b) and (c); 2005). Lastly, some of the discussants are unable to secure an initial foothold in the economy. They have migrated from rural to an urban area in search for better job opportunities but be unsuccessful, due to acute poverty, unsustainable dependency and lack of alternatives. They opt not to return back home and settle to encroach urban open spaces because they believe they will be allocated adequate housing (Cross and Seager, 2010; Somerville, 2013; Nooe and Patterson, 2010; UN-Habitat, 2000).

#### **4.2. Poor enforcement of land use regimes**

The Spatial Planning and Land Use Management Act (2013) states that the municipality must have a land use scheme to enforce law to all stakeholders. Issues that lead to poor enforcement include the dysfunctional nature of land use regimes and delays in decision-making processes in planning applications. Mangaung is challenged with poor enforcement of land use regimes that led to encroachment in urban open spaces and it was confirmed by the interviewees and discussants of focus groups. Areas that were earmarked for "parks" were encroached for residential purposes. Other urban open spaces are already rezoned for residential purposes whereas others are still in the process of being rezoned for residential purposes or are left open because they are inhabitable. Rezoning by replacement of informal shacks with formal housing in planned and serviced townships reveals that there is a gap between town planners' assumptions and reality (Watson:2002). The discussants affected by the loss of urban open spaces argue

that the municipality is failing them in that they allow encroachment by infill development. Infill development refers to the residential development occurring within the existing residential area (Rowley and Phibbs, 2012). Some of these spaces for infill development are referred to as opportunistic spaces. Maruani and Amit-Cohen (2007) classify opportunistic spaces under the opportunistic planning model which refers to the pattern where urban open spaces emerge due spaces left over after systematic planning process. These spaces are usually left over because they are either small, irregular or inaccessible for other land uses and can be poorly suited to be used as urban open spaces. Also, due to shortage of personnel in the municipality, interviewees confirmed they are challenged with poor enforcement of land use regimes. Should there be any encroachment, they cannot act promptly to evict land invaders of municipal land.

Olufemi (2004) confirms that land invasion and eviction is a challenge for land, housing and planning policy makers. Land invasion occurs due to desperation of space for shelter and is persistent because people lack resources to build their shelter formally and legally. Land invasion is led by poor enforcement of land regimes because urban open spaces are not used for their initial land use. People encroaching urban open spaces in Mangaung indicated that they invade these spaces because there is no proper enforcement of land regimes. They have seen properties that were zoned for recreational purposes, schools, commercial being rezoned for residential purposes. Some indicated that they have been on the “waiting list” for more than 10 years without provision of proper housing. The only way for housing allocation is continuous land invasion. Currently, some of the actual perpetrators of encroachment have been allocated properties with basic services on the land they have encroached.

## 5. Conclusion

Rapid changes in land use and occupancy patterns on urban open spaces remain a major concern in planning and development. This study seeks to proffer patterns for avoiding the incidence of open spaces encroachment in South Africa. Focus of the study is in one of the townships in Mangaung, Free State because there has been recurring gradual disappearance of urban open space due to encroachment for residential purposes. Semi-structured interviews focus groups and personal observations were used for data elicitation. Findings indicated that the incidence of urban open space encroachment is prevalent. Mangaung townships has lost some urban open spaces due to rapid urbanization and poor enforcement on land use regimes. The different stakeholders involved in planning have different perceptions on the uses and values of urban open spaces and these include economic, recreational, environmental and housing. This indicates that there are different value conflicts and it makes it difficult for the planners and other professionals to achieve the planning objectives for urban open space and for other issues, such as housing and land use management. In addition, collaboration between municipal officials during planning processes will assist in facilitating sustainable environments. As such, planners have a critical role to play in terms of promoting sustainable neighbourhoods and this includes formulation of policies that would curb the encroachment of urban open spaces. Planners, other professionals involved in the planning practice and the community members, must consider sustainable development concept in shaping sustainable neighborhoods.

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## A NEW MODEL FOR PLACE DEVELOPMENT – BRINGING TOGETHER REGENERATIVE AND PLACEMAKING PROCESSES

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### Summary

This paper describes the bringing together of two practices, placemaking and regenerative development. Placemaking is a relatively recent term describing a city making movement focusing on the process of developing places through the active participation of the citizens that conceive, perceive and live in that place. It aims to create place attachment, a foundational concept of environmental psychology linked to positive outcomes in health, community participation, civic behaviour and perceptions of safety. Regenerative development is an approach to supporting design for place to focus on the delivery of vital, viable and resilient places, able to evolve over time to support all human and non-human life. In this paper, these two practices are integrated under the 'Place Agency' model. This model harnesses the key strengths from both practices, while providing ways to address their limitations. The research approach used to integrate the models was discursive grounded theory; where each practice, its rhetoric, its tools and case studies was looked at. The content was analyzed using inductive coding to identify potential synergies. The resulting model indicates that merging these two practices can deliver a place designed for both human and non-human participants, potentially shifting city making from a largely anthropocentric based practice. The combined approach supports the ability to look across history and its attributes to understand a place's potential while providing a method through which the community can actively participate in the city making process. Placemaking can thus become a strategy to bring forward this potential, test, play and evaluate regenerative initiatives, in context of spatial, temporal, social and ecological influences.

Keywords: placemaking, regenerative development, cities, human and non-human agency

## 1. Introduction

### 1.1. Aims of this paper

More and more people are moving into cities, as such it is important to create places that support the future of cities as places of living, working, creating and contributing. Designing for people is only one aspect of city making though. Incorporating strategies for nature integration and the non-human aspects of life is also critical, not just for their own sake, but for the wellbeing of the whole system including humans, who have an innate need to be connected to nature (Wilson, 1984). This paper brings together regenerative development and placemaking to create a **Living Environments**. In this paper, we define living environment as “*a setting that is thriving, healthy, and resilient because its ecological, social, and economic systems are continually nourished.*” (Plaut et al., 2016, p. 2). This paper outlines the two practices in question, then presents the methods used to bring them together exploring their key strengths, concluding with a suggested integrated framework.

### 1.2. What is placemaking practice

Placemaking is a worldwide practice focusing on the process of developing places through the active participation of the citizens that conceive, perceive and live in that place (Arefi, 2014). It aims to create place attachment, a foundational concept of environmental psychology linked to positive outcomes in health, community participation (Anton and Lawrence, 2014), civic behaviour and perceptions of safety (Billig, 2006). It is possible to conduct placemaking through formal (i.e. strategic placemaking) to informal (i.e. tactical urbanism) approaches. The key characteristics of a placemaking project are: 1) a process which puts emphasis on deep engagement with the community of an area; 2) the use of relatively small projects to trigger long-term benefits; and 3) the aim of improving life quality by developing social cohesion and place attachment that contributes to the planning and investment in public places (Kyle et al., 2004).

There is strong evidence (over five studies) that placemaking can foster place attachment in increasingly dense, diverse and mobile communities (Hidalgo and Hernandez, 2001; Lewicka, 2010; Scannell and Gifford, 2010). The strengths of placemaking lie in its adaptiveness to context, its ease and often affordable ways to reimagining spaces (PPS, n.d.). Successful placemaking efforts are often community-led or have undergone extensive community engagement where the ‘placemakers’ take the time to build a relationship with the people of that area. In many ways, the placemaker role is to provide a safe space for the community to voice their opinions and needs and subsequently works with them to come up with key initiatives.

Placemaking is simultaneously a process (of community engagement) and a product (which may or may not be a design). It can be a time-consuming practice in which trained facilitation, communication and listening skills are critical. Because time is often limited, placemaking projects can easily be superficial in their engagement and thus, fail to achieve the intended long-term benefits and can contribute to inequality and gentrification across communities (Fincher et al., 2016). What is needed is a way to think long term to integrate the ecological, or non-human aspects, and to develop capacity over time for the place; to strengthen not only itself and its stakeholders but the broader systems on which it relies.

### 1.3. What is regenerative development

Regenerative development is an approach that applies the ecological worldview. Plaut et al. (2016, p. 2) defined it as “*the process of cultivating the capacity and capability in people, communities, and other natural systems to renew, sustain, and thrive*”. Simplified, our approach to regenerative development is to:

1. Understand the flows through a system that bring it to life, that create a living system. Flows are the various resources, including 'intangibles' like culture and social cohesion, that interact with the place,
2. Design place-based solutions that create multiple, mutual benefits between these flows by focusing on the opportunities for creating relationships and
3. Operate within the context of the place to ensure its relevance, resilience, and ability to adapt.

Though in its infancy in application, Regenerative Development is informed by systems thinking (see i.e. Meadows, 2008), ecological thinking (see i.e. Du Plessis and Brandon, 2015) and indigenous thinking (see i.e. Mang and Haggard, 2016). Critically, regenerative development is about working within a system to enable the potential of the system to emerge, to co-evolve the aspects of the system so that it can constructively adapt to change and evolve towards increasing states of health and abundance. There are examples of the application of regenerative development ideas internationally, mostly related to reflections on specific projects and their outcomes (Mang and Reed, 2012), and case studies found on practitioner pages such as Regenes and the Institute for the Built Environment (IBE) at Colorado State University. While these provide insights into the outputs of regenerative development projects, there is a need to better understand the process that supports regenerative thinking and contrast it to 'business as usual'. That is: how do we operationalize these abstract concepts of creating ecological, social, and economic benefit within place. It is in the operationalization that the potential of bringing these two approaches together is born.

## 2. Methods

The research started with a literature review of both scholarly and practice-based publications of placemaking and regenerative development initiatives. The following section presents a summary of the key aspects that were revealed from the literature review. This literature was coded inductively, identifying where their approaches complemented or mirrored each other.

Inductive coding allowed us to convert papers, case studies, manuals, online content and books into keywords, approaches and concepts that suggested synergy between the two approaches. Inductive coding supported the research process, with continual revisiting of the codes allowing an unfolding or revealing of how the two practices can work together, and a sense of the synergistic potential. This is unlike deductive coding where one is trying to prove a hypothesis and has pre-conceived ideas of the outcomes.

We used a 'discursive grounded theory' approach to bring this data together. Grounded theory is a systematic methodology in the social sciences involving the construction of theory through the gathering and analysis of data (Martin and Turner, 1986; Strauss and Corbin, 1994). Grounded theory is a research methodology which operates inductively. For this research we started with the question of the ability for regenerative development to contribute to the ecological potential of placemaking. We continually reviewed the data collected, repeated ideas, concepts or elements through coding. These were grouped into concepts, categories and themes, resulting in the approach outlined here in. 'Discursive grounded theory' is the term we used, because this was a collaborative and iterative process of discussion, argument, deliberation and negotiations between researchers and practitioners. This was not a single researcher and a computer using software; the 'codes' and their analysis, were developed through consultation, conversations and testing.

## 3. Outcomes

Much like placemaking, regenerative development is often regarded as a practice – one that requires co-creation between professional regenerative development practitioners and the users of the development project. Unsurprisingly, this is often centered around underlying connotations, experiences, stories, feelings and values that the stakeholders hold for a place (Mang and

Haggard, 2016). Co-creating an understanding of place identifies underlying patterns of meaning and interactions, which allows for better integration of human social and economic processes with ecological processes and is something both practices aim for. In placemaking it is also about co-creating an understanding of place, its values to the stakeholders and what will contribute to the betterment of the stakeholders and the place. Thus, although ends differ somewhat, practitioners of regenerative development and placemaking often perform many of the same tasks.

We contend then that both practices can lead to long-term care and evolution of places and promote wellbeing of all stakeholders. Yet they approach a place differently spatially, temporally, in their understanding of the potential of place and its ability to evolve. It is our contention that combining the two approaches creates the potential of a more holistic framework. This requires understanding and reconciling their different approaches with different practices, goals and visions (Table 1).

*Table 1 Differences and gaps between placemaking and regenerative development*

	<b>Placemaking</b>	<b>Regenerative Development</b>
Goals and human's place	Social Humans as beneficiaries Respecting meaning of place in and of itself Place as final product	Socio-ecological Humans as catalysts and co-evolving with environment Meaning of place as means and agent of co-evolution Focused on potential-building
Scale of actions	Local, with consideration of wider geographical, social or policy context on occasion Cross-scale influence may be important to ensure sustainability of local places	Nested within local, proximal and global spheres of influence Mutual cross-scale benefits are important
Orientation towards the future	Often neglected or assumed Place-keeping to ensure longevity and periodic revitalization of placemaking Uncertainty is something to be managed (if not neglected)	Co-evolutionary responses shaped by pattern discernment Lacks clear guidance on ensuring socio-ecological durability Respects uncertainty without guidance on what to do with it

Importantly, it is the differences between approaches that offer the opportunity to investigate if their integration will provide a greater potential to create living environments. The following sections consider their ability to support the evolution of place, ability to integrate spatial and temporal aspects of place and the ability to elicit the potential of place.

### **3.1. Evolution of place**

Living environments are resilient and respond to events and opportunities in ways that serve the whole system and makes it more vital and viable. Therefore, looking at the way both approaches address evolution is critical. For a place and its stakeholders to be able to evolve constructively through change it is important to support its ability to identify, respond and adapt to change.

In placemaking, the focus is usually on humans as beneficiaries of place, with the important requirement that such benefits should be tailored to how people make sense of place. Thus, placemaking is most often conceived as activities that develop or increase place attachment and place understanding (i.e. meaning) in addition to enhancing environmental quality and amenities. It is essentially anthropocentric, with the care for the ecosystem aspects of place being strongly related to the perception of the people involved in the value of the ecosystem to their thriving. Further, the support for the non-human aspects of place will reflect the values of the human stakeholders, meaning that sometimes what is perceived to be good for human stakeholders will have priority over the non-human. Examples include the recent push to continue mining and using coal because this results in jobs, or the strong views of wind power. Without a vision for the

complexity of a place and all its human and non-human stakeholders the opportunity to develop and address the place is reduced. Often it is the non-human that are the heralds of change, think the canary in the mineshaft. Therefore, being able to conceive place as creating mutually beneficial relationships between the human and non-human is critical in being able to identify and respond constructively to change.

Placemaking that leads to place attachment without the context of all the stakeholders of the place and its complexity also means that it can result in unhelpful outcomes; it can lead to conscious and unconscious bias that reduces the ability to evolve through change. For example, Devine-Wright (2014), suggests strong place attachment attitudes may actually make people more resistant to making changes. In worse cases, place attachment can result in self-segregation and the manifestation of xenophobia, as evidenced by residents in certain white neighbourhoods in South Africa bemoaning the arrival of black neighbours (Dixon and Durrheim, 2000). Such negative consequences can become a profound limiting factor for the evolution of places, or otherwise drive places towards degeneration.

Therefore, to create a living environment, the ability to create a strong place attachment is an outcome that needs to be carefully planned into the process of working in that place. Creating a strong story of place that connects people to the benefits of the ecosystems and to their continued thriving in that place is critical, as is the ability to be invested in that place so as to understand it and be able to work with it as circumstance change.

This is the contribution that regenerative development can provide. Regenerative development seeks a co-evolutionary relationship between humans and the ecosystems of that place. As Mang and Reed (2012, p. 5) explain, regenerative development is “*not preservation of an ecosystem, nor is it restoration. Instead, it is the continual evolution of culture in relationship to the evolution of life.*” The philosophy of regenerative development is therefore neither anthropocentric, nor explicitly strictly ecocentric either. Rather, proponents of regenerative development envision a relationship where development and ecosystems are changing in response to one another, such that each ultimately benefits from their relationship with the other. Moreover, they argue that value-generating capacity is only possible by (re)growing such a relationship over time, which is not only distinctive to each entity but itself an agent of evolution within open systems (Mang and Haggard, 2016).

To this end, regenerative development focuses on potential-building, feedback loops, understanding the human and non-human aspects of place and their relationship beyond the place therefore enables those involved to be more able to observe, plan and respond to change. Mang and Reed (2012) describe regenerative development as consisting of two central and interrelated endeavours: 1) choosing the right phenomena to work on so as to maximize the system’s potential for evolution and 2) building capacity and a ‘field of caring and commitment’ among stakeholders. Doing so is not only accepting change but committing to a never-ending process of change and openness. Humans’ role, then, in this co-evolutionary relationship is to be catalyzers and active participants, creating or contributing to processes with the potential to generate a healthy place without trying to tightly control the direction the system evolves in (Mang and Reed, 2012; Hes and Du Plessis, 2014).

From this point of view, place – more specifically, the storytelling of place – can be treated variously as a framework, a mechanism and a process, rather than as a final product (Mang and Reed, 2012). As a framework, story of place helps humans learn how to understand and co-evolve with their environments better, provided such storytelling explicitly addresses the relationship between humans and the ecology/non-human they are enmeshed in. As a mechanism, story of place helps create the field of caring and commitment necessary for continuous potential building. As a process, place itself acts a change agent after design and construction, calling on human actors to respond and remake meaning as its potential is realized or changes with regards to wider systemic changes through placemaking.



In summary, regenerative development allows stakeholders to understand their place in context, to think about how to support that place to become more vital, viable and able to observe and respond to change. Placemaking allows the testing of this with the stakeholders in a point in time, in a specific place. It is these temporal and spatial aspects that are discussed next.

### **3.2. Temporal and spatial scale of place to enable adaptation and resilience**

#### **Temporal**

As discussed above, placemaking is essentially an activity undertaken to connect people to place with an endpoint in mind, for example increased activation of a park, activating a dying main street, safety of a laneway, etc. As such it is mostly short-term, with some placemaking practice such as tactical urbanism being temporary. However, only thinking in endpoints and solving single space related problems can be a limitation when working in an ever-changing and evolving place.

In contrast, regenerative development's focus is on fostering co-evolutionary relationships between humans and places, culture and ecosystems/non-human. It does this while looking across time, in some projects taking the native American Indian concept of design for 7 generations (learning from the past three, designing for the future potential of three and the middle one now). Its aim is to create greater vitality, viability and ability to adapt (Mang and Haggard, 2016), by looking at what worked throughout history and improving the relationships between aspects of the place, its stakeholders and their ability to reach their potential.

Bringing placemaking in line with regenerative development practice provides a way to understand the place over time to ensure the making and management of the place aligns with the essence of the place, based on how it worked throughout history and using placemaking to test if that is still relevant now.

#### **Spatial**

Placemaking focuses primarily on the site itself and rarely addresses the reciprocal impact that occurs between the place, its stakeholders across different scales; it merely acknowledges that this reciprocity can occur. Arguably, this may be due to its essential focus on place attachment and meaning. As discussed in previously, place attachment can manifest as insularity if the local communities' understanding of their place and place identity do not mesh with external elements around them. Mere apathy, lack of understanding, time or ability to support external elements may also prevent cross-scale or cross-place considerations (Dempsey and Burton, 2012; Mathers et al., 2015).

Regenerative development practice recognizes that development projects are always limited in scale, regardless of how large they are. Thus, regenerative development takes a simple nested approach to the cross-scale interactions (think a village square, within a village, within a watershed). This nested framework considers three layers of influence: the project site itself, the proximate whole and the greater whole. The proximate whole refers to a relatively localized system that is immediately relevant to the project, as defined through an understanding of the natural flows in the system or through cultural and social agreement. The greater whole is the greater system that may affect and be affected by the project in more indirect ways or over longer periods. This may include entities at the city, regional, national or global scales, such as the international market or global climate patterns. The result of this approach is that the project acknowledges its role to provide positive benefits for aspects beyond the site, and this becomes part of its essence and its story of place. It also means that its capacity to influence the other levels is explicitly part of the development process, it is explicitly integrated into the project. In regenerative terms, it 'does what it can' (Hes and Du Plessis, 2014) to contribute beyond its

boundaries through its design so as to create a stronger whole. For example, the design of tracks of greenery in a housing development can provide a potential wildlife corridor.

In the process of bringing placemaking and regenerative development together, it is placemaking that provides place-based projects that can be 'acupuncture points' that catalyse a community engagement with the story of place and its potential. As Mang (2009) write, "*Places, as attractor points, therefore, are evolutionary agents in that they become points within a larger system in which new life and new distinct patterns of existence can emerge*" (p. 40). Additionally, whereas placemaking efforts can sometimes lead to communities responding to external threats by rejecting their influence, regenerative development's attention to the reciprocal nature of nested cross-scale interactions suggests a different response. Regenerative development gives a way to think of the proximate and greater wholes and their mutual relationships to the project, while placemaking provides a way to test and refine ideas of what happens in the place to manifest these relationships.

### **3.3. The ability to elicit potential**

Thus far this paper has outlined that both placemaking and regenerative development aim to create better places by working with its potential. A challenge lies in the amount of information required to elicit the potential of place particularly if integrating all the aspects of the site. Placemaking elicits potential through a process of strong community engagement throughout the design and development of the project. This can then be tested through tactical urbanism and other temporary techniques so that the lived outcome of the ideas can be experienced creating a stronger connection to the potential of the project. Yet as outlined above this is an anthropocentric approach, and ultimately may fail to lead to ongoing thriving and the capacity to evolve because it overlooks the non-human elements of the ecosystem of which humans are an integral part. Therefore, all aspects of the ecosystem need to be incorporated. Yet limitations on time, resources and capacity might make the data needed to do this seems to onerous.

Regenerative development practitioners have a counterpoint to this: they argue that though data of a site is important, it is more critical to identify the patterns that this data reveal. The often-used example is that of knowing your life partner, or children: you don't know them by the state of their liver, or blood pressure, or ingrown toenail, you know them by the pattern of who they are, and how that reveals their essence. For a project, Mang and Reed (2012) advocate for the use of storytelling to create a 'story field' to focus practitioners' and stakeholders' attention towards evolving patterns in "*the whole system and what [the system] is attempting to become*" (p. 12). As the short story above illustrates, it provides for a practical course of action for coming to a decision about what phenomena to work on. It is a way to bring together the complexity of the assessments of physical assets, ecosystems, geology, history, hydrology and so on. Again, placemaking gives the tools to engage people to work together at a specific point in time, at a specific place, while regenerative development provides the story and context of how this could be done to achieve greater potential.

## **4. Discussion: Integrating placemaking and regenerative development for continual co-evolution**

Placemaking and regenerative development have strengths and weaknesses that are complementary. Working together, these two frameworks have the potential to harness each other's strengths and use them to minimise their limitations. Placemaking benefits from regenerative development through the systems approach, ecological considerations, nested thinking beyond the project boundary, long-term visioning and planning and pattern analysis to identify potential. Regenerative development benefits from placemaking as it provides a way to test, refine, implement and learn, based on creating relationships to a place in a specific point of time. This is the Place Agency model. When integrating both practices, placemaking then becomes an acupuncture point where the regenerative potential of a place manifests itself.

The active nature of placemaking implementation brings life to a site allowing the community to build a stronger relationship to the place (attachment) and providing opportunities to become active participants of its ongoing growth (stewardship). Meanwhile, the reflective nature of regenerative development allows the community and place experts to continuously analyse the flows that bring the system to life, find the new patterns, design new solutions that lead to socio-ecological benefits and adapt the regenerative strategy in response to the acupuncture points.

The Place Agency model is a call for regenerative practitioners and placemakers to work together to integrate these complementary place-centric views. The collaboration process will harness the key strengths posed by each framework to deliver Living Environments that are constantly evolving. The process of integration would start as follows: A) during the conceptual design phase, the Place Agency model proposes the regenerative development approach for site analysis based on system's thinking. This analysis will holistically integrate human and non-human participants in their analysis and identify key patterns of the area. Placemaking is applied as part of this analysis to develop the community engagement strategy suited to the project and to lead a process where the community identifies their values, their needs and current perspectives of the site. This results not only in a design but a whole strategy for the ongoing evolution and improvement of the site from a social, ecological and economic standpoint. B) During the consultation and detail design process, placemaking is used to deliver some short-term interventions trialing different aspects of the design (e.g. using tactical urbanism techniques). These interventions constitute a quick and responsive way to observe the community response to the regenerative ideas while keeping the interest going throughout the design and planning process of any project. C) Finally, during the construction phase, the community engagement process is used to continue working with the community, design team and regenerative practitioners to develop a place management strategy which responds to the everchanging interests of the community, in celebration of the past and present of the place.

## 5. Conclusion

Placemaking and Regenerative Development are two approaches to design and project implementation aiming to deliver healthy built environments that are relevant to the unique attributes of each community and geographical areas. Both approaches are place-centric with placemaking also being people-centric while regenerative development represents a socio-ecological approach. These practices differ on three key elements:

1. **Evolution of place:** Placemaking has mostly grown as a social movement focused on delivering temporary or permanent people-friendly shared spaces. Regenerative development is a socio-ecological framework that brings in the importance of both social and natural systems to create vibrant and resilient places.
2. **Temporal and spatial scale of place:** Both frameworks comprise an ongoing and adaptable process constantly revisiting what is working and what is not. However, regenerative development works on much longer timeframes and detailed understandings of systems, while placemaking poses a much more flexible approach suitable for trial and error interventions, embedded in a specific space at a specific time.
3. **Eliciting potential:** While placemaking identifies opportunities through community consultation, regenerative development finds potential within a living system through observation of patterns.

These three differences are complementary and can support the alternative framework in moving beyond its limitations. This paper presents a new approach, the 'Place Agency' model, to harness these complementary aspects of placemaking and regenerative development. This model understands placemaking as a point of time, nested, within regenerative development path and allowing the potential of the place to manifest. It proposes placemaking as a fun, quick and responsive approach to trialing key ideas considered for the long-term outcomes sought by regenerative development. Placemaking providing an ongoing catalyst, or acupuncture point to revisit, adapt and re-align the regenerative development journey. By implementing regenerative development and placemaking together, places can grow from an anthropocentric approach to

one that is considers the whole system. Together, both frameworks can successfully support a co-evolving process suitable to deliver Living Environments.

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## RE-IMAGINING URBAN LEFTOVER SPACES

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### Summary

In most developed cities, leftover spaces in the urban fabric can be seen both as having potential and as threatening. Researchers have pointed out the issues, conditions, and importance of the positive utilization of leftover spaces. However, there is insufficient information available on how to go about using such spaces. The revitalization and aesthetic quality of leftover spaces could expand the dynamism of a city through strategic design interventions. This study seeks to understand the potential of different types of urban leftover space to be used in a more effective ways than they are presently. This paper therefore examines how such leftover spaces are defined and can be redesigned to become part of a built environment. The paper reports on affective and aesthetic responses that could lead to a better understanding of human perceptions of such spaces. A visual preference study, utilizing semantic differentials for reimagined leftover spaces, was carried out to understand the differences between participants' preferences. A further comparison between participants having occupations in built environment areas and those who did not showed that for both groups, the most preferred spaces were those that included vegetation. T-test analyses of the correlation results confirmed that participant professional expertise is not a preference factor when it comes to the design of leftover spaces and in this respect, the study contradicts theories that hold there are differences in the ways experts and non-experts perceive the environment.

Keywords: Urban Leftover Spaces, Environmental Perception and Aesthetics, Visual Preference Approach

## **1. Introduction**

The capital of New Zealand, Wellington, expects a major population growth of 200,000 to 250,000 inhabitants from 2015-2040 (DIA, 2015). This rapid population growth is a problem numerous cities face worldwide. New Zealand's population increased by 1.9% in 2015 (Statistics New Zealand, 2015), outpacing Australia, which had a 1.4% increase in the same year (ABS, 2016). Of the New Zealand population 87% resides in 138 recognized urban centers ranging in size from around 1,000 people to more than 1,000,000 (DIA, 2015). Globally the shift from rural to city living has increased the demand for resources, including water, food, and energy for urban populations (Satterthwaite, 2010). The growth and quality of future urbanization will, therefore, have a huge impact on international resource availability and sustainability, affecting the quality of life for many people. There is an urgent need to design, test, and implement effective policies to address these issues. Like many other places, Wellington's development growth plan has been set up with a focus on achieving sustainable solutions, conserving natural environments, maintaining livability, keeping the city compact, and achieving maximum affordability (WGTN, 2015).

Urban growth varies from area to area making it almost impossible to follow only one development model (Turok & McGranahan, 2013). To that end, any development will depend on the current infrastructure, traditional and cultural desires, topography, financial resources, and the institutional scope for planning and political stability for growth management. As cities expand out across productive arable land, it is important to investigate the potential value and usage of unused land or leftover spaces in currently developed areas of cities. An urban setting exists not only as a physical environment, but also as a shared space for personal perceptions and experiences, such that a city can be studied as an episode resulting from a continuing relationship between the built environment, civic processes, and human experience. When considering urban development, it is important to understand the potential purposefulness of leftover spaces. The redevelopment process, including space assessment, has layers and structures from reading a space to interpreting it and generating meanings through diverse activities. Capturing and engaging with the qualities of the intermediate, often invisible phenomena of the city, suggests the need for an alternative approach to utilizing leftover spaces in an efficient and productive manner. Urban leftover spaces invite many possibilities for the integration of new techniques from integrating natural attributes to tactical solutions for the built environment.

This paper investigates the potential value of redesigning semi-public urban leftover spaces in more creative ways within Wellington urban fabric. By 2040, Wellington city council aims to reduce the presence of cars and car parks in the city centre by making it more compact and leftover spaces have a great potential to be utilized in a strategic way as part of this process. What is required are practical design solutions for the usage of semi-public (privately owned but that can be used by the public) urban leftover spaces. The visual preference study reported in this paper investigates design initiatives that could be more compelling for the public in terms of preferred design solutions. The key concern of this study is to explore and evaluate different design options with different attributes that influence people's perceptions of the usage of such outdoor spaces.

## **2. Urban Leftover Spaces**

Trancik (1986) started theoretical research into urban leftover spaces approximately 30 years ago. He investigated aspects of these and referred to them as 'lost space' as such spaces were ill-defined, had no significant outlook, and had a negative impact on the built environment. Furthermore, he argued such spaces had no definite or measurable boundaries and created division in use through policies or zoning. Urban leftover spaces are a fundamental part of an urban system and can occur next to a planned development, along and under highways or railway lines, are often stumbled upon unnoticed, and are known as no man's space, or land set aside for development. These are spaces of uncertainty (Muller and Busmann, 2002), which are considered to be meaningless by a large segment of the community (Akkerman and Cornfeld, 2009). Lacking officially assigned uses, leftover spaces are abandoned spaces that lie outside

the rush and flow as well as the control regulations of a city (Qamaruz-Zaman et al., 2012). In the name of 'progress', they are commonly considered as places devoid of function (Doron, 2008). These spaces are vacant, unkempt, and underutilized with no defined function, often being between stages of formal development but indefinitely waiting for future use. Leftover spaces have been given different names throughout history but scale, spatial quality, and usability remain the real parameters with which to describe them. The literature employs different names for leftover spaces, often with varying scales, but no authors have dealt with or tested possible solutions for future regeneration from within. As some of the names suggest, these spaces seem vague and unloved. The key issue of time and temporality is entirely excluded from the official definitions of leftover spaces. Azhar & Gjerde (2016) have categorized urban leftover spaces into six types that can be seen as having potential for usage. These are between 2 sides of a building, between 3 sides of a building, in front of a building, at the back of a building, underneath a building, and on a rooftop. These spaces intervene between adjacent objects and often become problematic for the physical and social fabric of the city. There is thus a need to search for transformational opportunities. Urban leftover spaces exist because of several factors and are present in every major city, and often adversely affect the urban center by disrupting the flow of neighborhoods and districts, creating visually unappealing places, and reducing pedestrian interest in the surrounding businesses. Moreover, such spaces do not contribute to successful processes within cities by neglecting to provide significant programmatic and social functions.

### **3. Perception of an Environment**

Psychology plays a vital role in investigating the science of interaction between humans and their natural environment (Keniger et al, 2013). The field of psychology evolved in the early nineteenth century, however, it was not until the mid-twentieth century that the importance of understanding the human-built environment became vital. Wilson & Baldassare (1996) describe the built environment as the relationship of people's needs to their surroundings but that it is also has to provide symbolic and functional needs. Environmental psychology encompasses the natural and constructed setting for human existence. Furthermore, the main objective of environmental psychology is to enhance and upgrade the physical conditions for humans in the constructed setting. It also encourages improvement of the human-nature relationship. 'Experience' and 'Perception' are the most commonly used keywords in an understanding of environmental psychology (Gieseeking, 2014). Experience relates to the transaction between intuition and already assessed knowledge. It differs from person to person and produces social contrasts, whereas perception is about identifying and interpreting the knowledge by using different senses. Rapoport (1982) claimed that the interdependence of a person to his/her environment is most essentially linked to sensual experiences and perception, while Gibson (1977) elaborated the idea of perception more deeply. He claimed that human perception was not just attached to the environment, but also accounted for the potential outcomes of that environment for human benefit and usage. However, Brebner (1998) argued that human thoughts, emotions, and feelings are influenced but also affected both physically and emotionally by what surrounds them. Wohlwill (1976) stressed the importance of the visual aspect and its effect on human psychology. Taylor et al (2008) differentiated the two facets of perception: the dimension of sensory passiveness (or the idea of having any sort of sensual experience), and the physical response that involves the action of a body. However, Seamon, (2010) contradicted this idea by emphasizing that both aspects were intertwined with each other. He said that in a day-to-day routine both bodily actions and sensory responses are working continuously. The actions are coupled outcomes instead of a separate response and should be viewed as an integrated response.

#### **3.1. Aesthetic Assessment**

The idea of beauty or beautifying by the processing of human cognition and perception is known as aesthetics (McWhinnie, 1968). This also includes emotional behavior. People react varying to different environments around them, depending on their past occurrences and experiences, their closeness to all the views, and their expectations and the duration of exposure. Ulrich (1983) stated

that aesthetic response is about the individual preference that provides a feeling of happiness or sadness and works through cognitive activity by visual confrontation. The aesthetic quality of any built or natural environment is a measure of a viewer's visual perception and responsiveness to that area (Company & York, 2009). McWhinnie (1968) used aesthetics as a benchmark to explain the responsiveness of people towards a visual stimulus. Whether the stimulus is beautiful or not, it creates an analogy of aesthetics through human cognition. In addition, if a certain visual appearance is more beautiful or pleasing, the preference is automatically diverted to it. Beauty rating is a result of this hypothesis. It is argued that the visual impacts can be explained through various elements and not just a single factor. These include visual character and quality (e.g., form, line, color, and texture), visual exposure, the viewer's idealized mental image, and the number of viewers who are expected to see the project (Hagerhall et al., 2008).

### **Visual Preference Study**

Preference understanding is a vital element used to analyze how people judge an environment including how they characterize and project it. This judgment can be different from person to person based on individual preferences. Habe (1989) confirmed that visual elements in a building are important for a space preference. His study found evidence that photographs, responsiveness, and multi-dimensional scaling were essential in deriving the dimensions of perception. In visual preferences, photos of an environment are used as substituent agents for the original (Arriaza et al., 2004). Researchers like Kaplan & Kaplan 1989 and Sanoff (1991) have studied the reliability of this procedure. Nasar & Stamps (2009) suggested that showcasing photographs of a scenario or environment induce the same response in people as if the pictures were real. Tversky et al (2006) found that the visuals of an environment exist in the human cognition and can be as significant as real expressions. Furthermore, in 1957 Osgood, Suci & Tannenbaum used a linguistic analytical approach. They created a bipolar grouping to testify the efficacy of affective domains. As a result, photomontage became a way of creating altered images by coupling or omitting elements to form a well-composed picture of a future reality (Waldheim, 2006).

## **4. Method**

This visual preference study used photomontages to represent three alternative design modifications for six different types of leftover spaces in Wellington (table 1). All one-point perspective photos were treated in Photoshop to reconstruct the specific visions while emphasizing one attribute in each context, and noting that these attributes changed with the context. All leftover spaces were designed without changing the current usage of the site. Concepts of providing more vegetation, creating seating space, improving cleanliness, changing surface materials, removing the boundary walls, creating clear pathways, and installing wind turbines or solar panels were photomontaged for different types of space (table 1). These concepts were extracted from a previous study, where participants gave their suggestions for designing such sites. Each photo was rated using a 3-point Likert scale to reveal the differences and to understand the data more easily (1 Dislike, 2 Neutral, 3 Like). Benson (1971) recommended using a 3-point Likert scale for its practical convenience and some claim as few as two response categories might be adequate in practice (Jacoby & Mattell, 1971). The second part of the study was related to the semantic differential measures, which sought each participant's reaction to the redesigned space through a series of stimulus words/concepts. The concepts (adjectives) were evaluated through a 5-point bipolar rating scale. This section investigated reactions using the concepts of attractiveness (ugly-beautiful), satisfaction (annoying-pleasing), buildable (impossible-realizable), usability (boring-interesting) and mood (constrained-energetic). The adjectives were chosen according to how they best fitted the research aims and were consistent throughout the study. The Likert-scale reveals how much people agree or disagree with a particular statement, whereas the semantic differential scale decides how much of a trait or quality the item has as rated through the bipolar scale defined by adjectives (Osgood & Snider, 1969).

#### 4.1. Participants

The participants responded to an interactive web-based survey made using Qualtrics. The study was initiated after approval by the human ethics committee. Invitations to participate were sent through email and by putting up posters in local cafes. The invitation emails were sent to administrators in the different Schools of Victoria University, Wellington City Council, New Zealand Institute of Architects, University of 3rd Age<sup>1</sup>, and Wellington City Library with a view of inviting both adults and students to participate in the study. By the end, data were collected from 121 individuals and imported into the Statistical Package for the Social Sciences (SPSS) software for analysis.

#### 4.2. Sample Demographics

Overall 96 participants completed the survey and 25 partially completed it. In terms of gender, 42.7% of respondents were male, 55.5% female and 1.8% did not answer. Participants with built environment knowledge formed 23.6% of the sample, with the remaining 76.4% being from different fields. Just over half (52.7%) of participants had an NZ European background compared to 47.3% with contrasting cultural ethnicity. In terms of formal education, 68.0% of respondents had a postgraduate qualification.

#### 4.3. Procedure

The first step investigated the preferences for the whole sample of 121 respondents and identified the most appealing attributes (semantic differential) for each redesigned leftover space. The second step investigated the subgroups of 26 (23.6%) built environment participants compared to 85 (76.6%) respondents from other occupations, to see if there was any difference in preferences. Arnheim (1977) pointed out that built environment experts not only see what a building or a place looks like but also deconstruct it to understand how it was built and works. It is also claimed that built environment professionals perceive differently from other people and have different preferences (Posner, 1973).

#### 4.4. Data analysis

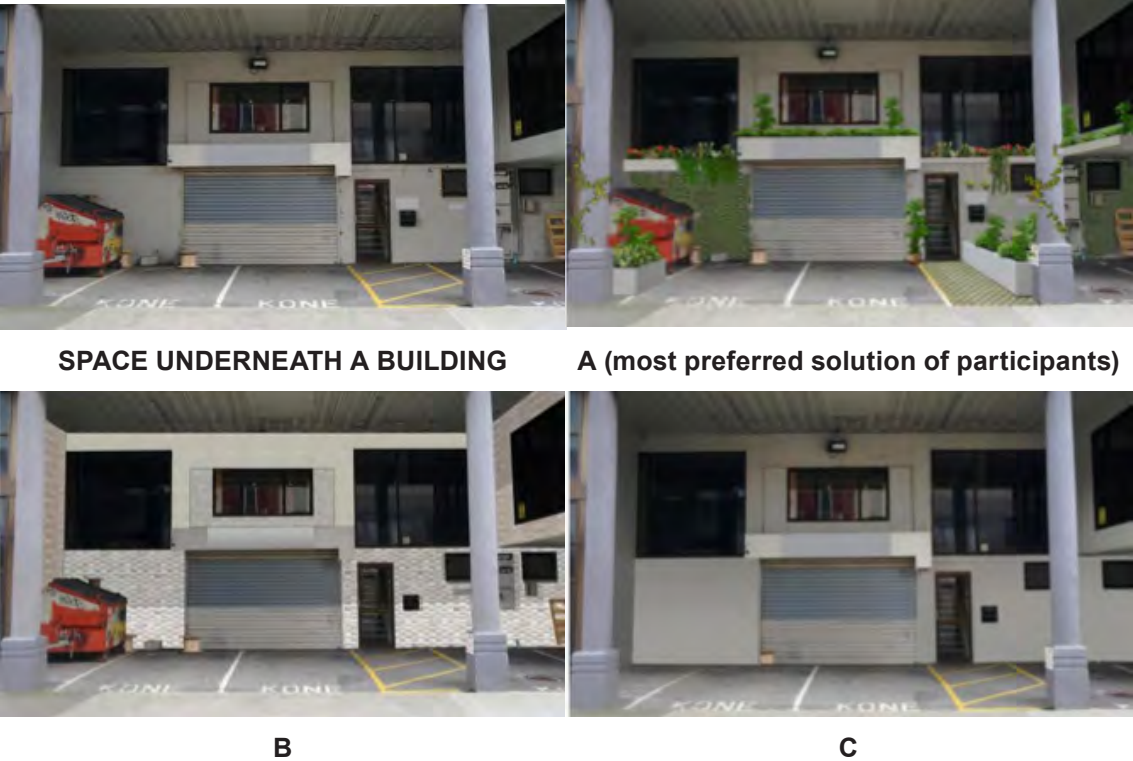
Different methods of analysis were deployed to understand the relationships between the sample groups. The mean preferences for the most and least preferred redesigned photos were measured on the Likert scale (1-3) by using a descriptive frequency test in SPSS. The simple technique of calculating the mean, standard deviation ( $\pm$ SD) and percentage of the most preferred design was used (table 2). Kendall's tau-b ( $\tau_b$ ) correlation test was conducted between the most liked images with the respondent's attitude (semantic differential scale). Kendall's tau-b ( $\tau_b$ ) correlation coefficient calculated the strength and direction of association in a nonparametric measure, such as exists between two variables measured on an ordinal scale (Laerd Statistics, 2016). A comparison was done to evaluate the alignment of built environment with the non-built environment participants. The percentages for the most preferred design on a 3-point Likert scale were calculated for participants from different fields of study (figure 2). The Cronbach alpha ( $\alpha$ ) reliability test was used to check the internal consistency of several variables for the semantic scale 1 to 5 before independent sample T-tests were carried out. Cronbach's alpha ( $\alpha$ ) was 0.81 and indicated a high level of internal consistency. The averages of semantic differential responses were calculated to find the difference in preferences among the respondents through an independent sample T-test. The differences of opinion between the built environment and the non-built environment participants were analyzed using independent sample T-tests.

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<sup>1</sup> An international movement founded in 1973. It focuses on improving living standards and helping the personal development of older or retired people (Marcinkiewicz, 2011).



Table 1 Example of a redesigned leftover space



## 5. Results

### 5.1. Whole Sample (n=120)

- The preference value on the 3-point Likert scale fluctuated but the most preferred design solution among all participants related to adding more vegetation to all leftover spaces (figure 1).

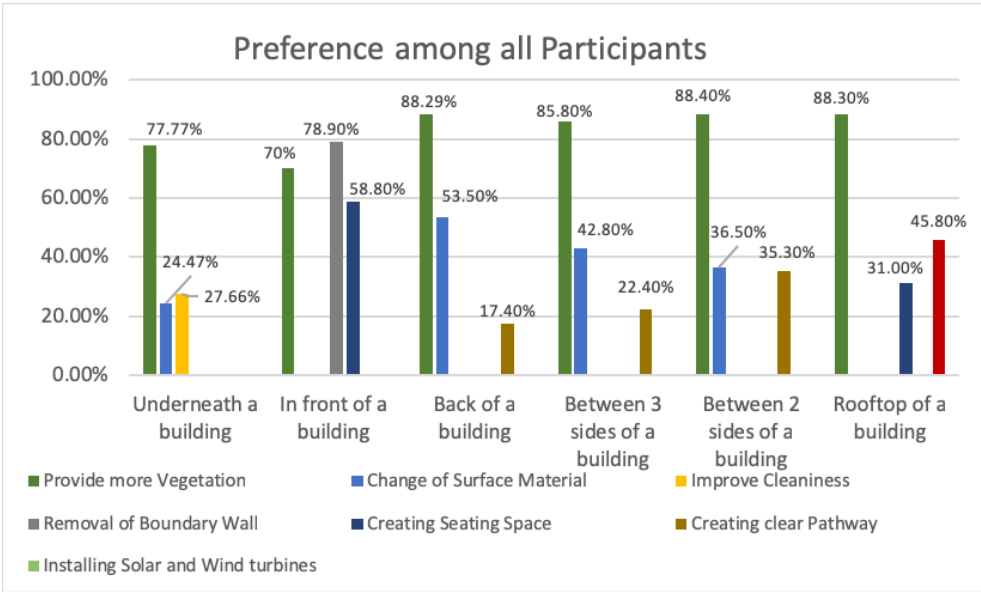


Figure 1 Preferences for Redesigned Leftover Spaces

- A Kendall's tau-b ( $\tau_b$ ) correlation test for all different images revealed the most likable image had a strong, positive association with all affective appraisals (semantic differentials) except for the bipolar category of "impossible to realizable". This suggested this category was independent of the association and was not influenced by the image's likability.
- The space in front of a building had a different preference ranking among all participants. The first preference was for removing the boundary wall whereas the second most preferred design was providing more vegetation. The Kendall's tau-b ( $\tau_b$ ) correlation test revealed the most likable image in front of a building had a weak, negative association with the one affective appraisal category of "boring to interesting".

## 5.2. Built Environment and Non-Built Environment Participants

The strongest agreement between both groups was for spaces that had an element of vegetation in them (figure 2).

An independent sample T-test for both the groups confirmed that there was no statistically significant difference in opinions between the built environment and non-built environment group ( $P > 0.05$ ) for all redesigned leftover spaces.

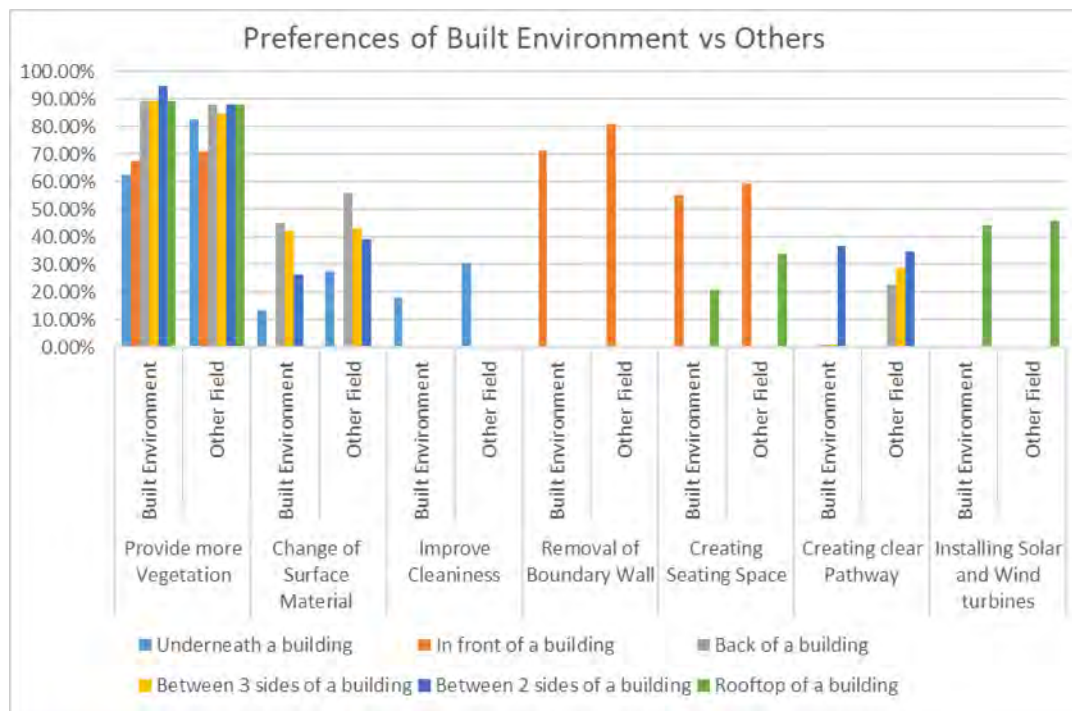


Figure 2 Preferences of Built Environment participants and others

## 6. Discussion

The quantitative study demonstrated (1) an overall desire for incorporating nature into built environments and (2) there was no difference in preferences for the built environment and non-built environment participants. The preferences for all six examples of leftover spaces were similar for each scenario. A study by Ulrich (1981) found that natural environments are usually evaluated as having a high rate of aesthetic quality over built environments and have relevance to aesthetic response. At the same time, Ulrich's study also suggests that incorporating vegetation is not always practical and can be expensive since it comes with maintenance, care or stewardship issues. Respondents also exhibited preferences for visual openness as evidenced by the preference scores for the scene depicting the removal of a boundary wall in front of a

building. This result suggests that the entrance to a building should be designed to be open and inviting and creating areas that are perceived as claustrophobic should be avoided. Visual quality can influence a person's experience significantly because people react to what appears before them. Different needs and demands can be catered for to create positive settings for each type of leftover space, and this could enhance people's attitudes and behaviors. The most realizable solutions among all designs were related to vegetation, change of surface material or its colors, improving cleanliness, and creating pedestrian pathways and seating spaces. The comparisons between the preferences expressed by built environment participants and lay people were similar for all design solutions. This suggests both groups perceived the designed spaces similarly and the sample T-tests for opinions of leftover spaces were the same. Also, the aesthetic judgments of preferences were aligned between all participants. Overall, it seemed that if a leftover space is designed with natural elements then this could induce a spatial preference. However, solutions regarding preferences for installing different types of plants (trees, shrubs, climbers, and ground cover) is nonexistent in the literature for leftover spaces, and this is a possible area for further research. Another issue that needs further exploration is the light exposure and scale when it comes to measuring preferences. In this study, only one view of each space was given, with an attempt to have a similar level of light in each. Ephemeral qualities, such as light level, affect emotional responsiveness. However, it does appear from the analysis that human intervention with natural design solutions is a key aspect of how leftover spaces could be improved.

## **7. Conclusion**

This study has examined and assessed three different design schemes for urban leftover space by asking survey participants about their evaluations, with the aim of gaining a fuller understanding of which solution is preferred. This study also suggests a direction for design schemes in that they should consider enhancing the aesthetic quality of a space with the use of natural elements. For example, the use of urban leftover spaces could aid in mitigating climate change through urban food production, if both the owner and the public agree with such changes in use. The importance of leftover spaces between, over, and under buildings as part of the public realm should be realized by city stakeholders, managers and end users. It is not clear yet what future cities will look like with the implementation of sustainable measures that include emerging technologies, but it is vital to develop new strategies to cope with humanity's demands for resources and designing such spaces through stakeholder participation is a need for future cities.

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**ENERGY**



# THE TOTAL COST OF LIVING IN RELATION TO ENERGY EFFICIENCY UPGRADES IN THE DUTCH, MULTI-RESIDENTIAL BUILDING STOCK

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## Summary

Decarbonizing the housing stock is one of the largest challenges in the built environment today, which is getting the attention not only from policymakers but also from social housing corporations, financial and tenants' organisations. In line with the international Paris-Climate-Change-Conference 2015, Dutch cities and housing associations have embraced this challenge with the ambitions to become carbon neutral in 2050. To reach such ambitious goals, both the rate and depth of renovation need to increase significantly. In the Netherlands, the Energy Agreement for Sustainable Growth, indicates that 300.000 dwellings have to be renovated annually, in accordance with the Energy Performance of Buildings Directive adopted by the European Union, to improve the Dutch building stock towards energy neutrality. Several technical solutions to eliminate the energy demand in dwelling have been developed and tested. Nevertheless, the intake rate of deep retrofitting is low. Currently, most improvements in residential buildings consist of basic maintenance and shallow renovation, but broader or deeper energy renovation measures are required. Despite more recent developments, there are still significant barriers related to financing, lack of information, and user acceptance. Complex technical characteristics are not always taken into account by tenants; the focus is usually on the ease of use, comfort and living expenses.

To this end, the present study sets of to investigate the relationship between energy efficiency upgrade measures and cost of living. Focusing on the post-war, multi-family social housing in the Netherlands, a framework of refurbishment measures that affect the energy efficiency were identified, and their performance was simulated. The variations refer to the façade design, thermal envelope upgrade, wintergarden addition and reviewable energy. The energy efficiency indicator is the energy cost reduction, as well as the carbon footprint of the energy use. Furthermore, the rental price adjustment was estimated, taking into account the refurbishment investment and the operation cost of the renovated dwellings. All tested combination of variables resulted in significant energy savings, up to 70%, while energy generation was proven to be cost-effective, as it has a considerable positive effect on the energy use and the energy cost, without increasing the rental price.

The results aim at supporting the decision making discussion between the stakeholders, primarily housing associations and tenants. The relation between the energy consumption and rental price for the different options identifies the effect of design variation and demonstrated the attractive solutions that the tenants are more likely to accept, taking into account the overall cost of living and sustainability benefits.

Keywords: energy efficiency, renovation, cost of living

## 1. Introduction

Decarbonising the housing stock is one of the largest challenges in the built environment today, which is getting the attention not only from policymakers but also from social housing associations and other institutional real estate owners, financial organisations and users. Several studies (BPIE, 2011, 2013; Crawford, Johnson, Davies, Joo, & Bell, 2014; IEAAnnex56, 2012) have reported that huge potential for energy savings, improved health and comfort of the occupants', elimination of fuel poverty, and job creation lay in the technical upgrade of the existing buildings stock. In line with the international Paris-Climate-Change-Conference 2015, Dutch cities and housing associations have embraced this challenge with the ambitions to become carbon neutral in 2050.

To reach such ambitions, both the rate and depth of renovation need to significantly increase (Artola, Rademaekers, Williams, & Yearwood, 2016; BPIE, 2011). In the Netherlands, the Energy Agreement for Sustainable Growth, indicates that 300.000 dwellings have to be renovated annually, in accordance with the Energy Performance of Buildings Directive adopted by the European Union, to improve the Dutch building stock to energy neutrality (DIRECTIVE, 2010/31/EU). Moreover, in the Netherlands, the housing associations have the ambition to achieve a carbon-neutral building stock by 2050 (AEDES, 2017). A number of technical solutions to eliminate the energy demand in dwelling have been developed and tested. Those solution target different levels of energy efficiency, ranging from a small upgrade of the energy label, most commonly up to label B, to achieving zero-energy demand.

Nevertheless, the intake rate of deep retrofitting is low. Currently, most improvements in residential buildings consist of basic maintenance and shallow renovation, but broader or deeper energy renovation measures are required (Filippidou, Nieboer, & Visscher, 2016). Despite more recent developments, there are still significant barriers related to financing, lack of information, and user acceptance (Matschoss, Atanasiu, Kranzl, & Heiskanen, 2013). The residents of the dwellings care less about the technical characteristics of a dwelling, but more about the use, comfort and living expenses.

To this end, the present study sets of to investigate the relationship between energy efficiency upgrade measures and cost of living. Focusing on the multi-family social housing in the Netherlands, a framework of refurbishment measures that affect the energy efficiency were identifies and their performance was calculated. The energy efficiency indicator is the energy cost, as well as the energy use. Furthermore, the rental price adjustment was estimated, taking into account the refurbishment investment and the exploitation cost of the renovated dwellings. The comparison of the energy use and rental price for the different options demonstrated the most attractive solutions that the tenants are more likely to accept, taking into account the overall cost of living and sustainability benefits. The results aim at supporting the decision making discussion between the stakeholders, primarily housing associations and tenants.

## 2. Methodology

To provide insights into the study's question on the relation between energy saving renovation and cost of living, the evaluation of the refurbishment options is based on Key Performance Indicators (KPI's). The key performance indicator is a measurable value that demonstrates how effectively a system, in this case, the refurbished buildings, performs. The KPI's used in this study- as concluded out of focus groups with stakeholders, such as residents and housing associations- are the energy use and its resulting cost, the rent price, because it reflects the refurbishment costs as it will be explained in section 2.3, and the total cost of living, as the sum of energy cost and rent. The sustainability of the solutions is indicated by the energy demand since the same heating system, and fuel is applied to all options. Hence, the energy demand and CO2 emissions are proportional

The steps to quantify the KPIs are hence related to the strategic organisation of the refurbishment measures, for starters, and then quantifying their effect on energy use, cost and rent price. The investigation is based on applying and refurbishment strategies on a case-study building. The specifics of the building were taken into account for the design and assumptions considered for the energy and cost calculations. The study focuses on low-rise, multi-family, walk-up apartments, as they present considerable challenges for their energy upgrade. Currently, there are still 799.956 apartments of all types from the period 1906-1965 in The Netherlands, 400.000 apartments of which are located in the four major cities. The building shown in Figure 1 was selected as a case study to apply the refurbishment options, as being a typical example of the post-war period (Platform31, 2013).



*Figure 1 Case study building: Camera Obscura, Overvecht Utrecht, 2016*





## **2.1. Define the alternatives and the combinations: General Transformation Framework**

In order to be able to evaluate the solution, the alternative refurbishment measures need to be defined. The measures are defined per category and per function, creating a “General Transformation Framework”. The parameters taken into account for the framework development came out of research the existing tenement building types of the inter-war and post-war period and their special characteristics and projects (Oorschot L et al., 2018).

Moreover, analysis of realised refurbishment project and interviews with architects and housing association helped to define the state-of-the-art. In the scope of the present study, the measures discussed refer to a cluster of technical interventions that can be employed to improve the energy efficiency of the apartments. Additional socio-cultural interventions related to the functional and cultural heritage qualities are possible to be applied, but outside the present paper’s scope.

As they are not likely to be applied individually, they have been combined into integrated solutions, before they can be evaluated regarding energy demand and cost. The alternative measures were defined based on analysis of current refurbishment practice, literature review and discussions with stakeholders. The aspects considered that have an impact on the energy use of the building are the following, as presented in below :

Table 1 Overview of the alternative refurbishment solutions proposed

Aspects	Alternative	Description
Façade Design	Existing	 Existing façade design. Sill height 1m. Window-to-wall ratio 80%, operable 30%
	Half open	 Half open facade with operable opaque ventilation openings, with respect of the most characteristic heritage elements. Window-to-wall ratio 60%, operable 0%
	Open	 Open facade with glass from floor to floor, with respect of the most characteristic heritage elements. Window-to-wall ratio 100%, operable 50%
Thermal properties upgrade	Level B	Basic upgrade Facade $R_c \geq 5,0$ Roof $R_c \geq 5$ Floor $R_c \geq 3,5$ Windows Double glazing / $U=1,2$
	Level A	Advanced, towards ZEB standards Facade $R_c \geq 5,0$ Roof $R_c \geq 6,5$ $U=0,15$ Floor $R_c \geq 4,0$ Windows Triple glazing / $U=0,8$
	Winter-garden	 Extension with a glass covered balcony. External wall: 100% glass Single.Open 80% at 24oC. Shading intern drapes Interior partition: double glazing, 100%. Open 80%. Min temp for Nat Vent 24oC
Extension	No extension	No additional construction.
Renewable energy Generation	None	No PV panels nor solar collectors
	PV	Calculated per apartment, based on the overall available area for PV application. Efficiency 255Wp
	PV+solar collectors	Solar collectors are assumed to be placed on the balcony, on the South side, producing up to 330kWh/m2, which covers the energy demand for hot water

## 2.2. Energy demand calculation and indicators

For the refurbishment options to be evaluated and for the total cost of living to be calculated, the energy performance of the case-study building is estimated. Firstly, the energy use for both building and user-related sources is calculated using dynamic thermal performance simulation. Then, the energy use is simulated after the proposed, combined solutions have been applied. The software used for the thermal simulation is DesignBuilder, which was chosen as appropriate for the purpose of this study because it can generate a range of environmental performance data such as energy consumption and internal comfort data. The actual data for the building's size and construction were used, data for the location climate were input, and occupancy data were based on the building's function, classified as "Tailored rating", according to European Standards EN15603 (2008).

### Inputs

For every energy consumption calculation, the way the building is constructed and operated needs to be specified, as input. When comparing current and new energy demand, an assumption is that the usage patterns will not change significantly. A nuclear family (four-person household, two parents and two children) will be considered, as it is the largest percentage in the demographics of the case study. The different inputs are summarised in Table 2.



*Table 2 Energy simulation inputs*

Parameter	Inputs
Location	Netherlands
Orientation	Depending on the specific building
Geometry and zones	Every room as a different zone, depending on activity (bedroom, living room etc.)
Occupancy	Based on zones function, for a four-person household
Openings	Layout: building design. WWR between 60-100%
Heating/ DHW	Gas boiler, efficiency 80%
Ventilation	Natural inlet through windows/ mechanical outlet through bathroom and kitchen.

### **Comfort, Energy demand, Energy cost and Carbon footprint**

The simulation resulted in the amount of energy in kWh a dwelling requires per year, including HVAC systems, domestic hot water and appliances. Moreover, the internal temperatures were checked to calibrate the dwelling function and comfort, existing and refurbished, and ensure that overheating is avoided. The energy costs are based on the prices indicated there, considering fixed amounts for the grid, as well as different prices for peak hours, the following costs were calculated for electricity 0,18/ kWh and gas 0,77/ m<sup>3</sup>, including tax (Eurostat, 2016). Those prices are then implemented to the simulation results, for electricity and gas demand respectively.

### **2.3. Total cost of living calculation method**

The refurbishment strategies are evaluated regarding the effect the investment has on the rent price. To this end, a Life Cycle Costing (LCC) was performed. The increase in the rent price was based on the assumption that for sustainable housing to be financially feasible, all investments must be covered by the exploitation period rent income. Firstly the investment costs of major renovations were determined without considering specific energy-saving measures. The investment costs have been defined according to the Dutch standard NEN 2699 (NEN, 2017) as: the value in use of the existing building + the construction costs of the renovation + the additional costs such as fees, connection costs and taxes. The construction costs of all renovation measures have been estimated by EcoQuaestor (2014) cost database. As a result, the cost level of the budgets is consistent with Dutch building practice. The rent of the apartments after renovation but without specific energy-saving measures was determined by the “Appropriate allocation” scheme under the 2015 Housing Act. Subsequently, the investment costs of specific energy-saving measures are added to the initial investment.

The investment for both scenarios, with and without energy efficiency measures, is then included in a cash flow survey of operating costs and benefits according to the life-cycle costing (LCC) model of the NEN 2699 standard. The cost of maintenance, management costs and other property expenses are included. On the revenue side of the balance sheet, the present value of rental income was added, for an exploitation period, assuming 30 years is the exploitation period for an apartment in the social housing sector. In the renovation scenario, the extra investment costs of the specific measures were included in the cash flow analysis. The present value of the rental income was adjusted to close the balance. The increase in monthly rent was then calculated as the difference required to balance the cost and income in the LLC.

It needs to be clarified that this method can result in differences in the rent price for the same combinations of energy efficiency measures combinations. The reason for this discrepancy is that the rent after renovation, which also depends in other parameters, such as the additional number of rooms, or the construction of additional dwellings, which are not within the scope of the current study.

### 3. The resulting cost of living for the different aspects

This section presents the effect of each aspect, as defined in Table 1, on the KPI's energy demand, energy cost, CO<sub>2</sub>, rent price and total cost of living. Not all KPI's are discussed in every case, depending on the significance of the effect. The numbers presented in the figures are based on averages values for the combination of measures that include the respective variations. These averages are the reason why the total cost of ownership is not always the sum of the average energy cost and the average rent in the following figures.

#### 3.1. Façade Design

There were three different options for the façade design. Those options differ in the window-to-wall ratio (WWR), layout and operation. The design of the façade is important for how the building is perceived, and our proposals came out of the analysis of the building characteristics and discussions with architects and housing associations.

Comparing the performance of the three façade designs, however, we can see that energy demand and, hence the energy cost, does not differ significantly, as shown in Figure 2. This similarity can be explained by the thermal properties of the different options, which are all upgraded to high thermal resistance. It is also the reason why there is a 50% reduction in the energy costs and 68% reduction in the energy demand, compared with the current building. Moreover, the WWR is all three variations are relatively high, ranging between 60% and 100%. Therefore the heat losses from the glazing, as well as solar heat gains are similar, resulting in similar energy use in the refurbished apartments. The choice of high WWR is consistent with heritage values of the existing building design.

Finally, the investment for the new façade, and the resulting rent increase is also similar, with the option of preserving the existing façade layout being marginally more economical. Nevertheless, the total cost of living is lower by 7%.

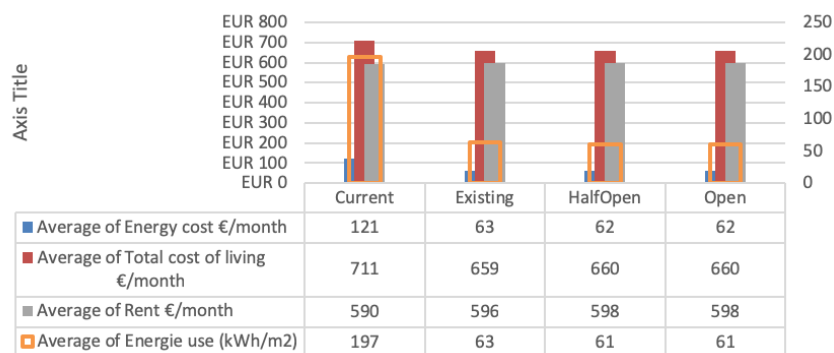


Figure 2 Comparison of the Façade design variations and the current building, in terms of energy cost, rent, the total cost of living and energy use

#### 3.2. Thermal properties upgrade

The building envelope is upgraded with the application of insulation on the façade and roof, as well as replacement of the windows. The basic upgrade (B) is the minimum required by the regulations in the Netherlands, while the second option (A) is going towards zero energy standards. The main difference between the two options is the glazing and the higher thermal resistance of the roof. As can be seen in Figure 4, the difference in the energy demand between the two variations is 5%, which is marginal. The marginal difference can be interpreted by the already good thermal performance of the basic upgrade. However, the investment for the more advanced upgrade has resulted in a rent increase greater than the energy cost savings. In this

sense, the cost-effectiveness of the basic upgrade is better. It needs to be noted, that in both cases the saving to the current energy use is significant, as already mentioned.

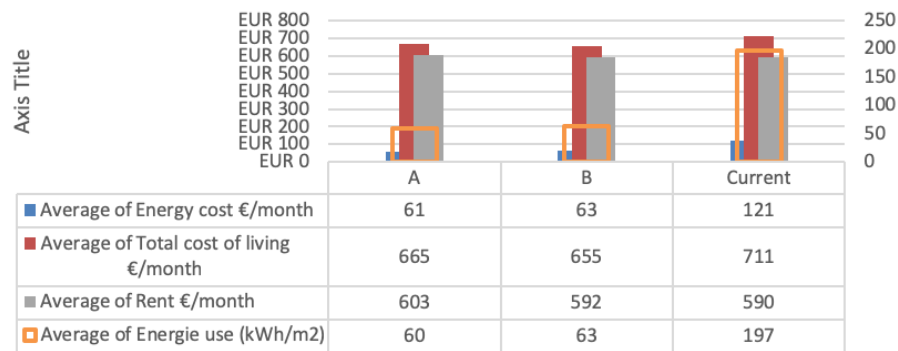


Figure 3 Comparison of the thermal properties upgrade options and the current building, in terms of energy cost, rent, the total cost of living and energy use.

### 3.3. Extension

The option to extend the living space is beneficial for improving the living conditions and functionality of the dwellings. Such examples range from the cladding of existing balconies to new construction. For the present study, the option considered included an additional construction, with mostly glazed external wall, having as a reference the project Tour Bois-le-Prêtre by Druot, Lacaton & Vassal. The new living space is not conditioned. Hence, the interior partition, previously external wall, featured insulated windows. Both interior and exterior windows are operable.

Figure 4 presents an overview of the KPI's with and without the extension construction, in relation with the thermal envelope upgrade. One of the first conclusions is that this investment does not affect the rent increase, as the average rent is the same. However, the energy use is higher in the dwellings with the winter garden. The higher energy use can be explained by the additional living spaces, which are not conditioned. The total cost of living in all cases is lower than in the current building.

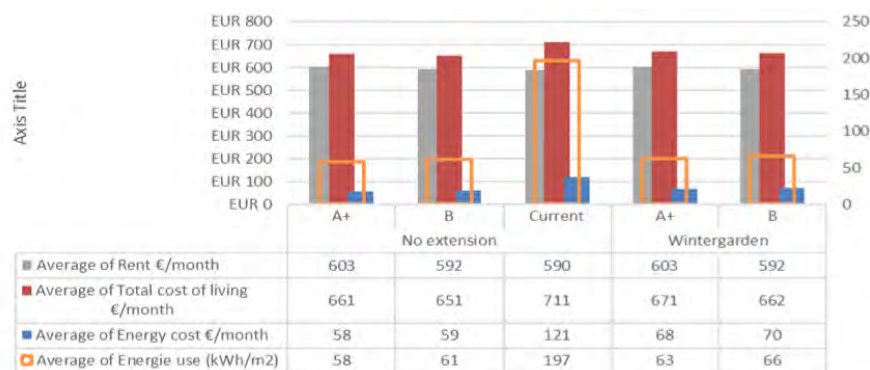


Figure 4 Comparison of the winter garden extension in relation to the thermal properties upgrades, in terms of energy cost, rent, the total cost of living and energy use.

### 3.4. Renewable energy

Energy generation is a necessary step in the ambition to achieve energy neutrality on building level, and it is also a common consideration in energy efficiency upgrades. As shown in the results in Figure 5, the application of renewable energy production technology can cut almost in

half the energy use and 1/3 the energy cost. The rent, on the other hand, is not affected by the initial investment.

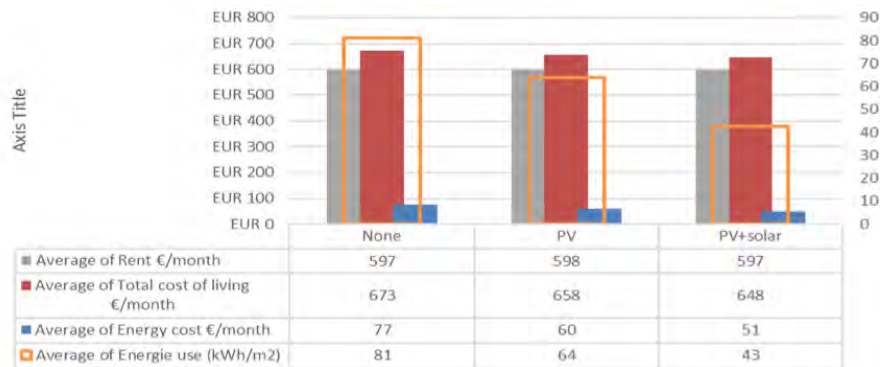


Figure 5 Comparison of the thermal properties upgrade options and the current building, in terms of energy cost, rent, the total cost of living and energy use.

#### 4. Discussion and Conclusion

The current paper described a methodology to combine the cost and the savings of energy efficiency upgrades in dwellings' refurbishment and identify the effect of design variation. Based on the aspects evaluated, the following main conclusions can be drawn.

- All tested combination of variables resulted in significant energy savings, up to 70%, due to the proposed the thermal envelope upgrade
- The variations in the façade design, given similar thermal properties, have a marginal effect on the energy demand
- The construction of a winter garden is possible without an increase in the rent
- Energy generation through the use of PV and solar collectors is cost-effective, as it has a considerable positive effect on the energy use and the energy cost, without increasing the rental price.

It is important to note that the savings on energy costs are greater than the capital burden of the energy-saving measures discussed in the current study. As a result, the total living cost to decrease in all cases. This conclusion is important to support the implementation of energy efficient measures; if the whole exploitation period is considered, the refurbishment is financially feasible, without burdening the household expenditure.

One of the main objectives of the study was not only to identify the effect the different parameters would have but also to inform the current practice in the context of energy efficiency upgrades of multi-residential buildings. To this end, the variations studied were selected based on commonly realized upgrades and focus groups with architects and users, and not in the interest of highlighting the effect on energy and cost. Thus, even if some of the variations result in non-significant differences for the KPI's, they are still valuable result to support decision making and provide options in the refurbishment strategy design.

The method presented in this paper was based on the energy efficient refurbishment measures and the specific KPI's. Other measures that may not be as cost-effective but do have additional environmental or living quality benefits, which can also increase the property value. These measures cannot be identified with the research method followed, which focused on energy efficiency. The conclusions on energy efficiency upgrades need to be considered both by the designers and other stakeholders, most importantly the occupants who will benefit of the reduced energy use, but also will need to pay the possible increase in the rent.

## Acknowledgements

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## ANALYSIS OF THE ENERGY-SAVING IN THE CONFERENCE CENTER ATRIUM

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### Summary

This paper investigates the influence of the Conference Center atrium design on energy consumption from an integrated perspective. Computer simulation techniques were used to assess the effects of the Stratification Cooling (SC) and passive energy-saving. The simulation results indicate that the effectively designed air supply system can perform two major functions: separation and utilization of natural air to help reducing refrigeration zone and cooling upper zone. The simulation results of a case show that the composite design method can make the air conditioning operation in the atrium of the hotel more energy efficient and maintain the ambience comfortable in summer season and that is recommend.

Keywords: Energy-saving; CFD; Conference Center Atrium; Natural air ventilation.

## 1. Introduction

What is a Conference Center atrium? Atriums are always located in the major axes of buildings. The modern building atrium has two attributes. It has indoor space specific, (it is major space of the whole building, a hub, public activities include arrival and distribution, multiple-function room), and outdoor specific (multi-stories, natural scenery are the present of this specific). A perfect atrium design should embody two kinds of functions: express theme entirely and to make it to have unique characteristic.

How about its shape? An atrium tends to be a tremendous space, which can create an atmosphere just like the feeling in nature (Fig.1).

The differences between atrium and other interior spaces can be clarified: a courtyard has no roof, a departure lounge does not have specific outdoor feature, a shopping mall's long shape space has no scenery function and appreciating function is lacking. The Conference Center atrium is the place which requires more landscaping to improve the image of the Conference Center and to attract more customers. Given the demands of the Conference Center atrium, as compared with other functioning buildings, it is open every day and emphasizes landscaping. Therefore we should think about a different method for air distribution.

The disadvantage of this space is its huge energy consumption, especially in summer. However it is based on the theory of stratified air conditioning, which states that only the lower space of the atrium needs to be cooled. Researches have pointed out that in summer the load of refrigeration (stratification) compared with refrigeration (total room) is about 2:3, see Shi (2011) and Li(2011). Moreover, due to the large size of the atrium (eg. 40 meters in diameter × 20 meters high) nearly 25,000 m<sup>3</sup>, cooling load is still a great burden to the Conference Center's operators because energy saving is inadequate. There are so many researchers concerned about different functions of atrium beyond Conference Center, and most of them consider that the transition seasons can only use buoyancy driven natural ventilation, some even try to find out if adding a chimney above the atrium can promote chimney effect, see Hussain S(2013) and Liu P C(2009). Using the atrium itself as an approximation of a tall chimney to help energy savings and integrate active with passive energy-saving methods both of which are used in the hottest summer day to deal with largest consumption, is the theme of my research paper, for which there has no same research before. This paper will begin with reviewing some theoretical research to see whether it works well in real situations.

### 1.1. Background investigation 1

Stratification Cooling (SC) is based on the theory of Thermal Stratification (TS).Some researchers (Torrance(1979) and Rees(2001)) use two models to demonstrate that there are TS gravitational waves indoors. These two models are laminar flow and turbulent flow.

It shows that through some methods (such as using correlation flow), there will be a few strata temperature zones indoor (horizontal layers).

The goal of SC is to cause TS, for which only the lower zone needs to be cooled. This paper will try to explain the reduction of the impact of the heat shift from the upper zone to the lower zone to save energy. A simple prototype is assumed to simulate the situation of using a glass tube filled with hot and cold water, a glass lens to separate the hot water above from the cold water beneath. This was used to simulate the separate correlating air masses in the atrium (Fig. 2).

By looking at Figure 2, the upper hot water will transfer its heat to the lower cold water. After a long time, the temperature of these two parts will become same. If we continue to cool the cold water, it also cools the upper part. We use this water model to simulate the situations of SC indoors, beyond some steady loads (energy consumption such as building envelope load, internal fever, fresh air load, etc).



Figure 1 Atrium photo.

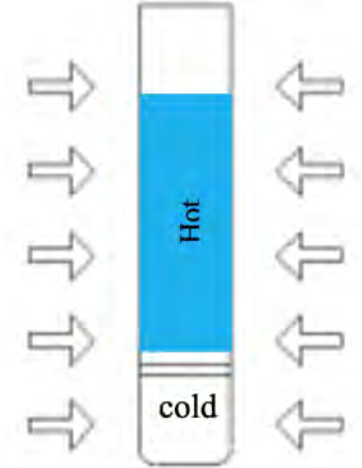


Figure 2 Prototype tube of separate cold and hot water.

In the atrium there is convection loss and radiant heat transfer (by Gao 2007). The principles of the model about water separated by glass in the tube and the air curtain in the atrium are almost same.

This shows that an important factor of Energy-Saving of SC is the main reason to affect the ratio of time periods between cooling the upper zone and the lower zone. It further indicates that we must consider how to cool the upper zone with less energy, and how to reduce its negative impact on the whole load in the atrium.

## 1.2. Background investigation 2

The theory of the Chimney Effect is based on different air pressures between outdoors and indoors, due to the cold air infiltration into the hot air. The air on the top is usually warmer than the air below indoors, with the Neutral pressure plane the outside air is pulled into the atrium from the bottom then rise to the top and ejects into the sky. We can define the pressure as in Eq. (1).

$$\Delta P = 3460 \left( \frac{1}{T_0} - \frac{1}{T_s} \right) h \quad (1)$$

where  $T_0$  = indoor temperature at the top;  $T_s$  = out-door temperature,  $h$  = height from the neutral plane of atrium; and  $\Delta P$  = pressure difference values. (Zhu et al 2008).

e.g. indoor 36.2°C for  $T_0$ , outdoor 31.2°C for  $T_s$ , 11 meter high atrium for  $h/2$ , the  $\Delta P$  is 83.72 Pa.

Can the chimney effect help to cool the upper zone? According to published research by Gao (2007), the effect is limited and little. His study is based on a CFD (Computational Fluid Dynamics) simulated model, Up-supply Down-return (common modern cooling system), combined with the natural ventilation. His conclusion is as following:

The difference between the two methods is that the temperature, compared with uncombined natural way in lower zone is 0.1°C down while the upper zone drop is more than 3°C. This make us confused, why the chimney effect is invalid?

Investigating the conditions of his model, apparently the author determined that the height factor can make no difference. His method has no natural air autocycle method and a lot of heat air shifting into the refrigerated area. The upper zone has many loads, including the envelope glass

wall is been warmed by the outside environment that is producing high thermal radiation. In the upper zone, the flow of air is contrary to the former, and the hot air does not eject.

From the above, we have every reason to say that this method fails to effectively promote the discharge of the heat of the upper air. The method that takes advantage of the natural ventilation method to reduce energy consumption is needed. The air flow should be organized.

## 2. Methods

In this research a case study was selected to demonstrate the feasibility of cutting down the summer consumption. The experiments are taken both by measurement and simulation that include dates of Temperature and Velocity. And performed by HD and Hobo, or Airpack(an CFD software).

Three sides of the atrium are surrounded by floors, except on the north side. It is a greenhouse style atrium in a typical subtropical seaside The Conference Center in Shenzhen city, whose north side is enveloped by a glass wall, on which the sun shines directly and is affected by the surrounding environments (Fig. 1).

### 2.1. Improving method one

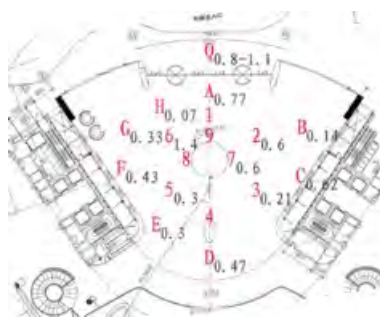
Firstly we have to figure out that, whether the original cooling system suitable or not. Here are the data which are processed by survey of instruments.

The former air distribution is shown in Figure 3. The experiment is put on at hottest summer day, (2018/06/17).

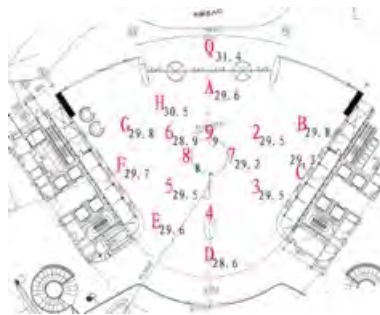


Figure 3 Middle-supply *Photo of air distributor* *Figure 4 equipments of HOBO and HD*  
and down-return (this method is being used mostly currently)

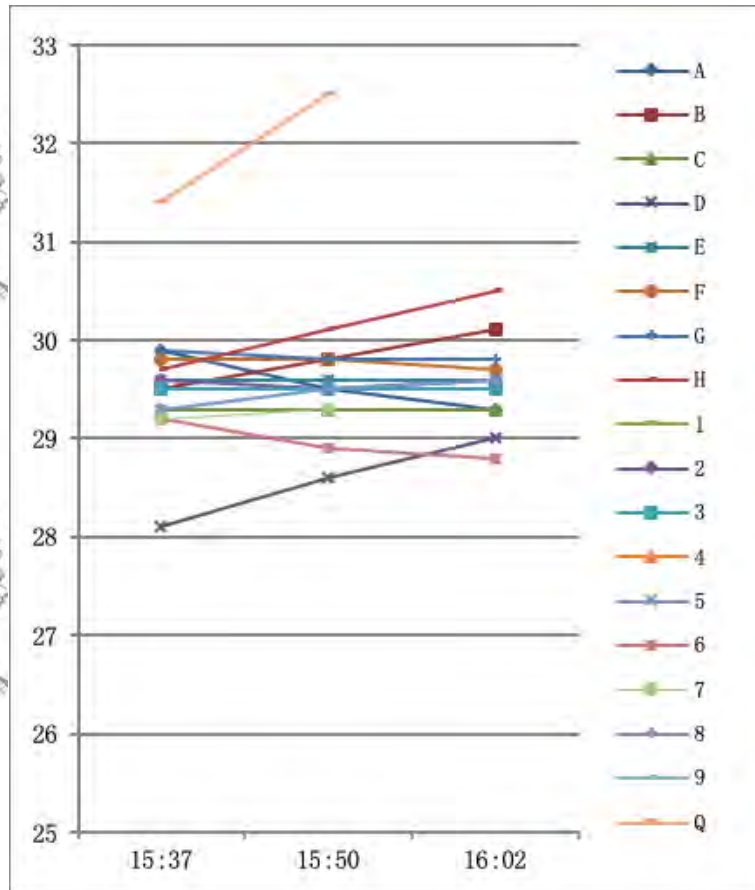




a. average of velocity



b average of temp  
outdoor temp 31°C, velocity  
1.1m/s  
indoor temp 29.3°C~30. 6°C



c Temperature curve of different positions

As shown in the figure 6, point 6 has the largest velocity which is 1.4m/s that indicates almost each ray of air flow converge in this point while it also has the lowest temperature which is 28.9°C.  $\Delta^{\circ}\text{C}=1.2^{\circ}\text{C}$ ;  $\Delta V=0.21\sim 0.6\text{m/s}$ . The temperature and velocity are varied in the atrium and that indicates there is not quite comfortable in the atrium. Meanwhile the energy waste deserves more concern.

If the Conference Center atrium uses different air distribution systems, such as air supply column tube, it can greatly reduce the cooling load. Therefore we have more than one choice (now cooling air is delivered into the middle from two bound walls). By setting the return inlet at 2.5 m high, it can improve the capacity of energy savings. Compared the traditional middle supply mode, the dwindle range of cooling was shown in the shadow (Fig.4).

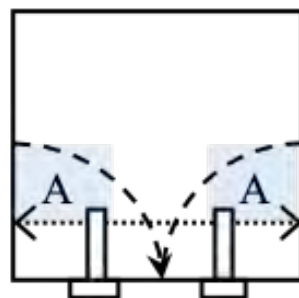
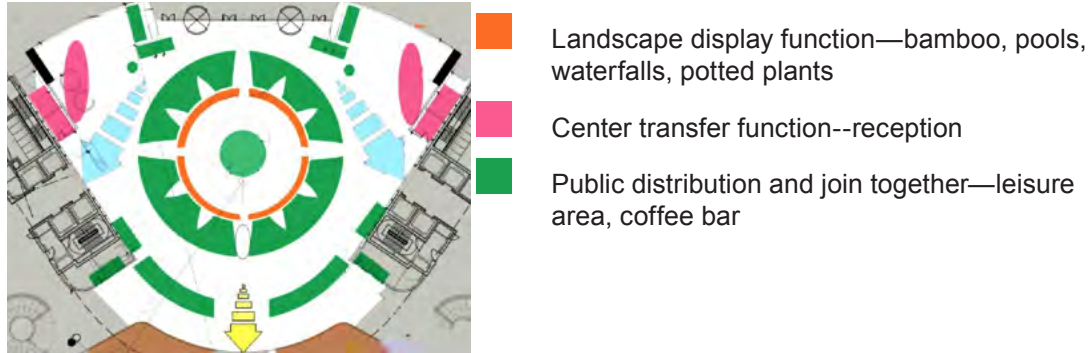


Figure 4 Reference of Air supply column type.

This is integrated design and it can either succeed or fail based on the satisfaction, usefulness and aesthetic. So next is to analyze the site function in the atrium to determine whether it is possible to use the integrated air supply system.

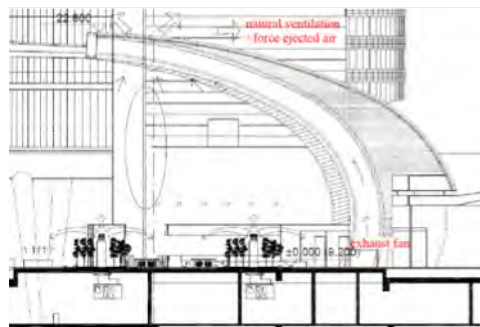
The atrium has a variety of functions and yet is difficult to be clearly separated into different parts. The Conference Center has four functions as mentioned before. The first three functions (Fig. 5) are related to areas, except the hub function of human traffic flow, which is possible to use an upward air supply system and the air supply column in the rest areas.



*Figure 5 Atrium function.*

Yellow represents sea view corridor; while blue represents a path of evacuation, and white represents active area for the hub. Pink represents the reception area, which is separated into two sides to ensure that customers can see the sea directly and clearly. By doing so, the designer wants to design spectacular scenery in the atrium.

The arrangement is as following, AHU equipments are set in basement right beneath the atrium center. Refrigeration air is supplied by six air columns, and then returned through six vents which are set on both side walls and one vent at the center fountain, then gathered to go back to AHU. Two electric windows are situated in the middle of north glass wall to control the direction of the air. Two scuttles are placed on the roof, and one fan on the center to enhance the air flow. According to Figure 5, air supply outlets can be uniformly placed.



*Figure 6 Upward air supply system combine with fans.*

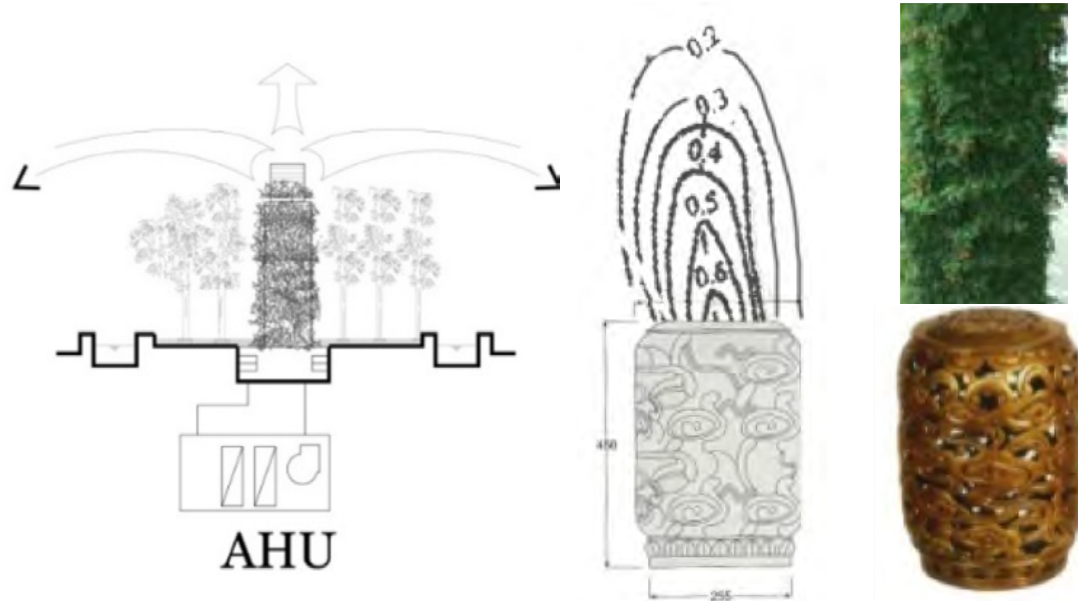


Figure 7. Air supply column tube with climbing plant. Figure 8. Vent outlet.

The outlets can be decorated in many methods to make them look beautiful, such as using vine climbing around the air supply column and then beside the bamboos, which are now set in the atrium (Figs. 7), and set the vent above the water or beside the potted plants (Figs. 8), or hide it under the vitreous table with shade loving plants. The flower can be seen through the vitreous table.

Air supply column seldom be used in Conference Center atrium, because of its ugly appearance, but when properly decorated and carefully arranged, the utilities can be merged into the scenery, and make the system more aesthetically acceptable. They can share the appearance (Fig.9).

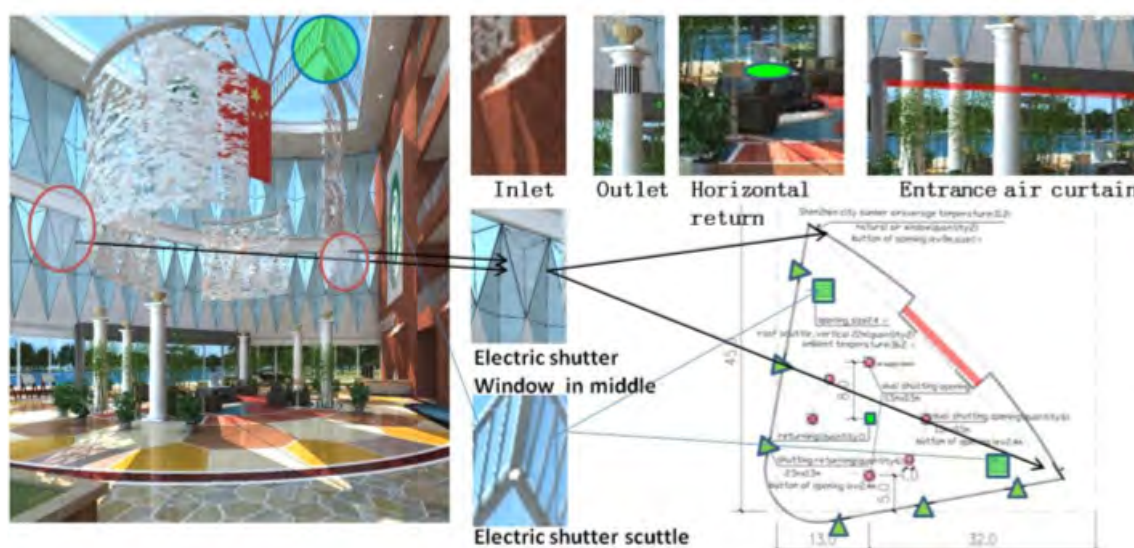


Figure 9 Integrated air supply system combine with natural vent.

Next we will discuss about that to take one more step further to improve the energy saving by using the nature air cycle, and that based on the Method one.

## 2.2. Method two

Our goal is to improve the chimney effect, so as to bring out the extract heat in the atrium. And the negative influence should be avoided or decreased. To facilitate the model establishment, some adjustments have been added. The simulation of air-flow is performed by Airpack, which is a CFD program.

## 2.3. Research mode

Table 1 Building database.

	Horizon	Vertical	Long
Room	45m	22m	45m
	Size	Quantity	Heat conductivity(outside temp)
Envelope			
Roof			78
Wall-front			50
Door			30.9
Floor			ambient
Man and equipment			
Man	1.5m	32	180W
Lamp	0.5x0.5x1m	25	34W
Copier	0.5x0.5x1m	2	85W
Printer	0.5x0.5x0.5m	2	160W
Computer	0.5x0.5x0.5m	4	65W

## Routing

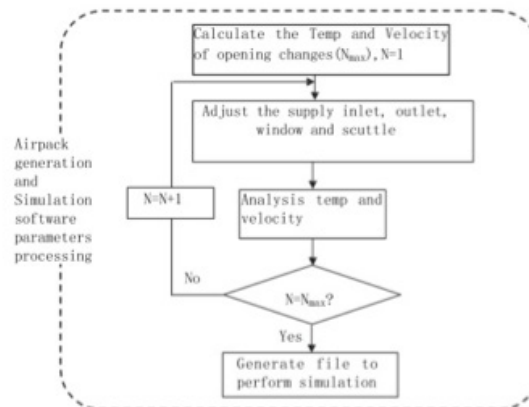


Figure 10 Generation and simulation program flow chart.

There are two kinds of analogy shown in the table 2. One is Natural-B method, which can be used in the transition seasons, and the other Down-C is used in hot summer.

## 2.4. Opening size and position

Table 2 The properties of Inlet and Outlet

	Position	Size	Parameters	Temperature °C	Vertical (m)	Quantity
Natural-B	Opening					
	Wall-F	4.6x2.4m	am-	31.2	10.5	2
	Vent					
	Roof	3.4x3.4m	1.5m/s	36.2	22	2
	Exhaust fan	1 x1m	0.5m/s	am-	22	1
Down-C	Opening					
	Colu-Fr	1.4x1m	5m/s	19	2.7	2
	Colu-Mi	1.4x1m	4m/s	19	2.7	2
	Colu-Ba	1.4x1m	2m/s	19	2.7	2
	C-M-In	1.4x1m	3m/s	19	2.7	2
	Colu-Fr	0.7 x1m	3m/s	19	2.7	2
	Door-a-c	3 x0.5m	3m/s	25	2.7	1
	Vent					
	Wall-w &e	2.5 x1m	-50Pa	26	3	6
	Floor	1 x1m	-50Pa	26	1	1

## 2.5. Simulation process and result

Five air inlet locations representing different situations: total heat gain (Off-A), natural flow with only middle window and top outlet (Nat-B), green house type atrium with air conditions (Down-C), Down-C with exhausting fan(Precedent) and integrated middle natural air inlet and artifact air conditions (All-D) are considered in the atrium, which reflect the cooling effects. The air flow organization is as shown in stimulated results.

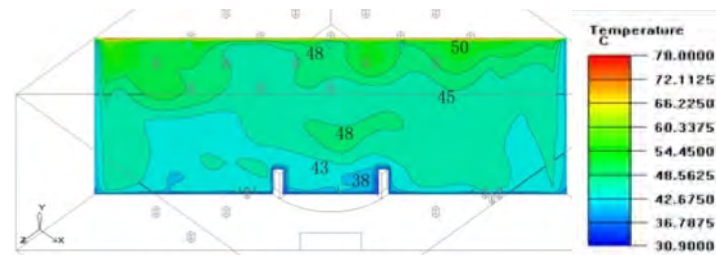


Figure 11. Off-A.

Figure 11 shows the lower zone(0~2.5m)  $t_e^d = 32\sim35^\circ\text{C}$ , middle zone(2.5~9m)  $t_e^m = 36\sim54^\circ\text{C}$ , upper zone(9~20m)  $t_e^u = 54\sim62^\circ\text{C}$

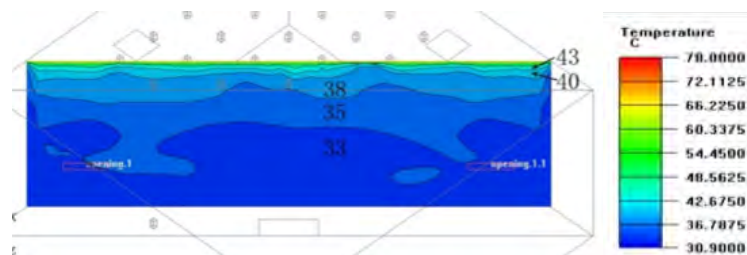


Figure 12. Nat-B.



Figure 12 shows  $t_e^d = 30^\circ\text{C}$ ,  $t_e^m = 30^\circ\text{C}$ ,  $t_e^u = 36\sim 40^\circ\text{C}$ . According to Figure 12, the outside natural air flow blowing in indoor, after that, most of flow descent and are sucked through the roof outlet. The Velocity magnitude of enter air is 1.5m/s; The speed of exhale air is 0.7m/s.

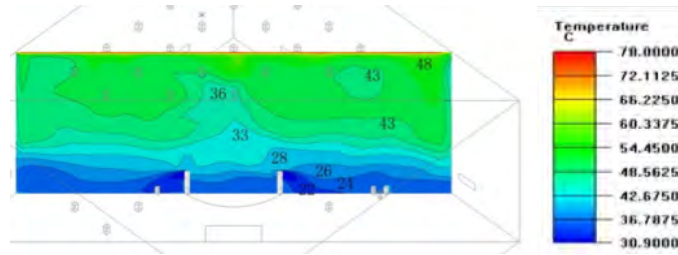


Figure 13. Down-C.

Figure 13 shows  $t_e^d = 22\sim 28^\circ\text{C}$ ,  $t_e^m = 35\sim 40^\circ\text{C}$ ,  $t_e^u = 49^\circ\text{C}$ .

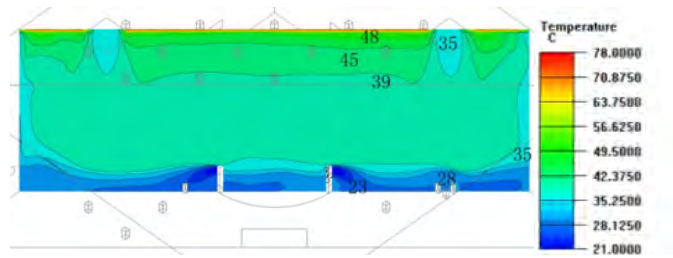


Figure 14 Precedent.

Figure 14 shows  $t_e^d = 22\sim 29^\circ\text{C}$ ,  $t_e^m = 35\sim 39^\circ\text{C}$ ,  $t_e^u = 45^\circ\text{C}$ .

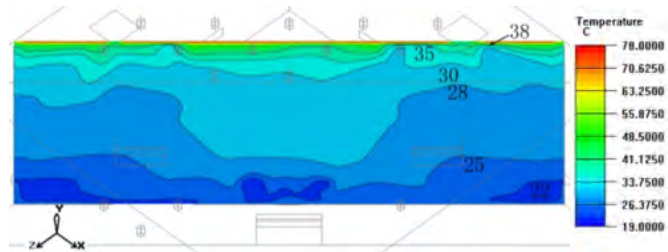


Figure 15 All-D.

Figure 15 shows  $t_e^d = 21.5\sim 28^\circ\text{C}$ ,  $t_e^m = 28^\circ\text{C}$ ,  $t_e^u = 33\sim 40^\circ\text{C}$ .

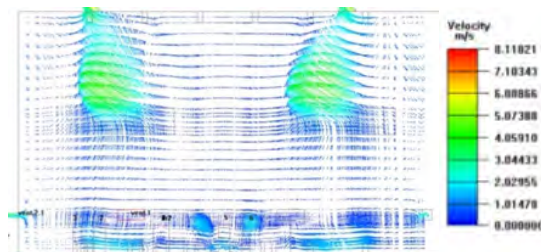


Figure 16 Vertical velocity of method All-D.

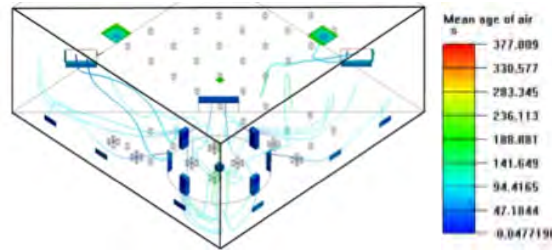


Figure 17. Mean age air.

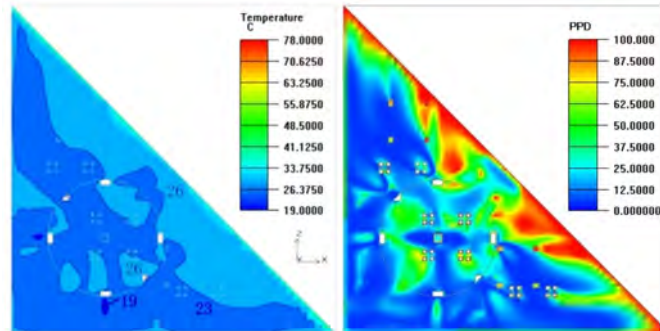


Figure 18 Temperature(left) & PPD(right) of 1.5 height.

With proper arrangement, the negative effect can be decreased. Furthermore, air distributed uniformly, as opposed to use middle-supply and down-return system, makes the air temperature converge, and improves thermal comfort (Fig.17&18).

### 3. Results analysis

The simulation results of Total heat gain without cooling facility (Off-A) indicate that there are temperate ladder in atrium, therefore we use the natural air ventilate (Nat-B), under the pressure of chimney effect, 2~5°C(middle-zone), 13°C(upper-zone). This kind of middle opening method barely influences lower zone, but cooling the upper zone in big deal. When  $(T_0 - T_s) = 5^\circ\text{C}$ , even without addition facility, the air rising is still significant.

#### 3.1. The effect of mechanical facility.

There is a lot of research using the exhaust fan to eject the hot top air outside, aiming to decrease the cooling load. According to Fig 14, partly refrigerated air in lower zone has been sucked to scuttle directly 3°C, 4°C. The result is similar to Gao's experiment. The height factor has not been fully considered, the only difference between use of middle-supply and down-return system and supply column is that the air temperature becomes more converged.

#### 3.2. The effect of integrated method

Comparing the conditions of (ALL-D) and (Precedent) 0.5~1°C(down-zone), 7~11°C(mid), 12~5°C(up). Usually a Conference Center operation schedule is more than 14h per day, some famous Conference Centers such as Sheraton are operational 24h. Based on long term operation, reducing the upper zone total heat gain could tremendously cut down the whole load in the atrium. After the temperature becomes steady, we could increase the supply air temperate 1°C, with the associate of cooled upper zone, the lower zone can keep the comfortable environment. In long hot summer of Shenzhen with more than 14h continued working, then lower 1°C supply air can save-energy greatly. Moreover, It is a passive method.

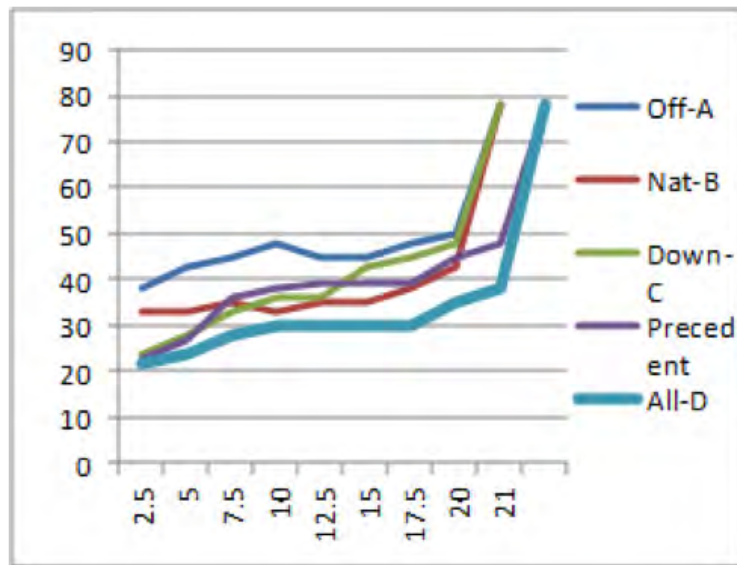


Figure 19 Temperature curve of five Methods

The best air conditioning design in this case had been figured out. It is significant because it is in summer. The simulation results prove the assumption of glass tube which was discussed before, even though there is no way to avoid the negative effect of natural air partly influencing the refrigerant zone as shown in the velocity and most of the hot air in upper zone is ejected out. Another positive effect is that the natural air forces the hot air to follow the curved glass wall on the north side, which separates the heat from the outside as shown in Figure 16. Certainly that can eject the exhaust air outside at the top (which can be combined design with fire served system) to extinguish the stagnate layer. As shown in Figure 16 the method can make the upper zone (above 2 m high) form a continuous flow of air to utilize the chimney effect. That means the method further effectively reduces the upper zone temperature.

One thing had to be noticed is that there is a misunderstanding in the SC system as to what should be used for the lateral supply down return organization (Fig. 20). However, this has led to a contradictory situation of using the chimney effect and natural ventilation. As seen in Figure 21, by Lu (2008), he considers this will take advantages to fully use of lower temperature contained in extracting waste gas which can help to cool the upper part. But we already find out that there is an air pressure coming from outdoor that will interrupt the flow organization because of the middle supply system forcing the part of cool air to rise up, and increase the cooling range and refrigerant load. It is no wonder that this method fails to properly use the natural ventilation if we use the column supply system instead, while setting fresh air inlet higher than the cooling area. As a result, it will reduce the whole air flow, and can also receive the SC effect to make sure just the lower area is cooled. With the upper area is cooled by the chimney effects, moreover, it can save a lot of energy.

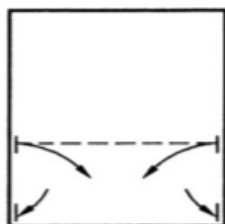


Figure 20 Usually method. By Lu (2008).

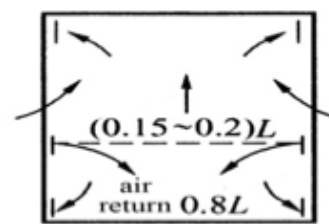


Figure 21 Combine method. By Lu (2008).

#### 4. Conclusions

As with the CFD stimulated case study, by using passive combined with active means have two main advantages: separation and utilization of natural air buoyancy. Firstly the cooling zone only covers the lower part, which to be specific covers two meters height of human activity areas, as opposed to use of a nozzle set at 6 meters or even higher. It can reduce the range of refrigeration more efficiently, almost half in this case. As is well known lower height air with lower temperature returning to the cooling below saves energy; Secondly, natural air performed energy-preservation cooling upper zone.

Using these two methods less investment and saving of energy can be achieved, the integrated refrigeration system is not only beneficial for saving energy largely, but also provides fresh air with comfortable thermal environment that is attractive and easily accepted by people.

The further study will be a comparison of the energy consumption between the original design and the improved method. Hopefully we can see exactly how much energy saving of the latter method.

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# SHARING URBAN RENEWABLE ENERGY GENERATION SYSTEMS AS PRIVATE ENERGY COMMONS

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## Summary

This study tested a new methodology for simulating shared electricity generation among small groups of neighbours with Ostrom (1994) principles of common pool resource (CPR) (human behaviour-based) efficiencies. The approach does not anticipate exclusive off-grid communities but instead, diverse energy users taking advantage of the averaging effects of aggregation, the social benefits of a CPR and direct action on emissions. The study tested three groups of 5 adjacent- or same-building- neighbours for three months to measure how electricity demand (import) is affected by an in-home display issuing nudges and sanctions by the group around a simulated (limited capacity) shared solar and battery system. A control group of 6 homes' energy data was obtained for the same period. All three groups reduced their energy demand with weak but significant correlation between stimulus and reduced energy demand and one group significantly shifted demand toward available shared solar energy resources during the intervention.

Keywords: solar power, commons theory, microgrid, behaviour change, energy sharing



## 1. 1. Introduction

The present trajectory for the Energy Transition in Australia in the absence of substantial demand management for electricity will see a doubling of demand to 2050 (CSIRO and ENA, 2015) and the likely scale of renewables being twice the nameplate capacity of despatchable generators (AEMO, 2013) in order to compensate for variability. That is, four times the generation power of 2018 carbon-based generators may be needed in 2050. The transition to very low carbon has already been estimated to cost AUD1,140 billion (CSIRO and ENA, 2015), a large component of this cost being met by private solar owners.

Accordingly, some form of demand management is often assumed to occur in popular “zero carbon” plans (for example (Ison & Lyons, 2013)) to the extent that electricity demand is expected to be *halved*. Usually this is proposed to occur through efficiency gains. However, a turnaround in demand of this magnitude would be unprecedented (Kelly, 2010). This electricity demand history is already moderated by long running government programmes for energy efficiency, behaviour change, domestic solar stimulus, electricity price increases and other effects that should suppress demand. These are delivered via energy saving information (DELWP, 2014) but also efficient device labelling (DEE, 2018), efficient product rebates, solar tariffs (DELWP, 2016) and others. The motivations for these approaches include that energy consumers can change their habits. However, the literature increasingly does not support this.

## 2. Demand management

Demand management is a mature field and it has rested heavily on Bandura’s Theory of Planned Behavior (TPB) (Bandura, Boone, Reilly, & Sashkin, 1977). The fundamental premise of this approach is that consumers are rational and when served with information and incentives, they will choose to consume differently. Studies of studies (Delmas, Fischlein, & Asensio, 2013) find that the largest effects of very many forms of demand management signals based on TPB seem to have a final impact on actual electricity demand of only 10%, usually less, and with many studies having identified methodological problems (also (Abrahamse, Steg, Vlek, & Rothengatter, 2005)). That is, interventions ranging from rewards, to goals, penalties, pecuniary incentives, home audits and others do not have large effects on actual demand and often the removal of the intervention results in demand returning to where it was. Most recently, a campaign for low-income families in several cohorts across Australia (n=18889) with respondents self-reporting changed energy practices (30-80% reported changes) after efficiency interventions were able to reduce their demand by only 2-12% (Russell-Bennett et al., 2017). Consumers are informed, they make changes to their routines, but the returns in avoided energy demand are small.

The challenge of demand management likely has at least four impediments: campaigns typically deal with the consumer in isolation, in the absence of their social environment or even family environment (for example (Lowe, Lynch, & Lowe, 2015)); electricity is offered as limitless, cheap and highly reliable (Abbott, 2001); electricity use is very difficult to disaggregate from social practices (Shove & Walker, 2014); and, there are no consequences for high demand - only higher electricity bills.

There are of course some notable exceptions to these. High-touch interventions such as personal in-home audits perform well compared to others (Delmas et al., 2013). High-tech interventions such as in-home displays (IHDs) have been observed to bring about a 20% reduction in electricity demand (Gans, Alberini, & Longo, 2013) and finally, the subject of this study, social approaches to sustainability (EcoTeams, energy communities), have established long running energy conservation behaviours that even improve in time (Hargreaves, Nye, & Burgess, 2008).

Reframing within social structures already seems successful for demand management in water. Prior to the Victorian Millennium drought (1999-2009) water was felt to be inexpensive, unlimited and reliable (Allon & Sofoulis, 2006, p. 49) - as electricity is presently understood by consumers. Melbournians discuss water now as a limited and valuable resource after a large

utility-led demand programme (Liubinas & Harrison, 2012). Can such a re-framing be achieved for electricity? This may certainly be harder to bring about because the visible impact of the drought has no equivalent for energy, and even the very likely climate change effects behind the large bushfires of 2009 were attributed to ocean currents (Australian Bureau of Meteorology, 2014) and not human-forced climate change. Simulating a re-framed electricity supply may cause greater conservation, but the re-framing itself needs to be compelling.

## 2.1. Commons

This study proposed another way to potentially re-frame the electricity supply as a means to conservation - that electricity should be presented as a Common Pool Resource (CPR) which is managed by a commons system. Traditionally CPRs have been natural resources which have limited productivity and have to be managed by those who appropriate from them. Not managed properly, the resource is overused and it collapses. Elinor Ostrom's work *Rules, Games and Common Pool Resources* (1994) spells out eight design principles for commons which have since been rigorously tested in hundreds of studies (Cox, Arnold, & Villamayor Tomás, 2010). It is also promising that rural and isolated distributed renewable energy systems can be successfully shared and that the naturally limited performance of the systems can be accommodated in behaviour changes (for example see (Gardiner, 2017)). Similarly commons systems successfully self-manage shared pasture, fisheries and forests. Can there be urban energy commons?

## 2.2. Commons theory

Ostrom's principles are derived from observations of (very broadly): borders, appropriation and maintenance, rule-making, monitoring, sanctions, conflict resolution, government interference, and scale. The definition of a managed commons is still not broadly understood - Wikipedia is not a managed commons: it is certainly managed and has its own system of governance and rules, but anyone can consume a Wikipedia article without impacting other users (it is not rivalrous, and there are no sanctions for misusing it). This makes Wikipedia a *public good*. Less certain are club goods or toll goods (Bollier, 2014) such as a collective solar and battery system that is owned in shares. This is not a commons according to Ostrom's principles because access to the toll good is artificially limited (by access limited to owners) and non-rivalrous (until there is congestion) (Ostrom et al., 1994, p. 7). Instead the energy commons (the *non-stationarity*) was defined in this research as the collective energy sharing agreement itself. To test this, the applicability of commons principles for sharing energy, principles 4 and 5, *monitors* and *graduated sanctions* (respectively) were chosen for testing because these principle were most often absent from public goods and toll goods management.

Electricity use at present occurs without any kind of signals about limits, let alone reciprocity. That is, one can use a large amount of electricity and apart from an eventual large bill there are no consequences. Since electricity costs no more than fifty cents a kWh, it may cost a fifty dollars to run a large air conditioner in summer. In reality, running a large air conditioner on the hottest days of the year can cost the utility AUD1,500 (Wood, Carter, & Harrison, 2014, p. 9) to deliver the electricity to *one air conditioner*. This is because in fact, electricity is rivalrous at the extremes and the cost of peak demand infrastructure (to support the grid for the top 10 demand days a year) exceeded 45 billion dollars over the last 10 years (Hill, 2014). This signal, however, is completely hidden from residential consumers and this high cost is spread across all electricity users, whether they use air conditioning or not.

The energy source to share in the proposed commons is a fictitious shared solar and battery system that a group of adjacent neighbours will operate and use. This system could be placed on the larger roofs and batteries installed on some of the other houses or where there is space. They are privately connected together (on a private easement) or there is some arrangement with a retailer to allow the exchange of electricity to happen among them via the distribution system. The homes (or in fact flats in the same building) are adjacent because a real private easement

would require this, but also there is likely social cohesion among such homes which is identified as valuable for CPRs (Bollier, 2014). Avoiding opt-in for energy sharing (instead recruiting with a spatial constraint) should reduce some self-selection effects in energy collectives (Bauwens & Eyre, 2017).

Thus the methodological approach considers the impediments listed above and attempts to meet or avoid them: the intervention targets the group as the subject, not the individual home - it is asserted here that this will take advantage of group effects. Second, the electricity supply is re-framed to a limited and valuable resource; the intervention does not rely on signals that target disaggregated behaviours; and, a social sanctions approach is proposed (as part of a commons system) so that there are social outcomes for using electricity at the extremes. The apparatus is an in-home display (IHD), a form of energy use feedback that has rendered promising results for self-management of electricity demand.

### 3. In home display

In order to signal to home occupants that they are draining a rivalrous, limited electrical supply, an in-home display was built for this study. The device is a Raspberry pi microcomputer with a 7-inch touchscreen in a 3D printed case. The computer has a 3G cell modem and a Radiohead low power packet radio receiver. An accompanying smart meter reader was created that counts the LED flashes on two brands of smart meters and radios the count to the IHD in the home. Twenty of each device (IHD and reader) were made. This setup is similar to the proprietary Watt's Clever IHD system (SmartUser, 2018) except that the study system is a networked colour touchscreen display with Linux operating system.

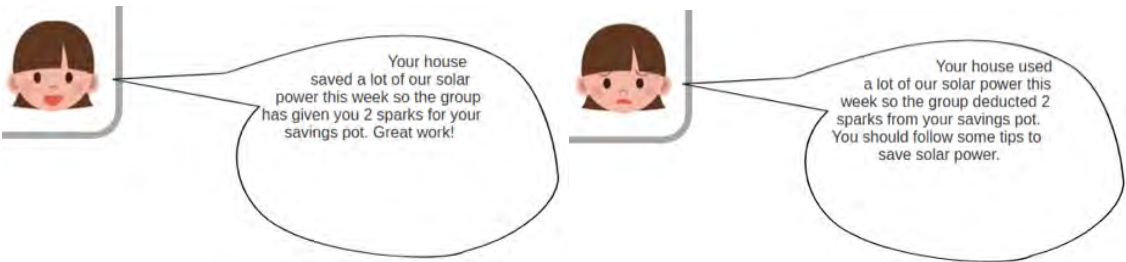
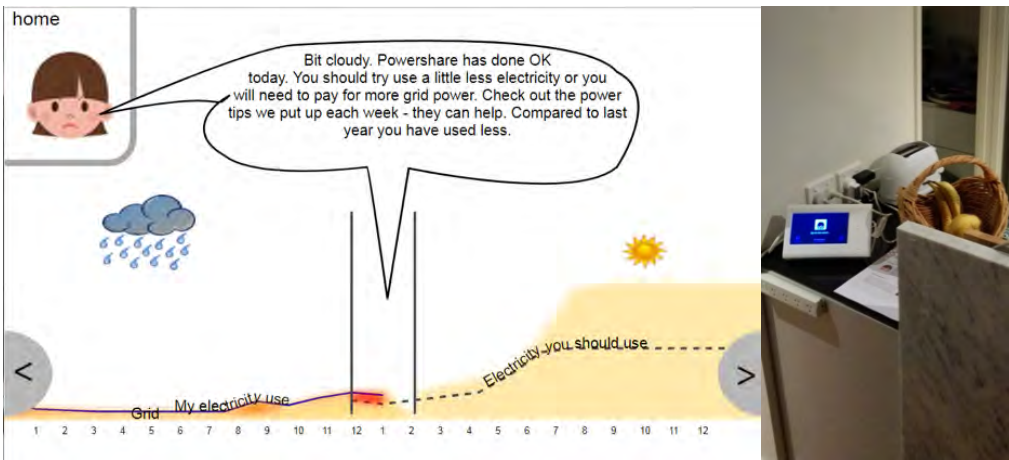


Figure 1 Negative and positive sanction triggered by home energy demand cause solicitations to the other group members, who may choose to fine or reward the household. An avatar, Rachel, reports the outcome to the affected household



Figures 2 and 3 (left) IHD screen capture showing ten different features to reinforce conservation and shifting of demand loads toward available simulated solar and battery power. 1) A centre

*“goals” area of the graph shows immediate situation (at 1pm) with 2) prediction at right (3) weather, 4) demand and battery/solar) and 5) performance today at left with 6) actual solar and 7) recent demand. Grid draw 8) is shown in red. Rachel an avatar, 9) emotes and gives 10) plain language versions of statistics The tabs with < and > are for navigating. Image of an IHD (right) in the kitchen of a participant home.*

Fifteen homes took part in the study, recruited via “champions” who live among them and were reached via personal and professional networks. Five homes at one site were in a CBD apartment building. Two other sites were five homes each, freestanding 1920-30’s era renovated wooden dwellings. About half the free standing homes had solar panels but the study disregarded these “real” systems and simulated a larger, shared system with battery modelled for each group. The modelling was performed with a numeric solver accepting the half-hourly aggregate demand of all participants in the group from 2017 along with previous solar records, energy costs and equipment CAPEX costs. The model produced solar and battery sizing and modelled performance for each group. This was used to configure each IHD. The size of the modelled system was broken down into unit holdings proportionate to the household demand size of 2017 so that large energy consuming households would not be unduly penalised (and small consumers would not be unduly rewarded).

Software was written for the IHD and a central server. Each IHD used its 3G modem to reach the central server and report hourly on interactions the IHD experienced with the occupants. Each IHD had a reinforcement schedule programmed to deliver signals and interactive prompts. These are given in Table 1 below. To norm the system, government- provided energy tips selected from (Sustainability Victoria, 2014) were programmed to be delivered over 20 days along with energy use information to make sure the IHD had the impact observed of other IHDs elsewhere. Signals about the presence of the group and the limited availability of the system generation began after 20 days and from 40 days, the system detected exceptional energy demand events and solicited the group to give positive or negative feedback to a deviant home.

*Table 1 Signals, schedule and function*

Signal and schedule	Form and purpose
Tips 1 to 10, each 2 days	Energy saving information
Sanctions 1 to 3, triggered during 20-40 days	Solicit for fines for an over-using household then report the fine
Rewards 1 to 3, triggered triggered during 20-40 days	Solicit for rewards for an under-using household then report the award
Satisfaction question each 5 days	Prompt for satisfaction with the service to detect problems

In addition to the timed prompts, pages of the system offered either statistics or commentary by a cartoon avatar, Rachel (Figure 1). Together with graphs these systems offered essentially the same information in three different modes. Figure 1 shows the pop up prompts that were served on top of the graphs shown in Figure 2.

A page of the system intended to reinforce a group goal, called the Paydown page, was removed close to deployment because the short run of the study meant that only three months of performance could not be effectively graphed against a payment duration of perhaps eight years. Still, commentary about paying down the system and certain statistics about this were retained.

## 4. Results

About a 100,000 event records were collected for the three groups along with a selection of 6 other homes used as controls in the period 1 Jan 2018 to 14 August 2018. The IHD signals ran for 100 days to 14 August. There were 617 interactions with the IHD collected and counted. A 4th order polynomial regression was fitted to the control group energy data series and then



this spline was subtracted from the study data series to adjust for seasonal, price and other externalities. The period after 1 Jan 2018 but before May 2018 was observed for study effects which may have contributed a Hawthorne effect to the outcome. None was observed. That is, the effect of recruitment, collateral and a smart meter reader before the IHD deployment did not have an observable effect on demand and all observed effects were more likely due to the IHD and its signals.

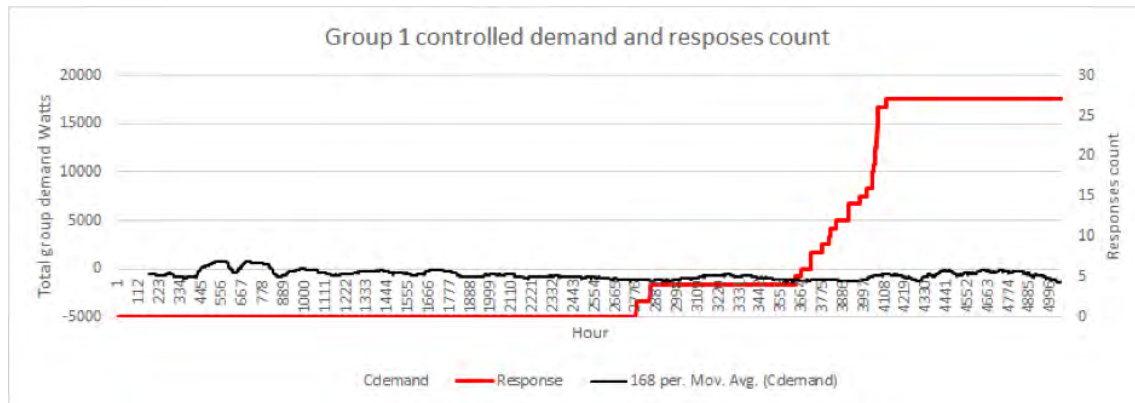


Figure 4 Group 1 responses to stimuli presented on the IHD are accumulated in red. This is plotted against moving average of a week of demand data (which have had control group effects subtracted) in black. Correlation between demand and responses in the IHD period is  $r=-0.156$  ( $P=0.000$ ).

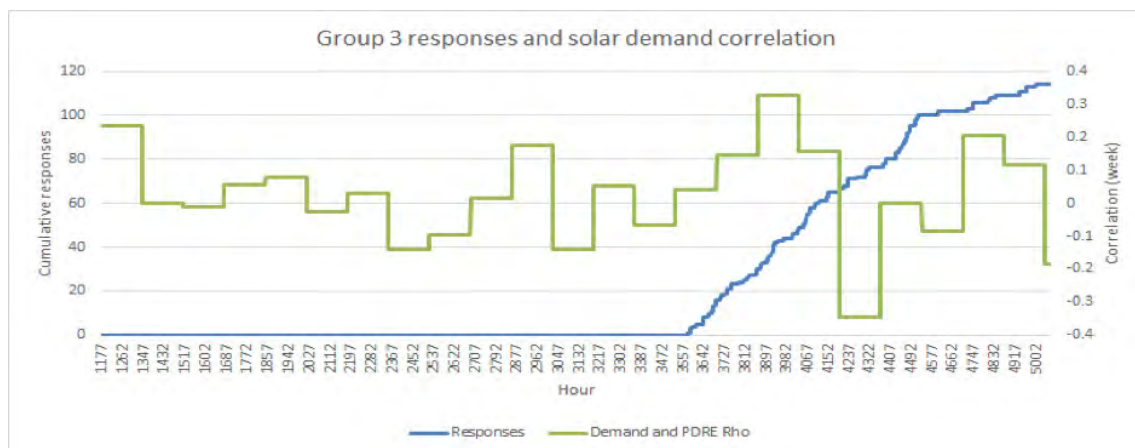


Figure 5 Group 3 Weekly Spearman's Rho correlation between PDRE and total group demand (green). Responses from the group are shown cumulatively (blue). The graph starts at hour 1177 which is when solar accounting began. From hour 2420 to the end,  $r=0.12$  ( $P=0.0001$ ).

Analysis of these results sought to find a negative correlation between demand and the cumulative signals with a increasing negative trend toward the end of the run to reflect increasing effects of more group- and socially- oriented signals on consumption of electricity. As an example, Figure 4 shows group 1 cumulative responses and electricity demand. This weak but statistically significant negative correlation is present for all three groups.

Analysis determined the correlation between demand and the hourly availability of simulated solar and battery (called Past Distributed Renewable Energy - PDRE). This was determined as an indicator of load-shifting behaviour change. Figure 5 above shows group 3 weekly correlation between demand and available simulated solar and battery. The overall Spearman Rho correlation for energy demand and solar availability within the intervention period for this



group was  $r=0.12$  ( $P=0.0001$ ). For groups 1 and 2 there was no significant correlation for time of day demand and solar-availability in the IHD period.

In the 100 days of the intervention in fact no sanctions messages were executed since no sanction events were triggered. Group messages were present from 20 days on per the schedule and are attributed to the increasing trends in declining energy use and demand-solar correlation.

## **5. Discussion and Conclusions**

This study deployed a specially designed in-home display (IHD) that simulated a large, shared solar and battery systems among 3 groups of 5 adjacent homes. The signals delivered by the study in-home display simulated a commons arrangement by purporting that the shared system provided limited, rivalrous, unreliable electricity. This, together with prompts to positively or negatively message group members who under- or over- used electricity (respectively) attempted to reproduce Ostrom's (1992) forth and fifth commons principles: monitors and graduated sanctions (respectively) identified as critical to actual demand moderation.

This approach adds to the field by testing a more black-box approach to home energy use, in contrast with Bandura's Theory of Planned Behaviour (Bandura et al., 1977) which sought to modify rational behaviour in energy consumption of individual occupants. This study exploited the more modern community-as-consumer (Mackenzie-Mohr & Smith, 1999) and simulated a large shared solar and battery system.

The study found statistically significant support for behaviour change due to the IHD and signals. Due to the scale and short time frames of the study, outcomes for this cohort are perhaps limited in their applicability but they do indicate a promising methodology for directly testing the potential of an energy commons without the need for infrastructure or utility cooperation. In future it may also be possible to force the sanctions events since none were triggered by consumption extremes.

IHDs are a promising way to provide signals - a large Northern Ireland study found 20% demand reduction (Gans et al., 2013) but these results were not as strong in Australia before the Victorian smart meter rollout (McKerracher & Torriti, 2013). There may be a new opportunity to pair IHDs with Victorian smart meters but also to go further a use the IHD, effectively a new messaging device, as a way to coordinate groups of homes as this study has demonstrated. The value of commons theory in this approach is promising because previous demand management studies did not reframe electricity as different from high available, unlimited and highly reliable. Renewable supply will not match these qualities and instead requires a kind of compromise between demand behaviour, available power and conservation. The greater agency of people in groups is already important for environmental conservation more broadly (Bandura, 2000) and the very difficult challenge of changing social practices around energy should also be a social effort. Shared energy can exploit these opportunities and commons theory provides a very rich history of stable, non-market, self-governing social efforts around critical limited resources.

This study does not propose urban off-grid communities but it may be possible for a private microgrid to be legally off grid (islanded) for electricity exchanges. The grid utility provides considerable value but it does not provide effective signals to moderate demand and the GHG emissions from electricity are very great. Instead, the modelling in this study showed a majority of electricity needed by a group of homes can be obtained efficiently (both in terms of energy and cost) from a shared solar system but also in concert with a demand management programme. This approach should be explored further for its potential to bring about substantial shifting- and reduction- of energy demand if renewable generation is to plausibly meet our future demand.

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# IDENTIFYING BOTTLENECKS IN THE PHOTOVOLTAIC SYSTEMS INNOVATION ECOSYSTEM – AN INITIAL STUDY

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## Summary

Solar energy is likely to play a major role in future renewable energy systems. One important part in that is the integration of photovoltaic (PV) systems into the built environment. Earlier studies show that the institutional framework plays a major role for achieving a broad implementation of PV systems. It has however also shown that the value network of PV systems needs to be understood and developed further. In that respect, earlier research on innovation diffusion into the built environment shows the necessity of involving and understanding key stakeholders. Stakeholder analysis may help in identifying key stakeholders but fail in assessing the stakeholders' role in the value network as it does not, for example, take into account the relational effects. Innovation Eco Systems is an approach that has the potential to do this as it addresses the alignment structure of the partners needed for the value proposition to occur.

The aim with this initial study is to address the use of innovation ecosystem as a way of assessing implementation of PV systems in the built environment. Two structured workshops with two key stakeholder categories, Clients and Suppliers, were held to identify the main barriers for a broader implementation of PV systems into the built environment in Sweden. The main results show that the earlier studies were right in that the institutional framework is a major factor, but also that the value network is important and that the problems in the value network is perceived somewhat different between the two categories. This suggests that it will be necessary to address the value network from the perspective of the actors by applying an innovation ecosystem analysis. It also helped in identifying other important stakeholders in the value network that will be needed to include in the future studies. To summarize, the findings of this initial study suggest that innovation ecosystem will address a more comprehensive picture on the implementation of PV systems in the built environment. However, to be able to identify bottlenecks and subsequent solutions to these bottlenecks further studies of the complete innovation ecosystem, with its stakeholders, is necessary. The ongoing project is currently carrying out these studies in a Swedish context.

Keywords: PV, implementation, innovation, ecosystems, bottlenecks, stakeholders

## 1. Introduction

Addressing the Agenda 2030 and in the 17 Global sustainability goals renewable energy solutions has been identified as one important contributor. Photovoltaic electricity is an important element in renewable energy systems. The pace of implementation differs in different countries. Germany has approximately 8% photovoltaic electricity in the electricity mix while Sweden only has about 0.2%, although the level of solar radiation is about the same. Achieving 100% renewable electricity of the electricity mix demands a larger share of photovoltaic electricity and a significant increase in the implementation rate of photovoltaic systems in the built environment. The Swedish Energy Agency states in its strategy for photovoltaic electricity that the potential is between 5 and 10% of the electricity mix. They also state that it will be necessary to reach these levels if Sweden is to reach its target on 100% renewable production of electricity by 2040 (Energimyndigheten, 2016). The same strategy identifies regulations and public policies as well as bureaucratic administration as the main bottlenecks to an increased implementation of photovoltaic systems. A report from the the Swedish Energy Agency maps the innovation system for the energy sector as a whole to identify overarching strengths and weaknesses through for example drivers and hinders for development and implementation. The result is mainly targeting public bodies, decision and policy makers. With specific regards to photovoltaic electricity production though, it is noted that there is an increased need of understanding the value chain and that the supply chain network is underdeveloped (Energimyndigheten, 2014). As a large part of the photovoltaic production of electricity will need to be implemented in the built environment it relates to the construction value chain and the supply chain network need to be understood and developed in that context.

Developing, diffusing and implementing innovations in the construction value chain has its specific challenges. A short-term perspective often characterizes the construction value chain and fragmented processes (see for example Barlow (2000), Widén and Hansson (2007)). It is also characterized by innovations being implemented in projects (Winch, 1998) and knowledge spreading between construction projects (Senaratne and Sexton, 2008), both of which are hampered by the short-term perspective. From earlier research it is known that the rate of innovation diffusion is depending on the involvement of key stakeholders already during the development stage of the innovation process (Widén et al., 2014). It is also known that different parts of the construction value chain experience different issues as main barriers to innovation implementation (Chen et al., 2018). In order to understand and to enable development of the construction value chain related to the implementation of the photovoltaic electricity production system there is a need for an approach that take the project-based nature of construction, the different perspectives of different actors and how it affects the value chain into consideration.

The research presented in this paper is an initial step in assessing PV related construction value chain using the approach innovation ecosystem. The aim with this initial study is to address the use of innovation ecosystem as a way of assessing implementation of PV systems in the built environment. The aim of the ongoing research is to identify bottlenecks in the value chain hindering or slowing the pace of PV systems implementation in the built environment.

## 2. Innovation ecosystem

The traditional way of looking at innovation is that an inventor, for example in the context of construction a supplier or a contractor, generates value for a client by supplying/selling a product or a service within a project (Winch, 1998). Research has shown that in reality quite often there is a need for other stakeholders to change their behavior, or in some instances even innovate as well, for the client to realize the value (Adner and Kapoor, 2010). An innovation ecosystem is a way to connect or relate the different stakeholders that have the potential to influence the possibility to create value from innovations from an actor's perspective (compare with (Adner, 2017, Moore, 1998). This system does not follow the traditional linear process of value creation and many of the stakeholders lie outside of the traditional value chain (Iansiti, 2004). It takes its starting point in value creation and analyzes what stakeholders need to interact and in what way they need to interact in order to realize the value (Adner, 2017). In this case the value of PV



produced electricity in the built environment. Innovation ecosystem can be said to complement the understanding between stakeholder analysis and technological innovation systems by relating the effects of the actions of stakeholders to the result for a single stakeholder. The stakeholders in the system generates value for the client as a system of interdependent companies rather than as individual companies. In other words, innovation ecosystems enables the understanding of value creation for the client that individual companies would not be able to do (Adner, 2006).

Innovation ecosystem can be studied or seen as either “ecosystem as structure” or ecosystem as affiliation” (Walrave et al., 2017). The earlier is more focused than the later. In this research, we have opted for “ecosystem as structure” thereby follows that the ecosystem’s value proposition is defining the innovation ecosystem (Walrave et al., 2017). This in turn means that the system boundaries are defined by those stakeholders and other elements that will have an effect on the realization of the ecosystem’s value proposition (Adner, 2017). It is important to note that the focus on realizing the ecosystem’s value proposition it is from the perspective of the end user (Clarysse et al., 2014). Another important aspect to be aware of is that due to the interdependencies between the stakeholders, failure to contribute by one of them may have negative effect on the others (Brusoni and Prencipe, 2013).

In the context of construction, an innovation ecosystem analysis is a tool for identifying stakeholders that are affected or can affect the implementation of an innovation in order to relate key stakeholders to the innovation process (compare with (Widén et al., 2014)). It is also important to analyze in what way stakeholders need to change/develop their behavior and what the incentive is to do so (compare with (Adner and Kapoor, 2010)).

In summary innovation ecosystems allows for the analysis of how different stakeholders, for example consultants, grid owners etc., need to interact, develop, change business models and more, as well as what incentives are necessary to limit the effects of bottlenecks and increase the implementation of PV systems. In other words, it gives a tool to understand how the value chain as a whole need to develop to ensure value creation through implementation of PV systems in the built environment.

### **3. Method**

In order to investigate the innovation ecosystem there are three features that need to be addressed. (1) The innovation ecosystem need to be identified, what stakeholders are part of the system and their relations. Within the system (2) locate the bottlenecks and (3) which ones are the easiest to address. As described earlier, stakeholders in the innovation ecosystem may be stakeholders not part of the traditional value chain. These are particularly important to identify.

We have opted for a structured workshop method (compare with Björkdahl and Holmén (2016) where the participants with strategic insight are given the task to identify and rate the key challenges as well as rank them according to ease of addressing them for a particular area. In this case the particular task was “what are the key challenges to increased implementation of PV systems in the built environment”. The ecosystem’s value proposition is improved value for property owners by implementation of PV systems. The aim of the workshop was to identify the three features describe above. The process of the workshops follow a pre-defined structure (Björkdahl and Holmén, 2016):

- Identification
- Clustering
- Relationship
- Ranking

In the Identification stage the participants identify the five top challenges for the particular problem area, in this case bottlenecks creating value for the client through implementation of PV Systems. An important part at this stage is to ensure that every one understand each challenge. In the second stage, clustering, the initial identified challenges are clustered into problem

clusters, similar challenges are brought together. The problem areas are then assessed for relationship to any other problem cluster, for example if one problem cluster leads or contribute to another problem cluster. The last stage is to rank the problem clusters according importance and manageability (Björkdahl and Holmén, 2016).

In this initial part of the research the clients/property owners and suppliers were targeted as those two were identified as the two types of stakeholders that without question would be part of the innovation ecosystem. The plan for the research following these initial studies is to target the types of stockholders that are identified in these two workshops as well as in the subsequent workshops. The two types of stakeholders were represented by the Solar Energy Association of Sweden, for suppliers and Swedish Energy Agency's group for procurement of energy-efficient multi family buildings, 'BeBo', for clients/property owners.

### **3.1. Solar Energy Association of Sweden**

The Solar Energy Association of Sweden is the national organization with approximate 200 professional members representing Swedish industry, as well as Swedish research institutes, working with solar energy. The association works for utilization of solar energy (direct transformation from solar radiation to heat and electricity) and plays an important role in a sustainable Swedish energy system.

Activities within the association and the secretary board consists of communication with authorities in order to improve the conditions for solar energy in Sweden, assembling information material for the public and decision-makers. They are the owner of the annual Solar Energy Award (Solenergipriset) for an exemplary plant and an exceptional contribution to the development of solar energy in Sweden, organizes meetings for the solar industry in order to discuss common activities, collects branch statistics over installed systems.

### **3.2. Swedish Energy Agency's group for procurement of energy-efficient multifamily buildings, 'BeBo'**

BeBo has been active since 1989 and is a network of property owners with the Swedish Energy Agency as a financier for the coordination of the network. The main focus is to reduce the dependence of energy in the form of heat and electricity in multifamily houses, and thereby reduce the impact on the environment. BeBo's activities will lead to the introduction of energy-efficient systems and products through a combined procurement competence. The Swedish Energy Agency therefore contributes funding and expertise to BeBo, which in turn, goes on to the property owners by means of, among other things, demonstration projects carried out with the help of the members.

## **4. Result**

The result from the workshop with the clients/property owners in BeBo is presented in table 1. The factor that is considered to be the largest bottleneck is the public policy system and the second factor has to do with the problem of transferring electricity produced between property boundaries, connection point, and the third correlates to technical development. Of all the bottlenecks identified, needs profile/dimensioning is the considered easiest to manage, with connection point on second and building regulations on third.

As can be seen in table 2, the client/property owners related almost all bottlenecks to their profitability. The only two bottlenecks that were not related to profitability were public procurement and the construction process. Two bottlenecks were understood to have relations to more than one other bottleneck. Public system affects both connection point and profitability, while Lack of knowledge affects public procurement, profitability and needs profile/dimensioning.

*Table 1 Bottlenecks according to clients/property owners*

Factor	Need	Need - weighted	Manage-ability	Manage-ability - Weighted
Policy system	12	<b>3,00</b>	0	0,00
Connection point	8	<b>2,00</b>	6	<b>1,50</b>
Building regulations	5	<b>1,25</b>	5	<b>1,25</b>
Procurement	3	0,75	3	0,75
Construction process	3	0,75	4	1,00
Technical development	6	<b>1,50</b>	2	0,50
Profitability	3	0,75	2	0,50
Lack of knowledge	2	0,50	1	0,25
Needs profile/dimensioning	0	0,00	10	<b>2,50</b>
Investment	0	0,00	3	0,75

*Table 2 Identified relations by clients/property owners*

	Policy system	Connection point	Building regulations	Public Procurement	Construction process	Technical development	Profitability	Lack of knowledge	Needs profile/dimensioning	Investment
Policy system		x					x			
Connection point							x			
Building regulations							x			
Public Procurement										x
Construction process									x	
Technical development							x			
Profitability										
Lack of knowledge				x			x		x	
Needs profile/dimensioning							x			
Investment							x			

The result from the workshop with the supplier representatives is presented in table 3. The main bottleneck they identified was the lack of a stable subsidies system. The second was lack of knowledge and the third has to do with profitability. Lack of knowledge is considered as the one easiest to manage and profitability the second. Subsidies, tax system and building regulations on joint third.

Table 3 Bottlenecks according to the suppliers.

Factor	Need	Need - weighted	Manage-ability	Manage-ability - Weighted
Subsidies	16	2,29	8	1,14
Tax system	7	1,00	8	1,14
Power grid	5	0,71	7	1,00
Politicians	4	0,57	0	0,00
Building regulations	7	1,00	8	1,14
Public procurement regulation	5	0,71	0	0,00
Construction process	1	0,14	0	0,00
Lack of knowledge	13	1,86	24	3,43
Profitability	10	1,43	13	1,86
Development recourses	0	0,00	2	0,29

Table 4 Identified relations by the suppliers

	Subsidies	Tax system	Power grid	Politicians	Building regulation	Public procurement	Construction process	Lack of knowledge	Profitability	Development recourses
Subsidies									x	
Tax system									x	
Power grid							x		x	
Politicians	x	x	x		x	x				x
Building regulations							x			
Public procurement							x		x	
Construction process						x				
Lack of knowledge		x	x	x	x	x	x			
Profitability										x
Development recourses										

The suppliers group identified more divers relations than the client/property owners group see table 4. There are three bottlenecks that are affected by three or more other bottlenecks; (1) public procurement, affected by politicians, construction process and lack of knowledge, (2) construction process, affected by power grid, building regulations, public procurement and lack of knowledge, and (3) their profitability, affected by subsidies, tax system, power grid and public procurement. There are two bottlenecks that affect six other bottlenecks; (1) politicians, affecting subsidies, tax system, power grid, building regulations, public procurement and development resources, and (2) lack of knowledge, affects tax system, power grid, politicians building regulations, public procurement and construction process.

## 5. Analysis

Both groups identified 10 problem clusters, bottlenecks, quite a few of them are the same but they did not always use exactly the same words. Both groups verified that earlier research that identified the importance of supportive regulations and public policies. There are also several other identified bottlenecks that relate both to the traditional construction value chain but also pointing towards stakeholders not traditionally part of that vale chain. The main difference between the two groups has mainly to do with how they understand the relation between the different bottlenecks. The client/property owner group related almost all bottlenecks to their ability to profit

from the investment. This is understandable as that is their main goal with their business. One of the participants in this workshop actually said that it was interesting to see how their perspective on bottlenecks actually changed from initial part of the workshop to the end. Initially everyone was talking about how the institutional framework was the major bottleneck, but in the end it was actually profit, or rather their inability to profit, from the implementation that was the main bottleneck. The supplier group had, at least to some extent, more focus on what bottlenecks affected others, whereas politicians and lack of knowledge came through as the most important ones. It is understandable that the two groups have different perspectives on this as their roles in both the value chain and in the innovation ecosystem are different.

In regards to which stakeholders should be included in the PV innovation ecosystem, the identified bottlenecks suggest that apart from traditional construction value chain stakeholders power grid owners and potentially politicians/policy makers should be included. Both groups has identified the potential to use existing power grids to transfer electricity between properties. This has both to do with regulation and a lack of interest from the power grid owners to find solutions to this issue. Both groups also identified a number of different factors being bottlenecks that has to do with political decisions suggesting they be included, on the other hand that could be considered as boundary conditions. Both groups, quite naturally, mentioned the construction process and related to that, the stakeholders of the construction process as stakeholders of the PV innovation ecosystem.

## **6. Conclusion**

To conclude, earlier research have been verified, both groups identified the need for a supportive institutional framework. It is also possible to conclude that there is a need to develop the understanding of the (extended) value chain. More importantly the findings of this initial study suggested that using the innovation ecosystem framework has the potential of getting a more detailed understanding. For example, just from these two stakeholders perspectives one stakeholder, the power grid owners, was identified, that would not have been identified through a traditional value chain or supply chain analysis.

Although quite similar, there are also some clear differences between the two groups in both the identified bottlenecks, but more in the perception of the relations between the bottlenecks. However, it is too early to draw a conclusion on the extent of the similarities and differences as well as the effects of these. There is a need to validate the findings from the workshops quantitatively. It is also too early to say anything about the actual innovation ecosystem. Therefore, workshops with other identified stakeholders needs to be carried out and those in turn need to be validated.

To summarize, the findings of this initial study suggest that innovation ecosystem will address a more comprehensive picture on the implementation of PV systems in the built environment. However, to be able to identify bottlenecks and subsequent solutions to these bottlenecks further studies of the complete innovation ecosystem, with its stakeholders, is necessary. The ongoing project is currently carrying out these studies in a Swedish context.

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**COMFORT**



# OUTDOOR COMFORT IN METRO MANILA: MITIGATING THERMAL STRESS IN TYPICAL URBAN BLOCKS BY DESIGN

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## Summary

Fast-developing Metro Manila has urban microclimatic conditions that continue to veer away from comfort primarily due to urban warming caused by the built environment. The hot and humid background climate, projections on global warming, and the urban heat island effect further aggravate the situation, thus leading more people to seek comfort in air-conditioned environments. With real estate developers and local government units building at an unprecedented rate, thermal stress is expected to worsen unless interventions are put in place.

This paper examines workable solutions to bring comfort back to outdoor spaces and extend the range of their use, particularly in Metro Manila's central business districts. With the aid of RayMan and ENVI-met as computer simulation tools, the impact of microclimatic strategies on the Physiologically Equivalent Temperature (PET) is assessed. PET is the thermal index used for its appropriateness in gauging outdoor comfort. The four selected interventions are the following: vegetation, shading, water features, and high-albedo materials. Their combinations are likewise explored.

Simulating an idealized model of the urban block on the warmest day and hour, it was found that as a single intervention, vegetation (trees and grass) is the most effective, reducing average PET by up to 2.4°C. As for the combined interventions, the use of vegetation, shading and water proved to be the most effective design strategy, decreasing average PET by up to 7.2% or 2.8°C, while providing, at the same time, better environmental quality.

Although the proposed interventions brought the PET values closer to the outdoor comfort range of 22 to 34°C and improving from Strong Heat Stress to Moderate Heat Stress, a more drastic approach in coverage is needed to keep outdoor urban spaces resilient and sustainable amid soaring temperatures.

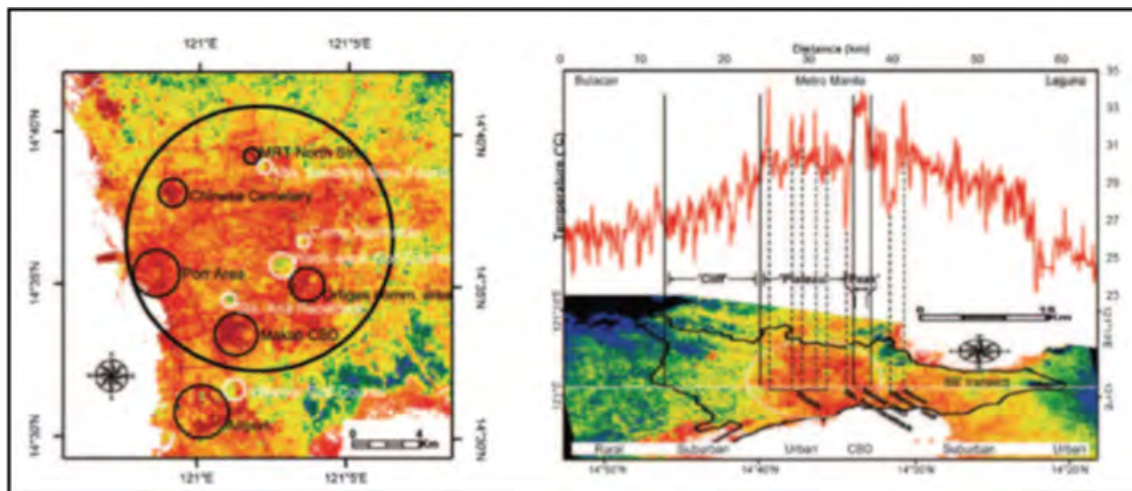
Lastly, the practical approach and replicability of the interventions are envisioned to facilitate local government units and real estate developers into incorporating outdoor comfort in planning and design.

Keywords: outdoor thermal comfort, hot and humid, urban, sustainability, EnviMET, Rayman, PET

## 1. Introduction

Comfort in the city, particularly in hot and humid outdoor environments of Metro Manila, is quite a challenge. On top of the background climate that is already getting warmer over the years, the city's morphology and human activities within tend to further aggravate warming of the urban environment. So is the case in Metro Manila's existing and emerging Central Business Districts (CBD), which are seen to alter the urban microclimates negatively.

Differences in temperature between central and suburban sites have been documented in Metro Manila, where temperatures could reach values up to 10-14K higher than surrounding rural areas (Estoque and Maria, 2000). Tiangco et al. (2007) also reveals that Metro Manila's Urban Heat Island (UHI) profile peaks at the Makati CBD, which indicates it as the hottest area (Figure 1).



*Figure 1 Metro Manila urban heat island map with profile peaking at the Makati CBD (Source: Tiangco et al., 2007)*

The UHI phenomenon is further compounded by the larger global warming effect. Global increase in air temperature was estimated at around 0.15K per decade over the last 20 years (Hulme and Jenkins, 1998). In the Philippines, the Manila Observatory reported a 1K increase in air temperature over a 35-year period or equivalent to an increase of 3K in 100 years (Estoque and Maria, 2000).

More people continue to migrate towards the metropolis and given such conditions, more are likely to experience thermal stress in outdoor urban environments. Consequently, this leads to less use of public outdoor spaces and reliance on air-conditioned environments will continue to increase.

Despite the apparent thermal stress being experienced by millions of its citizens on a daily basis, very few studies are made regarding outdoor comfort in the Philippine setting. Local government units and real estate developers, who are both at the forefront of the country's fast-paced infrastructure development, could highly benefit from performance-based design in their planning.

This research examines interventions to improve urban microclimate conditions in a Philippine CBD setting, with the aim of mitigating thermal stress on the pedestrians. Thermal comfort is investigated using RayMan (Matzarakis et al., 2010), which estimates the Physiologically Equivalent Temperature (PET) – an appropriate thermal comfort index for outdoors. ENVI-met parametric simulations are carried out to assess the impact of vegetation, shading, water bodies, and high-albedo materials on both air temperature and mean radiant temperature (after Chatzidimitriou, 2015). ENVI-met considers more variables in determining the mean radiant

temperature, such as local wind speed and diffuse reflected radiation and longwave radiation of buildings and vegetation (Naboni et al., 2017). The meteorological output from ENVI-met is then used to calculate PET via RayMan.

## 1.1. Outdoor Thermal Comfort Index

This study uses PET as the thermal comfort index given its suitability for outdoor environments. Based on the Munich Energy-balance Model for Individuals, PET is defined as the air temperature, at which in a typical setting (without wind and solar radiation), the heat of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed (Hoppe, 1999).

Matzarakis and Mayer (1996) developed the PET thermal index range, which is useful but not necessarily applicable to all settings due to climate specificities. In warm climates, for example, the mean radiant temperature can be twice as significant as the dry bulb temperature due to lighter clothing (Szokolay, 2014). Matzarakis and Mayer's range remains applicable for Western and Middle European locations but for the Philippines, a more fitting range is used based on a study by Lin and Matzarakis (2008) for Taiwan's hot and humid climate.

*Table 1 PET range for Western/Middle Europe and Taiwan/Philippines (Source: after Matzarakis and Mayer, 1996 and Lin and Matzarakis, 2008)*

Thermal Sensation	PET range Western/ Middle Europe	PET range Taiwan/ Metro Manila	Physiological Stress
Very cold	<4 °C	<14 °C	Extreme cold stress
Cold	4-8 °C	14-18 °C	Strong cold stress
Cool	8-13 °C	18-22 °C	Moderate cold stress
Slightly Cool	13-18 °C	22-26 °C	Light cold stress
Neutral	18-23 °C	26-30 °C	No thermal stress
Slightly Warm	23-29 °C	30-34 °C	Light heat stress
Warm	29-35 °C	34-38 °C	Moderate heat stress
Hot	35-41 °C	38-42 °C	Strong heat stress
Very hot	>41 °C	>42 °C	Extreme heat stress

Table 1 shows the adjusted range for Taiwan, with neutral temperatures at 26-30°C as opposed to the 18-23°C used in Europe. The neutral temperatures are considered within comfortable range. However, it is also true that expectations for outdoor spaces are different, thus allowing for a wider range of tolerable temperatures below and above the neutral. Light cold stress (PET 22-26°C) and light heat stress (30-34°C) do not necessarily render the outdoors uncomfortable, especially with adaptive opportunities that could be available at the site. This research endeavors to study solutions that could bring the PET closer to the defined adaptive outdoor comfort range of 22-34°C.

## 1.2. Background Climate and Fieldwork

Located 14°36' North of the equator, Metro Manila has a tropical monsoon (Am) climate as per Köppen-Geiger classification. This is characterized by hot and humid conditions all year long with a narrow diurnal temperature change of 5-6°C. The monthly mean minimum temperature is 25°C and mean maximum is 31°C. The annual average temperature is 29°C and relative humidity, 77%. Annual average wind speed is 3.5m/s.

The warmest months in Metro Manila are from March to May. This period is also the meteorological summer (as opposed to astronomical summer) for the entire country, during which the schools



are on holidays. With April being the hottest month, this study focuses on this period as regards analysis and proposed interventions.

Spot measurements during a fieldwork done in April at the Makati CBD, where the UHI profile peaked, are considered and used as RayMan input to determine the outdoor thermal comfort, or lack of it. The hours of 9:00 to 18:00 are also chosen, representing the typical busy hours in the CBD and during which foot traffic is also highest.

*Table 2 Makati CBD (Ayala Triangle area) PET calculation for selected hours using spot measurements and RayMan.*

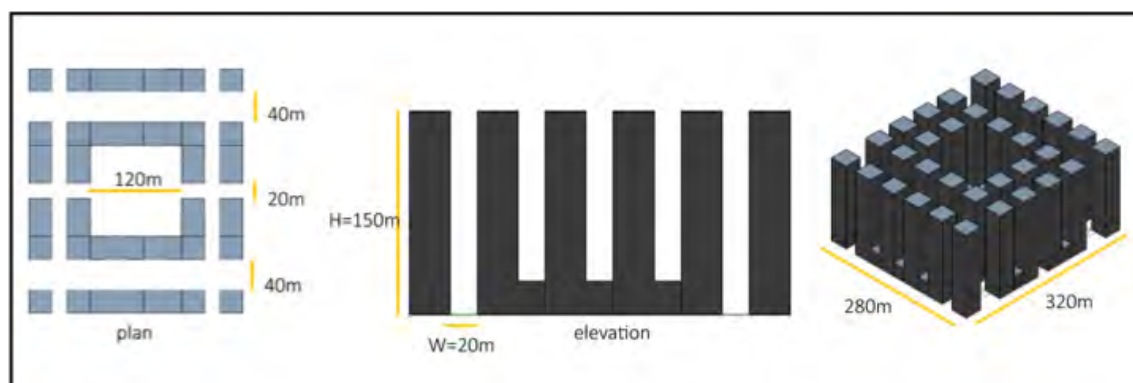
Hour	Ta	RH	Wind	Tmrt	PET	PET (shade)
09:00	30.9 °C	67 %	0.7m/s	60.6 °C	<b>45.0 °C</b>	31.5 °C
12:00	33.6 °C	54 %	1.2m/s	61.2 °C	<b>45.8 °C</b>	33.3 °C
15:00	32.1 °C	52 %	1.1m/s	60.6 °C	<b>44.5 °C</b>	32.4 °C
18:00	30.2 °C	66 %	1.9m/s	21.9 °C	26.5 °C	26.5 °C

Table 2 shows PET values reaching around 45°C from morning until early afternoon, which reveals how much heat stress typical pedestrians endure outdoors. Worth noting is that 12:00 noon registered the highest Ta and PET. Being under the shade, however, results in PET values that are comparable with the Ta and within the defined outdoor comfort range. By 18:00, when there is little or no direct solar radiation, PET significantly improves. However, many people are already on the way out of the CBD and back to their respective homes at this time so the critical period is defined from morning until mid-afternoon with noontime peak.

## 2. Improving the Typical Urban Block

With more CBDs proliferating Metro Manila, taller buildings crowd the typical urban block. The remaining open spaces are the streets, parking lots, and some existing pocket parks. With the urban block as the area of interest for this study, an idealized model is defined for the purpose of parametric analysis. The model is intended to represent a typical scenario, which can be applicable to other CBDs in Metro Manila.

Since the 1960s, taller buildings are being erected across the metropolitan capital. For this study, the urban block model assumes 150-meter high buildings to represent the average height of the newer skyscrapers. The block measures 320 x 280 meters and the buildings are arranged around an open common space.



*Figure 2 Dimensions of the idealized block representative of Makati CBD*

The ENVI-met model is made within the model area of 95 x 95 x 35. The size of the grid cells are 5 meters for both dx and dy and 10 meters for dz, which are within the 0.5 to 10-meter recommended

size for modeling (Bruse et al., 2014). The vertical grid has an equidistant generation. The simulation time is set for 12 hours starting at 6:00 in the morning to cover the peak working hours in the CBD wherein thermal stress is likely. April 21 is set as the start date, which is within the typical warmest week in the Philippines. The following meteorological conditions are used:

*Table 3 ENVI-met input data for meteorological conditions*

Wind speed at 10m height:	3 m/s
Wind direction:	45° (Northeast)
Roughness length at site:	0.01
Initial temperature of atmosphere:	302.87K (29.72 °C)
Specific humidity at model top (2,500m):	7.0 g/kg
Relative humidity at 2m:	73%

The base case run for the typical urban block generates results comparable to the fieldwork, having air temperatures at around 30°C, Tmrt at approximately 60°C, and PET also reaching close to 45°C. With the base case set, proposed interventions are modeled and subjected to runs.

## 2.1. 2.1 Proposed Interventions and Analysis

With the aim of mitigating heat stress at the typical urban block especially at peak summer conditions, the following variables are studied (after Chatzidimitriou, 2015):

### Vegetation

A typical tree is modeled in ENVI-met to mimic an ideal tree species for streets in the Philippines: the “dita” tree or *alstonia scholaris*. Bigger trees are used for major roads and courtyards while smaller trees are assumed for minor roads. A leaf area density (LAD) of 2 is used, which is typical of tropical trees. A total of 68 big trees and 72 small trees were added to the model’s open spaces. Grass with 10cm average density was also used, having a total coverage of 16,000 m<sup>2</sup>.

### Shading

The next parameter for testing is the effect of shading. Opaque canopies attached to the buildings along the pedestrian walkways are added to the base case model, with a height of 5 meters from the ground. This follows the typical ground floor height of commercial and office building lobbies in the CBD.

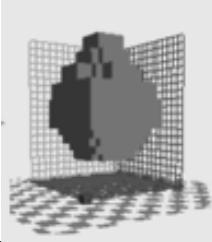

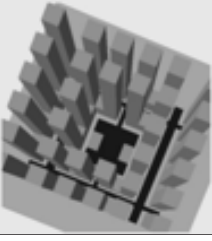

### Water

Water features in the ENVI-met model assume a pond depth of 0.60m and fountain height of 2 meters.

### High-albedo materials

The pavement and roadways, which are of dark granite and asphalt respectively, are changed into higher-albedo surfaces in the model.

Table 4 ENVI-met input data for each of the parameters

<b>1. Vegetation</b>		
	Tree species:	Alstonia scholaris
	Leaf Area Density:	2
	Tree height:	20m, 15m
	Tree width:	15m, 9m
	Foliage albedo	0.20
	Grass ave. density:	10cm
<b>2. Shading</b>		
	Structure:	Building canopy
	Canopy height:	5m
	Albedo:	0.20
<b>3. Water bodies</b>		
	Type:	Pond, fountain
	Water depth:	0.60m
	Fountain height:	
		2m
<b>4. High-albedo surfaces</b>		
	Roadway base case:	0.12
	Roadway albedo – light new concrete:	0.40
	Pavement base case:	0.30
	Pavement – medium coloured stone:	
		0.40

The individual and collective impacts of these interventions (Table 4) on the urban block are analyzed with respect to the base case. Results are compared in terms of  $T_a$ ,  $T_{mrt}$ , and ultimately PET, using data for 12:00 PM being the hottest hour as per fieldwork and weather data.

Comparing the individual effects of each parameter on the base case, vegetation and shading seems to be the most promising, thus reaffirming the choice of these two adaptive measures in Lin's (2009) study on a Taiwan public space. The vegetation demonstrated the highest reduction in air temperature (1.4%), whereas shading reduced the  $T_{mrt}$  the most (up to 6.2%). Water did not do as good as expected, with only less than 1% reduction in  $T_a$ ,  $T_{mrt}$ , and PET. The high-albedo materials did reduce  $T_a$  more than shading and water, but it worsened the PET values due to higher  $T_{mrt}$ .

To further illustrate the parametric runs spatially, four points are identified in the block model (Figure 3) to see the impact of location on thermal stress, aside from just employing the interventions.

Observing the four points (P1, P2, P3, P4), it can be inferred that the use of vegetation showed the highest potential in mitigating thermal stress, followed by shading. Areas closer to the buildings

also generated better PET values than the area in the middle of the open space. This can be attributed to the shading provided by the buildings.

In prioritizing improvement measures based on impact and according to simulation results, the following order of importance may be established: 1. Vegetation 2. Shading 3. Water features.

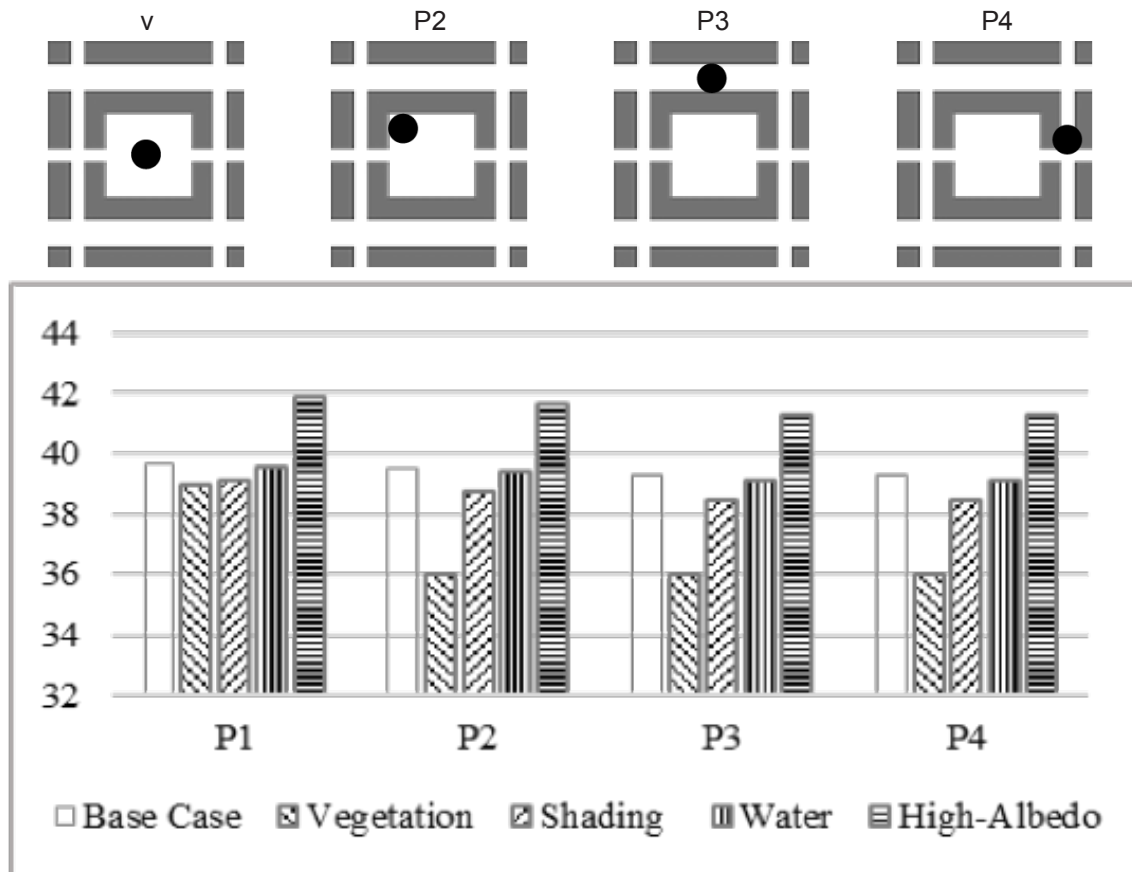


Figure 3 Impact of the individual parameters on PET at the four identified locations within the block model

## 2.2. 2.2 Optimization

Further analysis is carried out to assess the effects of combining the microclimatic measures, and examine if further improvement on outdoor conditions can be achieved. The following combinations are then simulated:

- Vegetation + Shading
- Vegetation + Shading + Water Features
- Vegetation + Shading + Water Features + High-albedo materials

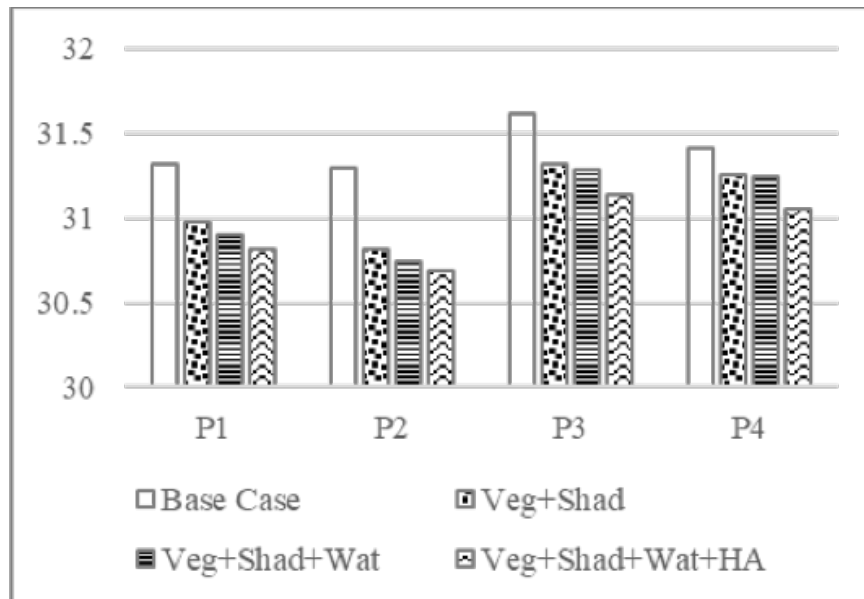


Figure 4 Impact of combining the different parameters on air temperature ( $T_a$ ) at four points within the block

Figure 4 shows the effects of the combined measures tested on air temperature. Results show that the combination of all four interventions managed to bring down  $T_a$  by up to 0.6K.

For PET, however, the combination of first three elements namely vegetation, shading, and water, is more effective (Figure 5) than all four combined. PET was reduced by up to 3.5K, such as in P2. These PET values, now within the region of 35 to 37°C, are much closer to the comfort range identified and have improved in scale from Strong Heat Stress to Moderate Heat Stress. Moreover, it is notable from the study that high-albedo materials have a negative impact on PET, even if they reduced the  $T_a$ .

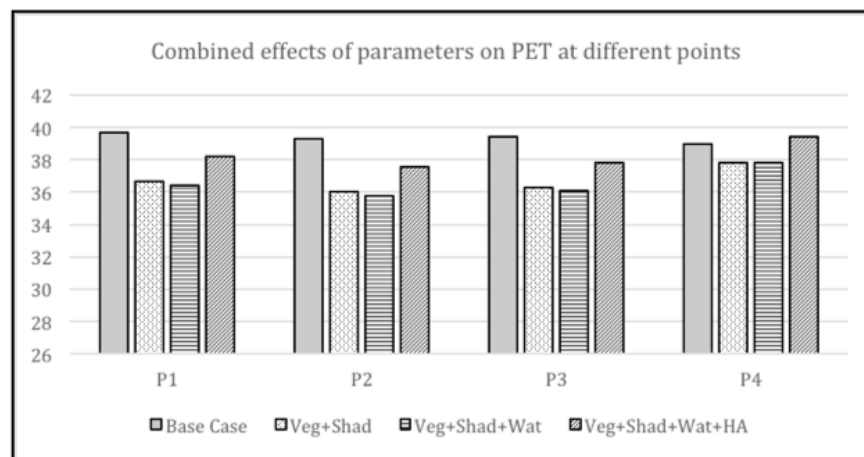


Figure 5 Impact of combining the different parameters on PET at four points within the block

In terms of average differences from the base case using data from the four points identified in the block, Table 5 summarizes the findings of the study, showing the potential of the interventions in improving outdoor comfort. As a single approach, use of vegetation alone lowered the PET by an average of 2.4K. Combining vegetation, shading, and water reduced PET by an average of 7.2% or 2.8K. This becomes a useful tool in decision-making for microclimatic improvements in urban areas, especially in hot and humid Philippine setting. These interventions, together with



adaptation and perceived control by the occupants, strengthen the possibility of reducing thermal stress.

Table 5 PET average differences of intervention/s from base case based on ENVI-met run at 12:00 PM of April 21 (hottest day and hour)

Intervention/s:	PET	
	Ave. diff.	Ave. $\Delta\%$
1. Vegetation only	-2.4°C	-6.2%
2. Shading only	-0.7°C	-1.7%
3. Water only	-0.1°C	-0.3%
4. High-albedo materials only	+2.2°C	+5.5%
5. Vegetation + shading	-2.7°C	-6.7%
6. Vegetation + shading + water	-2.8°C	-7.2%
7. Vegetation + shading + water + high albedo	-1.1°C	-2.8%

### 3. Conclusion

In Metro Manila's CBDs, people do experience thermal stress as confirmed by the fieldwork and simulations done for this research. As more CBDs emerge and more people move city-wards, the situation is likely to aggravate. Real estate developers and local government units, who are at the forefront of the country's physical development, continue the building spree with little guidance from performance-based design research.

The study proposes improvements in typical urban blocks within the CBD, with the aim of reducing thermal stress. Gauged by PET, which is deemed appropriate for outdoor comfort, interventions are studied singly and in combinations. An adjusted comfort range for PET is used, with 22 to 34°C as the target region.

The 4 interventions studied are vegetation, shading, water features, and high-albedo materials. In reducing PET, only the first three have been effective based on the simulations. The most significant improvement is brought about by vegetation, which reduced PET by up to 3K in extreme conditions and 2.4K on average or 6.2% improvement. The use of shading followed, with an average PET reduction of 0.7K. By combining both vegetation and opaque shading, PET is reduced by up 2.7K on average.

Best performance is by the combination of vegetation, shading, and water features, which reduces the base case PET by 3.5K in extreme conditions and 2.8K on average or equivalent to 7.2% improvement. In simulating the extreme condition using data from the hottest day and hour of the year, this combined solution brought the PET values closest to the target comfort range.

Despite the overall reduction in PET (from Strong to Moderate Heat Stress), a more drastic approach is needed for the PET values to be comfortably within the range of thermal neutrality. For vegetation, even more trees and larger grass coverage are recommended. Increased coverage of opaque shading should also be in place. As temperatures continue to soar, these practical interventions will keep the open spaces in city blocks resilient and sustainable.

In Metro Manila where CBDs are mostly managed by private estates and local government units, budgets are usually very limited so this study could help the entities managing the estates to decide on which intervention to use based on budget, timeline, and progressive interventions. For instance, using vegetation alone would yield similar PET improvement as using the combination of vegetation, shading and water features. But in terms of cost or overall environmental quality, the differences are more pronounced. On the side of the government, integration of appropriate

interventions discussed could form part of local ordinances and guidelines, which could be replicable in other existing and emerging CBDs across several cities in the metropolis.

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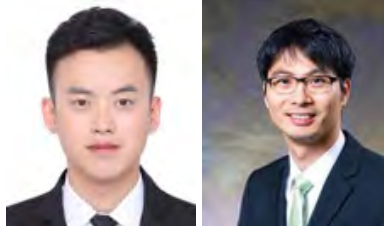
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# MARKOV LOGIC NETWORK BASED GROUP ACTIVITY RECOGNITION IN SMART BUILDING

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## Summary

The rise of the smart building has promoted various pervasive computing technologies to be used in the intelligent building system. People tend to be in a group inside the building, such as working together, having class, having the meeting, etc. Being able to recognize such group activities will be a key to functionalize building to be an activity-aware smart system. In that way, the system can adjust surrounding atmosphere automatically according to the detected group activity and adapt to the needs of individuals or groups. Existing works on group activity recognition (GAR) mainly focus on computer vision through surveillance hardware, which suffers from privacy and illumination problems. We decide to use the smartphone to identify GAR after considering its pervasive and ubiquitous property as well as various built-in sensors such as accelerometer, gyroscope, microphone, etc. In this paper, we first conduct extensive literature review relating to GAR in smart building, an explicit ontology concerning individual activity, location, sound level factors have built to effectively represent group characteristics. Our goal is to recognize fine-grained group activity by utilizing coarse-grained smartphone sensors.

**Keywords:** Group activity recognition, Smart building, Markov logic networks, Sensors

## 1. Introduction

Smart building aims at integrating intelligence into the building environment to provide occupants with attractive services, reliable safety system and user-centered control information (Goldstein et al., 2015). The building collects information from occupants to recognize their status, like activity, location, heating or lighting preference to refine settings that enhance occupant's satisfactory (Fruchter et al., 2016). More recently, however, the attention has shifted from the understanding of individual occupant's status to group status comprised of multiple occupants, as nearly 70% of the time we spend is inside the group to achieve goals, acquire emotional needs and improve social circles (Moussaïd et al., 2010). Understanding group activity in the building has more meaningful prospects in achieving smart building.

Group Activity Recognition (GAR) in the building has many meaningful applications. Firstly, the building designers are able to explore the relationship between space usage by the group with corresponding group activity (Kim, 2013), and group preference in choosing the space for specific group activity (Kim et al., 2018), to optimize building space design. Secondly, building management system can provide accurate response for occupants' group activity, for example, meeting activity needs a bright lighting, and comfortable temperature, multiple discussion activity, on the other hand, might needs more cooler temperature considering heating emission of the group. Also, GAR in the building may related to evacuation research, when the building is in emergence situation, people tends to stay in the group with friends or families for feeling sense of safety during evacuation (Mawson, 2005), group activity and group location will provide valuable information for rescues, the group that is walking or running can be guided to different exits to avoid congestion and stampede event, while those group that is sitting or standing may needs more rescue and guidance.

Our objective is to recognize group activity recognition using smartphone, we select smartphone by considering its pervasive and ubiquitous characteristics, as well as scalability and popularity among modern people. we proposed Markov Logic Network (MLN) based group activity, we first build up an ontology that encode relationship between group activity and its context information: individual activity, location, role information, sound activity. We mainly focus on four group activities: take class, meeting, but it can also be extended to more group activity. The generated ontology is then converted to the equivalent first order logic, which will be used to generate probabilistic ontology through the novel utilization of MLN. The probabilistic ontology serves as knowledge base that offer consistent knowledge, enable uncertainty modeling, contextual modeling and GAT in a unified framework. We validate the propose methods in an academic building, the results reveal the effectiveness of our method.

## 2. Related work

Depending on the use of sensors in data collection, GAR can be categorized as vision based and sensor-based GAR. Vision based GAR has been in-depth explored in computer vision domain (Murino et al., 2017). Although this approach can provide a global perspective towards group, it may violate occupant's privacy and lack of scalability to different scenes. While sensor-based GAR monitoring the occupant's states using unobtrusive sensors, like smartphone, ultrasonic or wearable sensor, this method provides a ubiquitous and nonintrusive way to monitoring occupant's states. Sensor based GAR can be re-classified as data-based GAR and knowledge-based GAR (Liang et al., 2015):

Data-based GAR normally recognize group activity in machine learning perspective by extracting discriminative features from collected dataset to detect group activity with uncertainty. Group activity can be characterized with different features. Firstly, group member's activity can provide important cues for their collective activity, (Zhang et al., 2006) proposed a two-layer Hidden Markov Model (HMM) to detect individual activity and use it to inference group activity, similarly. (Gordon et al., 2013) collect sensor data from cafe cups holding by group members, the individual activity recognized for each café cup are fusion together with group classifier to detect group

activity like meeting, presentation and coffee break. Secondly, interaction among people in the process of group activity can be used to differentiate group activity. (Wang et al., 2011) collected data from acceleration, audio and RFID to model interacting among people, and feed the extracted feature to two probabilistic models- Coupled HMM and FCRF to recognize multi-user activities. In addition to individual activity and interaction feature, role which a group member is performing also provide important cues for GAR(Forsyth, 2018), for example, in the speech activities, there will be two speech related roles: questioner and talker, a group member play the role of context to guide the detection of group activity the member is evolving. (Hirano et al., 2013) use GMM to clustering group member's roles and extract the feature from clusters, the extracted feature then feed to HMM to recognize group activities. The proposed model is robust against changes in the number of participants and roles and do not need finely labeled training data. Data-based GAR needs an efficient collection of data to accurately model the group activity which introduces an overhead problem, this approach also has re-usability problem as we need to build a new group activity model for new group members and different group size.

Knowledge-based GAR, on the other hand, constructs an reusable contextual model that represents and defines the knowledge related to the group activity with location, time and individual activity(Chen et al., 2012), this approach can also be categorized as mining-based, logic-based and ontology-based GAR(Liang et al., 2015). (Gu et al., 2009) developed an mining-based knowledge pattern "Emerging Patterns (EP)" to describe significant changes between different activities, the EP is mined from training dataset that serve as knowledge base for further use. (Ijsselmuiden et al., 2014) deduced group situation from annotated person tracks, object information, and annotated information about gesture, body pose, and speech activity, the author utilizes situation graph trees and fuzzy metric temporal logic rules to buildup knowledge base, thus inferring the corresponding group activity. Also, the starting time and duration of group activity also performs an important role to characterize group activity.(Choi et al., 2015) build up rule-based knowledge that encode group activity with relevant duration time, location and member's behavior. (Loke et al., 2017) proposed a knowledge-based group detection language named "GroupSense-L" that encode context information like location, member's activity, member's sound level as well as start time to differentialize group activity. Although knowledge-based GAR has properties like scalability and reusability, it has limitations in performing reasoning over temporal and uncertain data, making the GAR a challenging task.

To address the above issues exists in both data-based and knowledge-based GAR, an activity model that integrates the advantages and eliminate the shortcoming of above two methods is in its urgent. Markov Logic Network (MLN)(Richardson et al., 2006) is one of methods that satisfy the requirement. MLN is a probabilistic logic which applied the ideas of Markov Network to inductive logic programming, thus enabling uncertain inference on knowledge base.

### 3. Proposed method

Fig.1 shows an overview of our system. The framework is segmented into three layers: Data layer, Individual layer and inference layer, we first collect raw data from smartphone ,which collect sensor data that monitoring occupant's motion information, and iBeacon (received signal strength index) RSSI information that localize spatial position; Individual layer aims to recognize occupant's status at certain time, the raw dataset needs to be pre-processed, discriminative feature that represent people's status, including activity, location and speech recognition are then extracted, the processed data then feeds to three parts: human activity recognition part, indoor localization part and speech recognition part respectively.

**Data Layer:** In data layer, we collect two types of data from people, sensor data that monitor user's motion, orientation, rotation etc, in our work, we mainly collect accelerometer, gyroscope, magnetometer and rotation sensor data from smartphone, secondly, we also collect RSSI from surrounding Beacon tags which is pre-installed in the building, this information will be used for indoor localization.



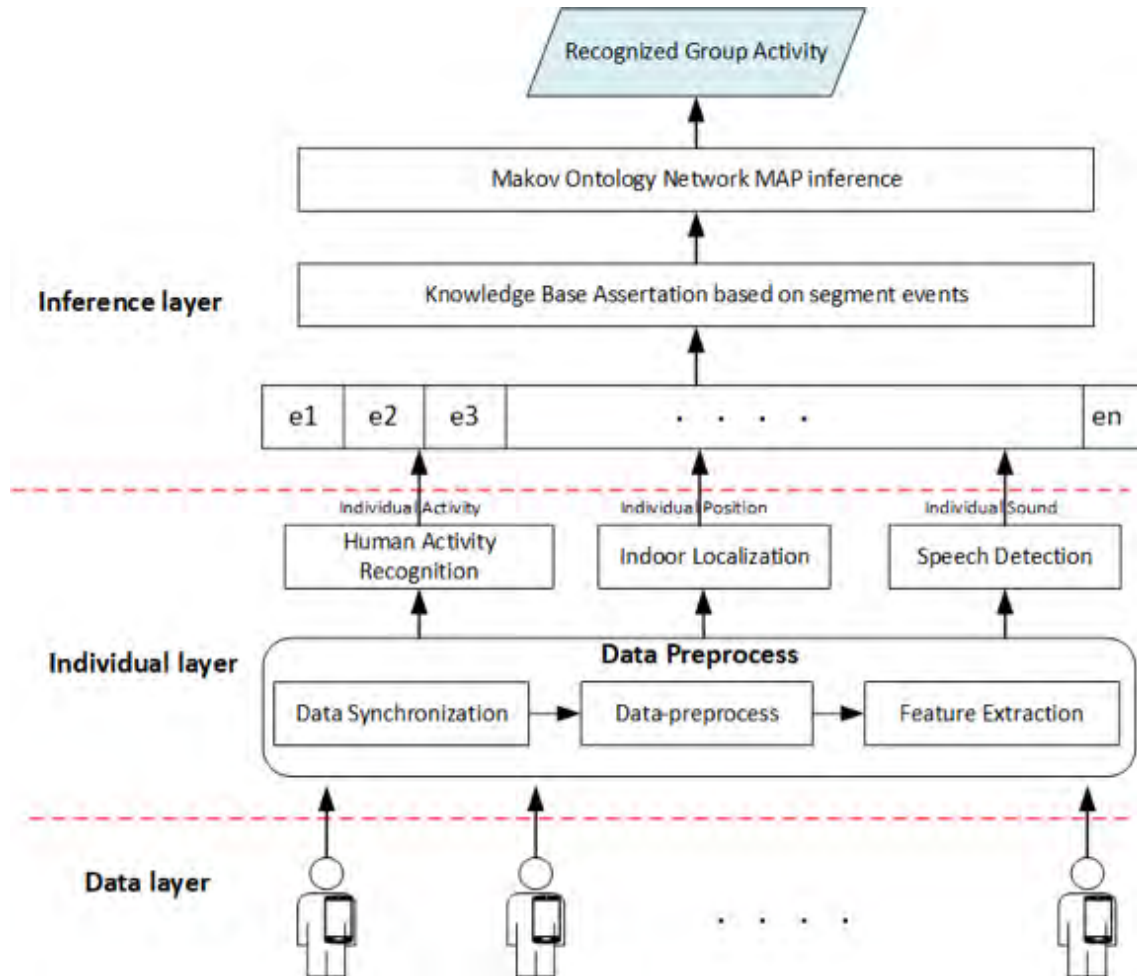


Figure 1 Overall framework

- **Individual Layer:** In this layer, we first synchronize group member's data to avoid device heterogeneity and setup same starting point, the data then cleaned using resampling and butter low-pass filter techniques to remove outliers and smooth raw data. According to different part we're going to use the data, we can extract discriminative feature from cleaned data. The human activity recognition part is to recognized individual simple activity followed this work (Bulling et al., 2014), that is, in our work, sit, stand and walk. Indoor localization parts localize occupant with the help of RSSI information and trilateral positioning method, we follow (Zhou et al., 2017) for its effectiveness and simple implementation, while speech detection follow by the threshold-based method by assuming that a person is considered speaking when the corresponding sound level is larger than 300db.
- **Inference Layer:** takes individual status (activity, location, sound) as input, based on the sound feature, we developed an algorithm to segment time series data into small event, which will feed into trained MLN knowledge based to compute the inference group activity. More specifically, we first make an assertion of event and add them into ABox and make inference on the markov network.

### 3.1. Buildup Ontology

We use Web Ontology Language(OWL), a Description Logic(DL)-based markup language to formally define the semantics of group activity, individual activity and context factors, specifically, DL is a formalism for knowledge representation that describes a given domain by defining relevant concepts(Terminological Box) and vocabularies of asserted individual and their relationship, also

different operators and development of SWRL rules makes OWL 2 DL even more expressive and extensive in terms of knowledge representation.

In this research we proposed a Group Activity Ontology comprised of four main entity: Person, Activity, Location, Role, and the corresponding relationship among them, and all together defined the what, who, where and how for each event, here we provide an excerpt of our ontology shown in Fig 2.

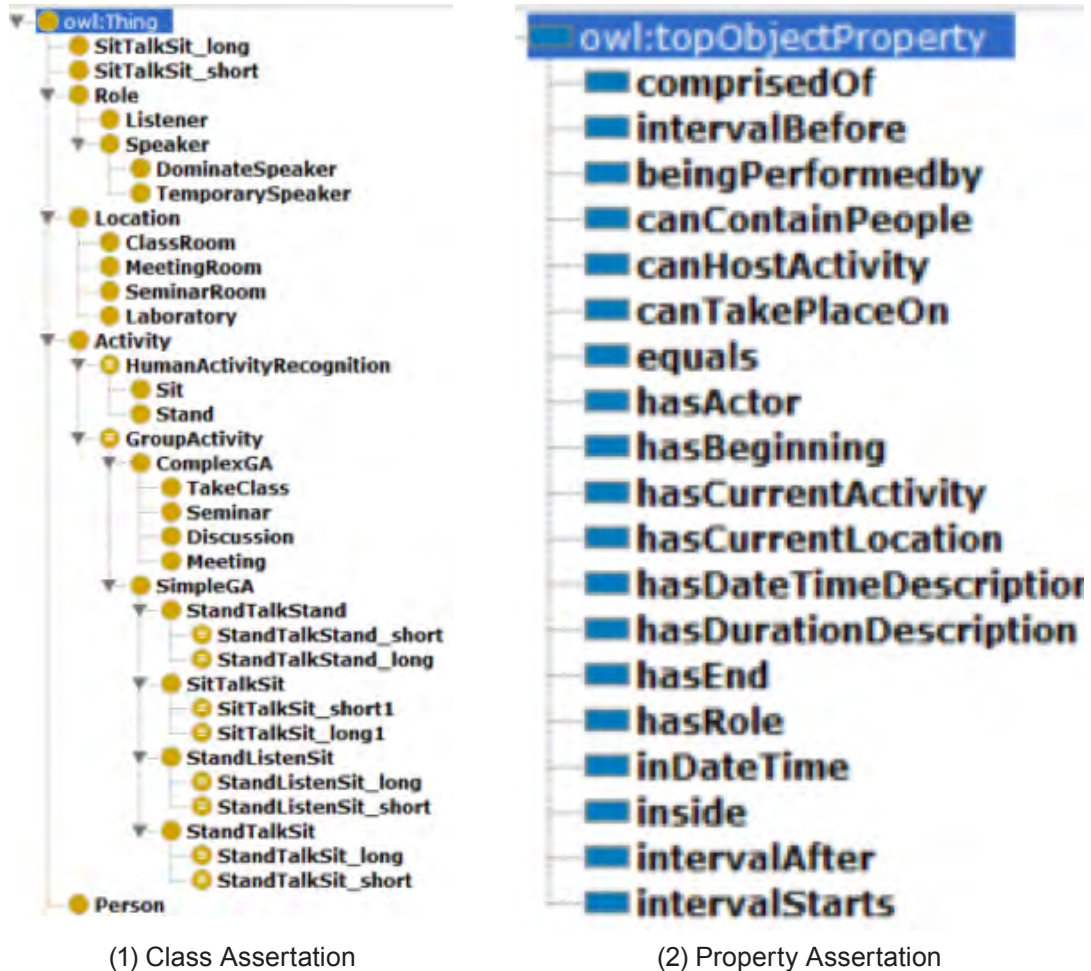


Figure 2 Group Activity Ontology

The basic idea is that complex group activity(CGA) can be decomposed into a hierarchal simple group activity(SGA) while SGA comes directly from ontology reasoning based on input user's status information, We use "Action-Role-Action-Duration" schema to define SGA, for example, "StandTalkSit\_long" can be represented as any group activity who has only one member that stand and performing DominateSpeaker, and has at least one member that sit and perform listener role. In terms of role definition, we define explicit rules for representing role information:

```
Person(?p), hasRole(?p, ?r), Role(?r), hasSoundLevel(?p, ?sound), xsd:integer[>= 330](?sound),
hasDuration(?p, ?du), xsd:float[>= 90.0f](?du) -> DominateSpeaker(?r)
```

Where the above rule defines that any person who has soundlevel larger than 330db and consistently speaking for more than 90s are considered to perform "DominateSpeaker" Role

### 3.2. Markov Logic Network Modeling

Markov Logic Network (MLN) is a powerful approach in representing uncertain knowledge as it combines first-order logic (FOL) and Markov networks in the same representation. The main idea behind Markov logic is relaxing the hard rule with attached weight on the FOL, so a world that violate the FOL is not impossible, but less probable (Oliveira, 2009). Higher weight represents bigger difference between word that dataset and the rules. Using the weighted formulas, we are able to model probabilistic uncertainty on well-defined ontology knowledge base, in our words, combined the advantage of data-based and knowledge-based characteristics.

A MLN  $M$  is a finite set of pairs  $(F_i, w_i), 1 \leq i \leq n$ , where  $F_i$  is a formula in FOL and  $w_i$  represents formula's weight. Together with a finite set of constants  $C = \{c_1, \dots, c_n\}$  it defines a Markov network  $M_L$ , a binary node on  $M_L$  is built based on each possible grounding of each atom in  $M$ , and also defines a log-linear probabilistic distribution on a ground Markov network:

$$P(x) = \frac{1}{Z} \exp\left(\sum_{i=1}^F w_i n_i(x)\right) \quad (1)$$

Where  $F$  is the number of formulas in the MLN.  $n_i(x)$  is the number of true groundings  $F_i$  in the world,  $w_i$  and is the weight of formulas.

## 4. Experiment Analysis

To evaluate our approach. We conduct an experiment in an academic building with different functional rooms, like classroom, meeting Room, Seminar Room, laboratory, etc., we deployed Beacon tag with 4m intervals on top of ceil to avoid human effect when receiving signal. Samsung android devices were used to sample the accelerometer, gyroscope and magnetometer at 50Hz and record Beacon RSSI data at 1Hz.

The smartphone was put into the right leg pocket for capturing motion of human center and 2 group activity are performed by 5 subjects (P1, S1-S4): Take Class, Meeting for 10 minutes each. The subjects were made up of 4 males and 1 female. The collected data from 5 subjects were synchronized, re-sampled to 50Hz, for human activity part, time and frequency domain feature were extracted to recognize simple activity, while indoor localization parts takes RSSI data as input, and compute distance from unknown point (current device position) to pre-installed Beacon coordinates using signal propagation equations (Zhou et al., 2017). Fig 3 shows the localization results for take class activity:

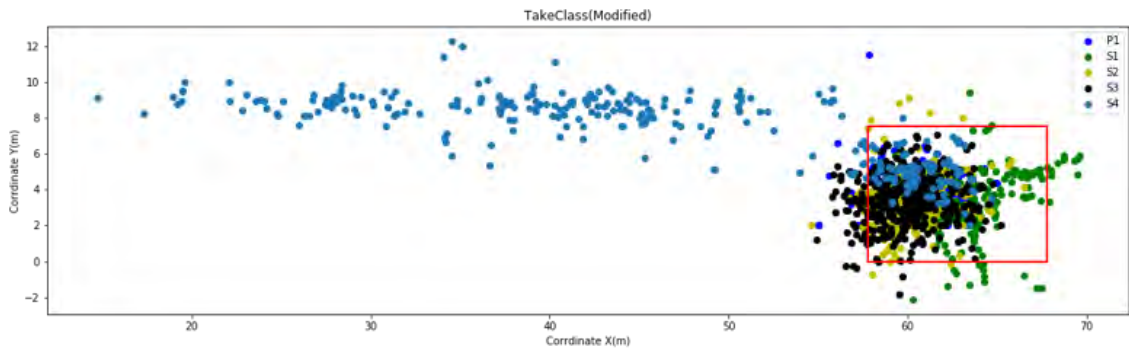


Figure 3 Take Class data distribution

Clearly, we can easily observe that teacher and student share similar motion characteristics, noticing that S4 seems strange compared with other trend, this is because S4 is late student, who join class activity after 5 min, we design this scene to situation the real-world situation more realistic. Moreover, P1 dominate the whole speaking activity, while S3 serve least sound level because S3 is more than P1 compared with S1 and S3, the occasionally high sound level happens in S4 refers to collection variation, which may be effetedly removed by camera records.

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# IMPACTS OF HIGHLY REFLECTIVE BUILDING FAÇADE ON THE THERMAL AND VISUAL PERFORMANCE OF ONE SURROUNDING OFFICE BUILDING IN SINGAPORE

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## Summary

The study examines the impacts of glare caused by highly reflective building façade material on the thermal and visual performance of surrounding development under tropical climate context. A 9-story commercial building with a curved stainless-steel façade was investigated, as it produces discomfort glare to the surrounding buildings when its metal façade is directly exposed to the sunlight. A 6-story nearby office has been affected by the reflective sunlight from the stainless-steel façade, and thus it was selected for the case study.

Nine measurement points were selected and evenly distributed at level 2, 4, and 5 of the affected office building. Vertical and horizontal alignments were maintained for all measurement points at respective locations in the building. Sensors were put in strategic locations to record air temperature ( $T_i$ ), glass ( $T_g$ ) and wall surface temperatures ( $T_w$ ), and indoor illuminance (lin). Parameters such as weather condition, horizontal location, vertical location, and orientation were evaluated based on the data collected from the on-site measurement.

Data analysis has been carried out in diverse aspects. Results indicate that weather condition plays a vital role in both indoor thermal and visual environment. The average  $T_i$ ,  $T_g$ ,  $T_w$ , and lin are higher on a sunny day that has high incoming solar radiation. Specifically, on a sunny day, the increase in average  $T_i$ ,  $T_g$  and  $T_w$  is more than 1°C compared to the rainy day. The difference of the maximum  $T_i$  between a sunny day and a rainy day can reach to 3.26°C, and the maximum illuminance value on a sunny day is 610.64 lux higher than that on a rainy day. These temperatures and illuminance differences are considerable in the working environment.

Additionally, horizontal location and orientation also affect indoor thermal and visual performance of the affected building. Data evaluation concludes that points directly facing and nearer to the affecting reflective façade indicate worse thermal and visual performance during the affecting period which is 16:00 to 18:00 in this case study. When the stainless-steel façade was exposed to the sun, reflective sunlight generated and a sharp increase in  $T_i$ ,  $T_g$  and  $T_w$  can be observed at measurement points which are directly facing to the reflective façade. This phenomenon is more evident at the point nearest to the reflective façade than other points.

Furthermore, vertical location is another significant factor. Results show that temperatures and illuminance at the higher level will normally be higher than that at the lower level. However, the external heat source such as the reflective sunlight, in this case, will lead to an abnormal increase in temperatures and illuminance during the affecting period. This changing trend is more obvious for points at the lower level. During the affecting period from 16:00 to 18:00, the average  $T_i$  at level 2 is 1.66°C higher than that at level 4.

Keywords: reflective building façade; reflected sunlight; thermal performance; visual performance.

## 1. Introduction

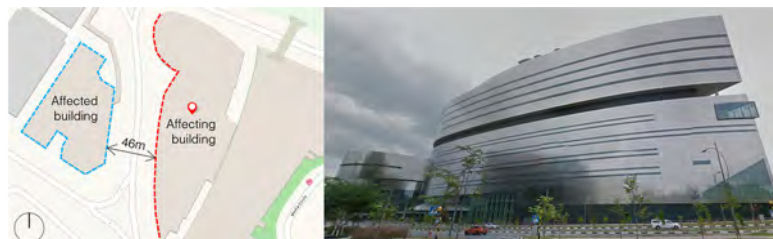
The trend of using highly reflective building materials such as glass or metal claddings has been increasing in the building industry in Singapore. However, the highly reflective building façade materials can generate reflective sunlight which may affect both thermal and visual environment of surrounding developments (Danks, 2016). This phenomenon is more urgent in Singapore than other regions due to the strong solar radiation of tropical climate.

Previous studies have been conducted to examine the relationship between the building façade and reflected sunlight. Wong (2016) developed a ray tracing model to investigate the impact of solar reflection from building façade on the surrounding environment. Brzezicki (2012) evaluated the effects of glare reflection on the surrounding environment by comparing differently shaped glass facades. Yang (2013) conducted one parametric study using Rhino and Grasshopper to simulate and compare the reflected daylight from different building envelopes. Suk (2017) found that there are strong correlations between human visual discomfort and excessive sunlight reflections from building envelopes. However, few researchers have studied the impact of highly reflective building façade on the indoor thermal and visual environment of surrounding developments. Hence, the study to investigate how highly reflective façade will affect the thermal and visual performance of the surrounding building is necessary and meaningful.

The research objectives of the project are: to study the impact of reflected sunlight on the indoor visual and thermal environment of the surrounding building; and to analyse the impacts of design parameters (vertical location, horizontal location, and orientation) and weather parameters on the performance of reflected sunlight.

## 2. Field Measurement

In this case study, the affecting building is a 9-story commercial building developed with a curved façade which features metal claddings and glazed curtain wall as shown in Figure 1. Due to the reflective property of the building façade material, complaints were received from a 6-story office building nearby. Field measurement was conducted in the affected office building during the period of 1st April 2018 to 4th May 2018. The distance between the affecting building and the affected building is 46 meters as shown in Figure 1. The office building was under air conditioning environment from 7am to 7pm during weekdays.



*Figure 1 Affecting building with a curved stainless-steel façade.*

Based on the feedbacks received from building occupants and information collected during the site visit, nine measuring locations were selected in the affected building for the field measurement. As demonstrated in Figure 2, these nine points were evenly distributed in level 2, 4 and 5, and the vertical alignment was maintained for all measurement points at respective locations in the building.



Figure 2 Location and alignment of measuring points at the affected building.

The interior surface temperatures of the concrete wall and the window glass were measured by using HOBO thermocouple sensors and data loggers. Air temperature sensors and data loggers were installed on the internal glass surface to measure the indoor air temperature near the window area. Additionally, illuminance sensors and data loggers were placed on the internal glass surface to measure and record the illuminance level of every measuring points. All sensors were installed at the same horizontal level which was 1.6 meters from the floor. The time interval for recording the data was set to be 1 minute for all data loggers.

### 3. Results

To examine the impacts of reflected sunlight caused by stainless-steel façade on the thermal and visual performance of neighbourhood developments, measuring points with different horizontal locations, vertical locations, and orientation were allocated and compared with different weather conditions. Building thermal performance was studied by analyzing data collected from indoor air temperature, glass and wall surface temperatures sensors, whereas building visual performance was investigated by analyzing the illuminance level changing trend.

#### 3.1. Impact of weather condition

Data collected on the 25th and 27th of April were compared as these two days displayed contrasting weather trends, which assists evaluation of the impact of weather conditions. As shown in Figure 3, the 25th of April was a sunny day with high incoming solar radiation during the daytime and without rainfall throughout 24 hours, whereas 27th of April illustrated comparatively low solar radiation and there was rainfall from 13:00 to 20:00.

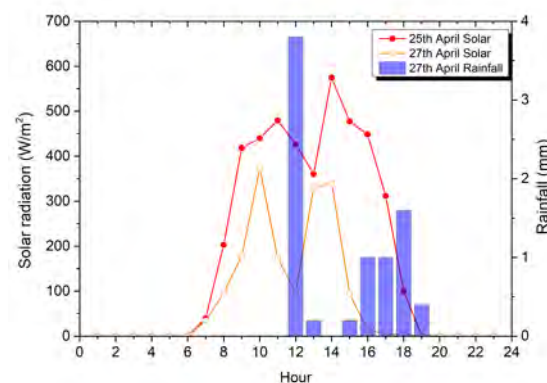


Figure 3 Solar radiation and rainfall on the 25th and 27th of April.

### Building visual performance

Point S-2-3 was chosen to examine the impact of different weather conditions. Table 3 describes the average and maximum illuminance values at point S-2-3 from 7:00 to 19:00 on the 25th and 27th of April. It is viewed that the difference of maximum illuminance level between selected days can reach to 610.64 lux, which is considerable in the working environment. Data indicated in Table 3 reflects that higher solar radiation generates higher illuminance value, and consequently affects the visual performance of the affected building.

*Table 3 Average and maximum illuminance during the daytime (7:00-19:00)*

	Daytime average (lux)	Daytime maximum (lux)
25th of April	230.85	810.47
27th of April	71.96	199.83
Difference	150.89	610.64

### Building thermal performance

Table 1 indicates the average  $T_i$ ,  $T_g$ , and  $T_w$  on both the 25th and 27th of April. It can be found that even it is an enclosed and air-conditioned environment, higher incoming solar radiation during the daytime can result in higher temperatures. On average, the ascent of temperatures is more than 1°C when there is a sunny day. Looking at the maximum temperatures during the daytime on selected days which is shown in Table 2,  $T_g$  illustrates the largest temperature difference which is 5.75°C between the 25th and 27th of April. Meanwhile, the maximum  $T_i$  difference and  $T_w$  difference between selected days are 3.26°C and 2.27°C respectively. It can be concluded that higher incoming solar radiation can generate higher maximum temperature during the daytime period.

*Table 1 Average temperature during the whole day*

	$T_i$ (°C)	$T_g$ (°C)	$T_w$ (°C)
25th of April	25.00	26.11	25.44
27th of April	23.91	24.46	24.41
Difference	1.09	1.65	1.03

*Table 2 Maximum temperature during the daytime (7:00-19:00)*

	$T_i$ (°C)	$T_g$ (°C)	$T_w$ (°C)
25th of April	28.42	32.18	28.10
27th of April	25.16	26.43	25.83
Difference	3.26	5.75	2.27

### 3.2. Impact of horizontal location and orientation

The impact of horizontal location and façade orientation on the respective indoor thermal and visual environment is investigated by comparing the data collected at measuring points S-4-1, S-4-2, and S-4-3. As illustrated in Figure 4, point S-4-1 was located on the façade that was not directly facing the affecting building, whereas S-4-2, and S-4-3 were parallelly facing the affecting facade.  $T_i$ ,  $T_g$ ,  $T_w$  and  $I_{in}$  at these three points were evaluated and compared.

## Building visual performance

To minimize the glare issue caused by stainless-steel façade of the affecting building, 3MTM sun control window film has been installed on the windows of the affected building. Based on the tests, the sun control film can reduce the illuminance by 93%. As shown in Figure 8, from 16:00 to 18:00 on the 25th of April,  $I_{in}$  at point S-4-2 and S-4-3 (directly facing to the reflective façade) increased sharply when the affecting façade was directly exposed to the sun. Such abnormal illuminance increase did not occur during 16:00 to 18:00 on the 27th of April. On the rainy day, the illuminance profile is more analogous to the profile of solar radiation which peaks at 10:00 and 14:00.

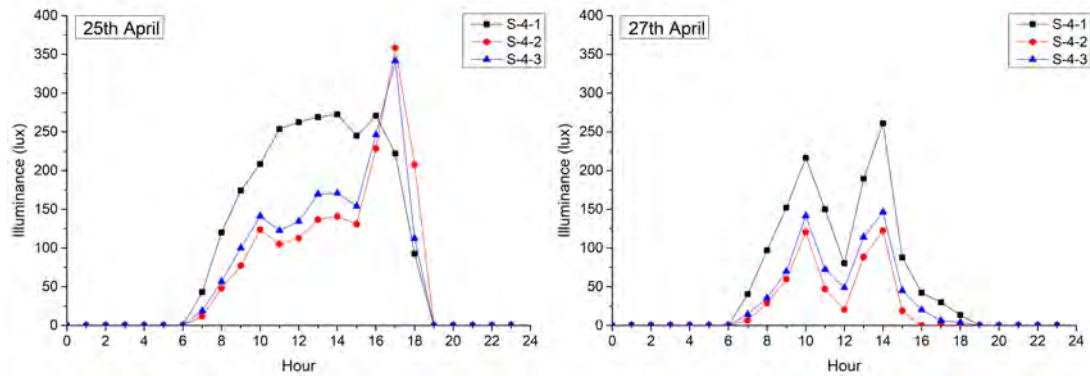


Figure 8 Illuminance level at point S-4-1, S-4-2, and S-4-3 on the 25th and 27th of April.

## Building thermal performance

### Air temperature

Figure 5 displays the changing trend of  $T_i$  at selected points on the 25th and 27th of April. On the sunny day, from 9:00 to 16:00, point S-4-1 illustrates the highest  $T_i$ , followed by S-4-2, and S-4-3. During the period from 16:00 to 18:00, the affecting building façade was directly exposed to the sun when the sun is moved to the west side. This generated reflected sunlight entering the affecting measuring areas. It is observed that there is a sharp increase in  $T_i$  at point S-4-2 and S-4-3 during this affected period on the 25th of April. This phenomenon did not occur at point S-4-1 whose location was not directly facing to the stainless-steel façade. On the rainy day, the temperature increase during 16:00 – 18:00 did not occur.

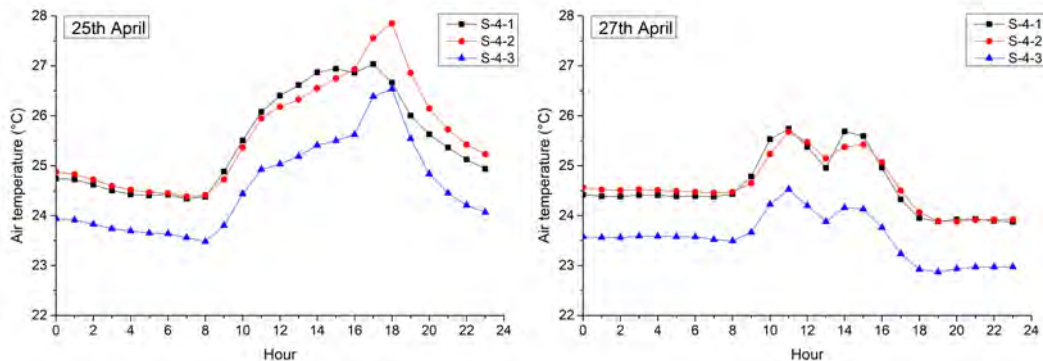


Figure 5  $T_i$  at point S-4-1, S-4-2, and S-4-3 on the 25th and 27th of April.



### Glass surface temperature

The glass surface temperature at point S-4-1, S-4-2, and S-4-3 were compared.  $T_g$  at these three points shares the same trend as  $T_i$ . As shown in Figure 6, from 8:00 to 16:00, the  $T_g$  at point S-4-1 was considerably higher than that at point S-4-2 and S-4-3. It is noticed that the trend of  $T_g$  at point S-4-2 and S-4-3 experienced a significant growth from 16:00 to 18:00 on the 25th of April. Whereas on the rainy day, such phenomenon did not take place.

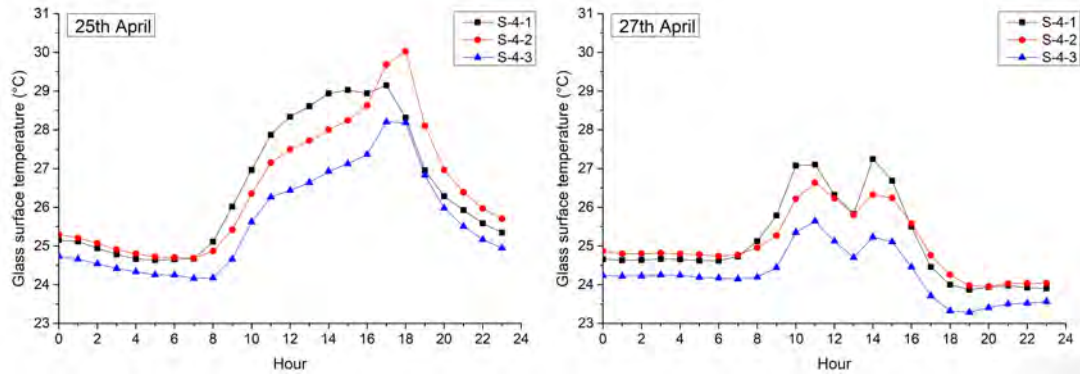


Figure 6  $T_g$  at point S-4-1, S-4-2, and S-4-3 on the 25th and 27th of April.

### Wall surface temperature

The internal wall surface temperature at measuring points S-4-1, S-4-2, and S-4-3 were compared. As illustrated in Figure 7,  $T_w$  at point S-4-2 ranks the highest and followed by point S-4-1, and S-4-3 from 0:00 to 16:00. While, during the affected period which is from 16:00 to 18:00, an obvious increase in  $T_w$  at both points S-4-2, and S-4-3 which are nearer to the affecting building can be viewed. The average wall surface temperature difference between point S-4-2 and S-4-1 is  $0.81^{\circ}\text{C}$  during 16:00 to 18:00 on the 25th of April. Whereas on the rainy day, the three points share the same  $T_w$  changing trend.

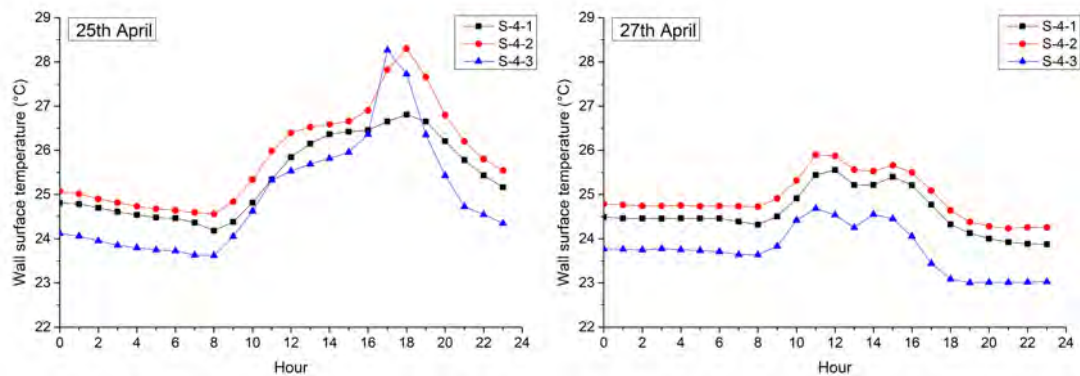


Figure 7  $T_w$  at point S-4-1, S-4-2, and S-4-3 on the 25th and 27th of April.

### 3.3. Impact of vertical location

The impact of vertical location on the respective indoor thermal and visual environment was examined by comparing and analyzing the data collected from three measurement points which allocated at different levels (Level 2, 4, 5) while sharing the same horizontal location in the selected building, namely, S-2-3, S-4-3, and S-5-3.

## Building visual performance

Illuminance value at point S-2-3, S-4-3, and S-5-3 were compared to evaluate the impact of vertical location on the visual performance of the affected building. As illustrated in Figure 12, from 10:00 to 18:00 on the 25th of April, S-2-3 displays the highest  $I_{in}$  followed by S-4-3 and S-5-3. It is noticed that an anomalous ascent curve occurred at all three points from 16:00 to 18:00, and point S-2-3 performed the most considerable change. The maximum  $I_{in}$  at point S-2-3 reached to 810.47 lux during 17:00-18:00, which is 468.89 lux higher than the illuminance at point S-4-3. On the 27th of April, the differences among the three points were insignificant.

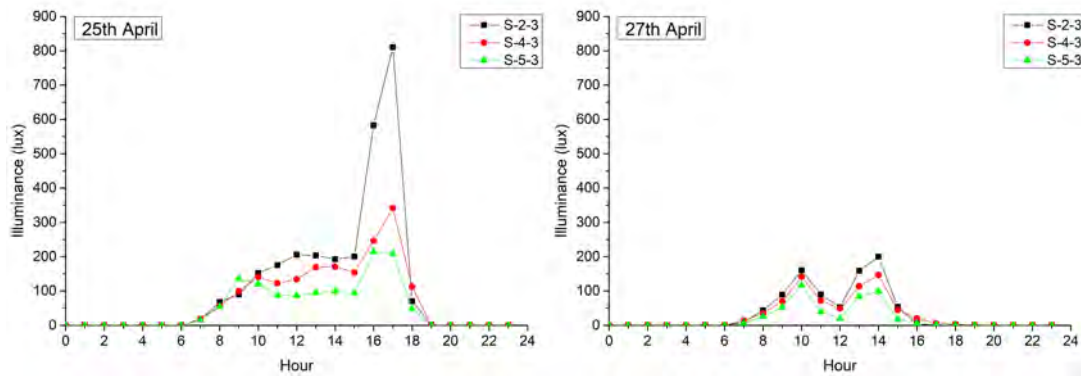


Figure 12 Illuminance at point S-2-3, S-4-3, and S-5-3 on the 25th and 27th of April.

## Building thermal performance

### Air temperature

As illustrated in Figure 9, on the 25th of April, there is a sharp increase in  $T_i$  occurred in all three points from 16:00 to 18:00, during which the selected building was influenced by the reflective sunlight from the affecting building. This phenomenon is more obvious at point S-2-3, whose maximum  $T_i$  reaches to 28.42°C during 17:00-18:00, followed by S-5-3, and S-4-3. During 16:00-18:00, the average temperature difference between S-2-3 and S-5-3 was 1.19°C, and that between S-2-3 and S-4-3 was 1.48°C. On the 27th of April, the temperature differences among the three points were insignificant during 16:00-18:00.

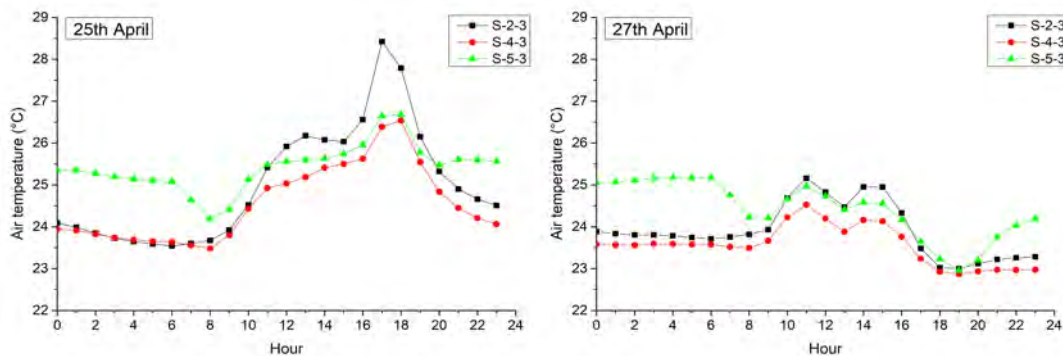


Figure 9  $T_i$  at point S-2-3, S-4-3, and S-5-3 on the 25th and 27th of April.

## Glass surface temperature

As shown in Figure 10, on the 25th of April, when the façade of the affecting building was directly exposed to the sun (16:00-18:00), a significant increase in  $T_g$  occurred at all three measurement points, point S-2-3 illustrates the most obvious change. The maximum  $T_g$  at point S-2-3 was 32.18°C during 17:00-18:00. The average difference in  $T_g$  between S-2-3 and S-5-3 was 2.64°C and that between S-2-3 and S-4-3 is 2.90°C during 16:00-18:00. Whereas on the 27th of April, no such temperature increase can be observed during the affected period.

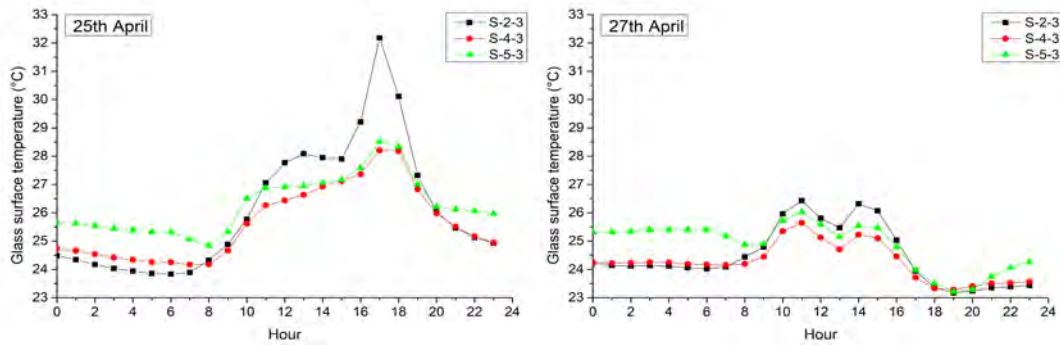


Figure 10  $T_g$  at point S-2-3, S-4-3, and S-5-3 on the 25th and 27th of April.

## Wall surface temperature

Internal wall surface temperatures at point S-2-3, S-4-3, and S-5-3 were also studied and analysed. As shown in Figure 11, from 0:00 to 16:00 and 19:00 to 23:00 on the 25th of April, point S-5-3 which located at relatively higher level displays the highest  $T_w$ , followed by S-2-3 and S-4-3. However, in the period from 16:00 to 18:00, it can be observed an abnormal growth in  $T_w$  at all three points, which is due to the reflective sunlight generated from the stainless-steel façade on the opposite side. On the 27th of April, point S-2-3 shows the highest  $T_w$  during the daytime, followed by point S-5-3 and S-4-3.

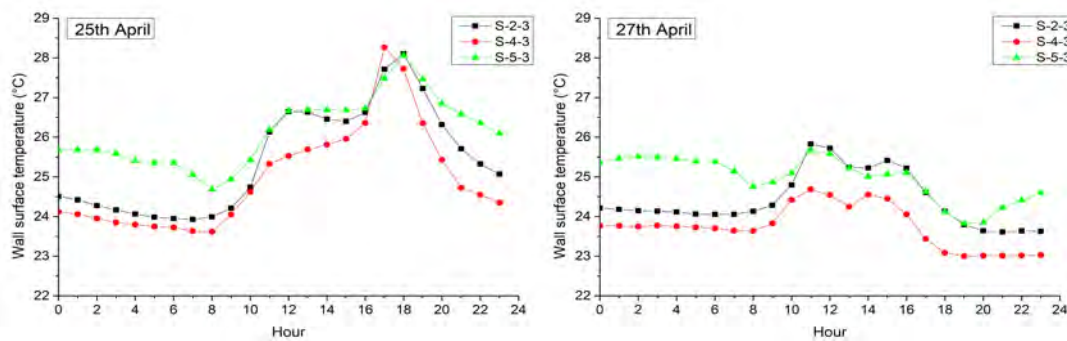


Figure 11  $T_w$  at point S-2-3, S-4-3, and S-5-3 on the 25th and 27th of April.

## 4. Conclusions

The internal and external heat sources are two main contributors to the increase of air temperature and surface temperatures. For the affected building, the internal heat sources which include occupants, lighting, equipment and human activities are assumed to maintain the same condition throughout the measurement period. Thus, the external heat source that is mainly the reflected and diffused sunlight in this case condition is considered as the main reason that leads to the increase in temperatures and illuminance.

Weather condition is crucial in indoor thermal and visual environment. On a sunny day with high incoming solar radiation, the ascent of average indoor air temperature, glass and wall surface temperatures is more than 1°C compared with a rainy day. By comparing a sunny and a rainy day, the difference of maximum indoor air temperature near the window area can reach to 3.26°C, and the difference of maximum illuminance value can be 610.64 lux, which are considerable in the working environment.

Horizontal location and orientation also play a vital role in the indoor thermal and visual environment. Points which orient directly facing and nearer to the affecting reflective façade indicate worse thermal and visual performance.

Furthermore, vertical location is another considerable element that will affect both the indoor thermal and visual environment. Data analysis provides us with a conclusion that temperatures and illuminance at the lower level will be more affected by the highly reflective facade. The external heat source such as the reflective glare, in this case, will lead to an abnormal increase in both indoor temperatures and illuminance level during the affecting period.

Parametric study through computer modeling will be conducted in the future to propose a guideline for building designers to mitigate the negative impacts from nearby building façade on the indoor visual and thermal environment.

## Acknowledgement

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# A FIELD STUDY ON OCCUPANTS' COMFORT AND COLD STRESS IN CLT SCHOOL BUILDINGS

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## Summary

The goal of achieving a smart and sustainable built environment starts with the design, construction, and maintenance of intelligent and sustainable occupied thermal environment. Such an environment must be designed and constructed to achieve thermal comfort of occupants and their overall well-being. This paper presents a field investigation of occupants' comfort and cold stress in cross-laminated timber (CLT) school buildings during the cold seasons (fall and winter). The study was conducted from October to November 2017 for the fall season and from December 2017 to February 2018 for the winter season. The case study comprises of spaces constructed with structural timber products. The case study is a LEED certified school building. It has been identified as one of the first green school buildings in the Northeast region of the USA. The building explores HVAC systems, and it utilizes ground source heat pumps for heating and cooling. The research employed physical measurements of environmental variables such as temperature, relative humidity (RH), dew-point temperature, air velocity and CO<sub>2</sub> level in the selected spaces such as the administrative office, science, and art classrooms and the multi-purpose hall. The sensors were mounted on the internal walls at 1.1m above the floor to measure the variables at every 60 minutes throughout the cold seasons. The study also calculated the Wet-Bulb Globe Temperature (WBGT) in the spaces to understand the average cold stress index within the thermal environment. The mean outdoor temperature was 11.3°C in fall, and 0.5°C in winter. In the fall season, the results showed that the mean indoor temperature was 21.2°C. In the same season (fall), the mean RH was 50.7%, and the average dew-point temperature was 9.3°C. In the winter, the average indoor temperature was 20.5°C while the average RH was 23.9% and the mean dew-point temperature was -1.9°C. The overall mean temperatures measured in the spaces during the cold seasons were within the comfort temperature thresholds (20.3°C/23.9°C) recommended by ASHRAE. In the fall, the mean RH was within the comfortable range (30%-60%). The mean RH value was below the comfortable range in the winter. The study recorded a higher mean temperature, RH and dew-point temperature in the office space than the classrooms and the main hall during the cold seasons. Lower cold stress indexes were also calculated in the multi-purpose hall than the classrooms and office space. The study revealed occupants are more likely to experience cold temperatures in the hall than the office space and classrooms. The difference in the floor level (the main hall is on the lower floor while the classrooms are on the upper floor), hours of occupation (more extended hours of occupation in the office space), and floor area may be the contributing factors to the lower temperatures measured in the hall than the other spaces. By applying the WBGT mathematical model, the research recommends the WBGT of 16.0°C and 13.7°C as the cold stress indexes in the building for the fall and winter seasons respectively. Finally, the study recommends a WBGT of 14.9°C as the average cold stress index in the spaces evaluated in this paper.

**Keywords:** field study, occupants' comfort, cold stress, cross-laminated timber (CLT), school buildings, cold seasons, WBGT



## 1. Introduction

This study aims to contribute to the body of knowledge by evaluating occupants' comfort and cold stress indexes in school buildings during the cold seasons. Recent studies have stated that prefabricated lightweight building materials including engineered timber products such as cross-laminated timber (CLT) are steadily considered as major building materials for various structures (Adekunle, 2014). Existing research also explained such structures are susceptible to elevated temperatures in summer (Adekunle and Nikolopoulou, 2014, 2016), and low temperatures in cold seasons (Adekunle, 2014). Based on this premise, it is important to consider a study that examines occupants' comfort in cold seasons to understand the cold stress index and the temperatures at which the occupants in CLT school buildings will be subject to cold stress.

## 2. Literature Review

Different studies on occupants' comfort in school buildings in various locations across the globe are reviewed and widely discussed in the existing literature (Rupp et al., 2015). Occupants' comfort in school buildings (Teli et al., 2013; Adekunle, 2018) and the effect of the various age in rating the thermal environment in the buildings have been examined (Corgnati et al., 2007; Hussein and Rahman, 2009; Mors et al., 2011, Teli et al., 2013). A few studies have evaluated occupants' comfort in school buildings with natural ventilation (Hussein and Rahman, 2009; Hwang et al., 2009; Teli et al., 2013), and hot, humid climate (Hussein and Rahman, 2009). Hussein and Rahman (2009) stated most of the survey participants (that is, 80%) accepted the thermal environment of the buildings. Also, the responses provided by the participants regarding the sensation are well above the specified ASHRAE 55 baseline (ASHRAE, 2013). Hwang et al., 2009 highlighted the acceptable rate by the respondents have a broader range, and the comfort range has a smaller range when it was assessed using the adaptive comfort standard.

Mors et al. (2011) evaluated different environmental parameters in warm and cold seasons in school buildings. The study (Mors et al., 2011) showed a preference for lower temperatures. In another research conducted in a warm and fully humid climate with cold winters, Teli et al. (2013) explained the comfort temperature was at least 2.0°C above the comfort temperature computed from applying the adaptive thermal comfort standard. The existing research showed that people are prone to high temperatures within the thermal environment (Teli et al., 2013; Adekunle, 2018). A study surveyed over 4000 students in Italy during cold and warm seasons in approximately 200 classrooms (Alfano et al., 2013). The investigation (Alfano et al., 2013) revealed the effectiveness of the PMV model in predicting occupants' comfort in the buildings. The existing research also found that variations in air velocity in the school environment can influence occupants' perception of air being more refreshing and cooler when compared with the thermal environment if the air velocity is kept constant (Wigo, 2013). Corgnati et al. (2007) also explained that people accepted the thermal environment even when responses ranged from neutrality to warm on the evaluation scale. Pereira et al. (2014) maintained that the acceptable temperature for the respondents in school buildings exceeded the recommended comfort zone. Nevertheless, none of the studies highlighted above evaluated the cold stress index for people in school buildings during cold seasons.

Liang et al., (2012) explained that the building fabric energy regulation has a considerable effect on the thermal comfort of people in school buildings. Hwang et al. (2006) stated that relative humidity has a less substantial impact on the thermal sensation of people. Zhang et al. (2013) noted that the occupants in school buildings located in hot and humid climates have more tolerance to high temperatures and relative humidity when compared with the occupants in school buildings located in temperate climates. Also, people in non-naturally ventilated buildings are likely to take adaptive actions to regulate the thermal environment than the people in naturally ventilated buildings (Zhang et al., 2013). Zhang et al., (2013) explained further that people in the non-naturally ventilated spaces are more sensitive with a higher perception of the thermal environment than the people in naturally ventilated areas. Serghides et al. (2014) mentioned

excessive cooling in school buildings that can lead to low temperatures in summer and excessive heating that can cause elevated temperatures in winter.

According to the National Institute for Occupational Safety and Health (NIOSH, 2015), indoor monitoring of environmental parameters is important to identify the variables that influence the occupants' perception of comfort in the spaces. NIOSH (2015) explains that the occupants' perception of comfort is closely associated with the physiological adjustments, the heat transfer from the human body to the thermal environment, and body temperature. The study (NIOSH, 2015) stressed further the heat transfer from the human body to the immediate environment is influenced by various environmental parameters such as relative humidity, temperature, air movement, clothing layers, and metabolic activities. ASHRAE Standard 55 (ASHRAE 2013) recommended the operative temperature of 20.3°C (68.5°F) to 23.9°C (75°F) in the cold season. The Standard specified that the comfort temperatures baseline within the thermal environment are determined by humidity, seasonal change, activity level, clothing insulation and other variables (ASHRAE, 2013), and a range of RH from 30%-60% is recommended for indoor environments to reduce and avoid mold growth (EPA, 2012). Also, relative humidity is specified not to exceed 65% within the thermal environment to prevent or reduce microbial growth (ASHRAE 62.1, 2013). Based on the literature, indoor temperatures of 20.3/23.9°C will be considered as the lower and upper thresholds for comfort temperatures in this paper.

USDOE (2018) explained heating and air-conditioning systems are often operated in different seasons to improve the thermal comfort of occupants which make buildings consume more energy with additional financial implications. In some situations, the cooling or heating systems may come on when the exterior temperatures rise or fall due to the provision of thermostats in the buildings (Nicol and Humphreys, 2007; Nguyen et al., 2014). Based on the gap identified from the literature, this study evaluates occupants' comfort and the thermal behaviour of the spaces in CLT school buildings. Moreover, the literature review considered the recent and current studies on occupants' comfort in school buildings. None of the studies examined occupants' comfort and cold stress at the same time in school buildings built with CLT. As a result, this study evaluates occupants' comfort and cold stress in cross-laminated timber (CLT) school buildings during cold season by assessing the Wet Bulb Globe Temperature Heat (WBGT) threshold. The results on occupants' comfort in the school buildings are also compared with the results presented in the recent research to determine if the comfort temperatures exceed the recommended comfort temperature thresholds for buildings during cold seasons.

### **3. Research Method and Mathematical Expression**

This study considered the physical measurements of environmental parameters (temperature, relative humidity, air velocity, dew-point temperature, and CO<sub>2</sub> level) during the cold seasons (fall and winter) as the primary research method for data collection. The study also considered the mathematical expression to compute the Wet Bulb Globe Temperature (WBGT) using the variables measured in the case study. Regarding the physical measurements in the fall season, the survey was conducted from October to November 2017. The winter survey covered the whole meteorological winter months (that is, from December 2017 to February 2018). The parameters were measured at 15-minute intervals. The HOBO sensors were installed at a 1.1m height above the floor level. For this paper, the environmental parameters recorded at 60-minute intervals were extracted and analysed. Also, the WBGT which has been recently used to assess the heat stress in other usable spaces (NEHC, 2007; OSHA, 2016). The detailed information regarding the WBGT heat threshold has been presented in the literature (Stull, 2011; Lemke and Kjellstrom, 2012). Regarding the windows, the users of the case study can open and close windows without using additional energy (that is, manually operated). The users operate the windows manually for ventilation purposes while mechanical ventilation and heating systems are used depending on the thermal environment of the spaces, external conditions, and seasonal change requirements.

As discussed in the existing study, the internal WBGT can also be described as  $WBGT_{ind}$  °C. According to Equation 1 (Lemke and Kjellstrom, 2012), the  $WBGT_{ind}$  is defined as the function of

natural wet-bulb temperature ( $T_{nwb}$  °C) and black globe temperature ( $T_g$  °C). In the field study that considered physical measurements of parameters, measuring the globe temperature within the thermal environment could be challenging. Based on this idea, Lemke and Kjellstrom (2012) also validated an existing equation to compute the WBGT index. The validated equation (expressed as Equation 2) has been applied to assess the thermal environment by evaluating the function of air velocity (Vm/s), psychrometric wet bulb temperature ( $T_{pwp}$  °C), and dry bulb temperature ( $T_a$  °C). The air temperature is similar to the radiant temperature as expressed in Equation 2. Also, the combined effect of air temperature and low air speed within the thermal environment is known as the operative temperature. Based on this premise, the operative temperature is a function of air temperature, radiant temperature, and low air velocity recorded within the thermal environment. The operative temperature is also influenced by other variables such as the radiant factor.

$$WBGT_{ind} = 0.7T_{nwb} + 0.3T_g \quad (1)$$

$$WBGT = 0.67T_{pwp} + 0.33T_a - 0.048\log_{10} V (T_a - T_{pwp}) \quad (2)$$

Stull (2011) proposed that the psychrometric wet bulb temperature can be computed. From the explanation, Stull (2011) explained in Equation 3 that psychrometric wet bulb temperature ( $T_{pwp}$  °C) is similar to the wet bulb temperature -  $T_w$ . Equation 3 shows the arctangent (atan) evaluates the values that are the same as values expressed in radians. From Equation 3,  $T_w$  is a combination of  $T_a$  (°C) and RH (%). For equation 3, a standard pressure value of 101.325 kPa (101325 Pa) is considered for the computation. Figure 2 generated by Stull (2011) features the psychrometric chart for the pressure of 101.325 kPa. The equation will be explored to compute the WBGT index for cold stress.

$$T_w = T_a \text{atan}[0.151977(RH\% + 8.313659)/2] + \text{atan}(T_a + RH\%) - \text{atan}(RH\% - 1.676331) + 0.00391838(RH\%)^{3/2} \text{atan}(0.023101 \times RH\%) - 4.686035 \quad (3)$$

#### 4. The Case Study

The case study is a school building. It is built with engineered structural timber products such as cross-laminated timber (CLT) panels. The study building is sited on an inner-city park area of over 8 hectares located in the New England region (that is, Northeastern part) of the United States. The study building is designed and developed as a mixed-use project for various purposes. The case study consists of a high school, an inner-city farm zone, and a dedicated education and resource centre for environment and sustainable living. The development is one of the first projects in the US to use CLT as the principal structural building material for the construction. Regarding the floor area, the study building has a total area of about 1300m<sup>2</sup> and comprises different usable spaces such as a hall that is being used for multipurpose events including art and dance performances, sports activities, and other communal and local events. The other spaces include offices, classrooms, including laboratories and study areas, as well as an art classroom. The hall has a double volume, and it is located on the ground floor with the administrative office. The classrooms, including the laboratories, the study, and the art classroom are situated on the upper level of the building.

Regarding the construction of the building, the tension surface and ceiling finishes are implemented with the black spruce CLT panels. The bearing and shear walls are designed and constructed using vertical CLT panels. About the U-values of the CLT walls, the values varied between about 0.13 W/m<sup>2</sup>K and 0.20W/m<sup>2</sup>K based on the thickness of the CLT panels. The insulation (cellulose) used for the case study is one of the approved insulation materials recommended by the US Department of Energy to improve the performance of newly built or refurbished buildings (USDOE, 2018). The case study is a recipient of numerous sustainable and green buildings awards and recognition. The building is also a recipient of the LEED-NC 2009 v3 based on the performance rating of 61% energy cost-saving and more than 25% below the ASHRAE Standard 90.1 baseline recommended for lighting power density in school buildings.

Environmental monitoring occurred in the main hall located on the ground floor, the administrative office on the ground floor, the classrooms, including the laboratories and the study areas, located on the upper level. In summer, the building is naturally ventilated but also provided with mechanical heating, ventilation, and air conditioning (HVAC) systems. The project also utilizes ground source heat pumps for heating and cooling. The case study meets the High-Performance Schools criteria set by the regulatory body in the state, and it is aiming to attain the LEED Platinum status. The case study features an exemplary earth-coupled energy system. Due to the period of the physical measurements, the systems were in operation. The HOBO sensors were placed in each of the spaces selected and approved by the school administrators to record and log temperature, relative humidity, air velocity, CO<sub>2</sub> level, and dew-point temperature at equal intervals during the cold seasons. The outdoor weather data recorded at a nearby weather station were used for the analysis. During the cold seasons, the case study was in use from 8am to 5pm and partially or not occupied from 6pm to 7am. Environmental monitoring considered in the spaces and the analysis of the data collected will be discussed in this study. In terms of the placement of the sensors, the sensors were placed in the following spaces: administrative office (south orientation), multipurpose hall (northeast orientation), science classrooms (southwest, west, and southeast orientations), and the art classroom (north orientation).

## **5. Analysis of Data**

The analysis of the annual external weather data collected (historical) from the nearby weather station revealed that the climatic condition of the study location is fully humid, cold winter and cool summer (Dfc) based on the Koppen-Geiger climate classification (Kottek et al., 2006). The mean highest temperatures (monthly) varied from 1.7°C in January to 28.3°C in July. The analysis showed that the period of the field investigation is the coldest period of the year. The detailed information on the average temperatures (such as high, low, record high, record low) and mean precipitation is presented in Figure 1.

For the outdoor weather data collected during the field investigation, the mean outdoor temperature ranged from 6.5°C to 16.0°C for the fall season and from -2.0°C to 3.3°C for the winter season (Table 1). The overall average outdoor temperature for the period of the field study is 4.8°C. The average external dew-point temperature was 6.0°C in the fall and -5.0°C in the winter. Regarding the average outdoor RH, it ranged from 45.8%-91.4% with an average RH of 69.3% in the fall and 66.0% in the winter. The average atmospheric pressure (Pa) at sea level for the duration of the field study is found to be 1019Pa in the fall and ranged from 1017Pa to 1022Pa in the winter. The average outdoor WBGT indexes were 9.4°C and -0.7°C in the fall and winter in that order. The summary of the essential features of the outdoor weather data from the location of the field survey is presented in Table 1. The analysis revealed that people in the outdoor environment of the case study might be subject to thermal discomfort such as freezing to slight cold stress at a temperature below the freezing point (0°C) especially in the fall. In the winter, the occupants in the study location may also experience cold stress at about -13°C and possibly strong cold stress at a temperature close to -27°C. The investigation revealed that the stress index was below the slight cold stress range for some days during winter.

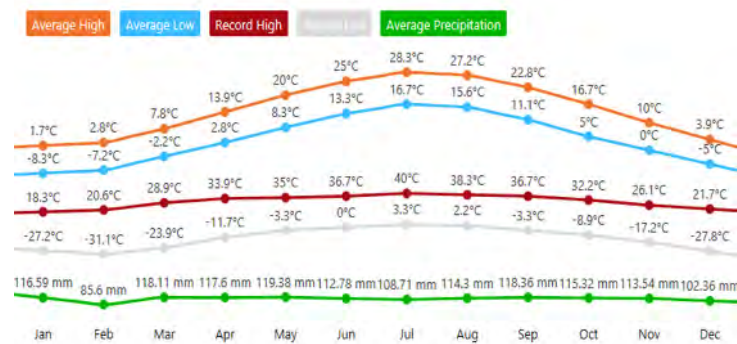


Figure 1 The mean monthly external variables in the study location (historical data).

Table 1 Summary of the outdoor weather data for the fall and winter seasons

Variables	Fall season (Oct. – Nov. 2017)						Winter season (Dec. 2017 – Feb. 2018)								
	October 2017			November 2017			December 2017			January 2018			February 2018		
Max. temp. (°C)	27.0	22.0	22.0	22.0	17.0	11.0	15.0	12.0	9.0	12.0	7.0	3.0	18.0	11.0	6.0
Min. temp. (°C)	14.0	8.0	2.0	4.0	-1.0	-6.0	-9.0	-11.0	-13.0	-10.0	-12.0	-17.0	-1.0	-6.0	-9.0
Average temp. (°C)	21.2	16.0	11.5	11.6	6.5	1.5	3.5	0.3	-2.9	2.3	-2.0	-6.2	7.5	3.3	-0.6
Dew-point (°C)	22.0	11.0	-3.0	17.0	1.0	-18.0	13.0	-6.0	-22.0	11.0	-8.0	-25.0	12.0	-1.0	-19.0
RH (%)	91.4	72.1	52.9	84.9	66.4	47.8	78.2	62.0	45.8	78.0	64.0	50.0	90.6	72.0	53.4
Precipitation (mm)	1948.2	132.1	0	360.7	43.2	0	218.4	27.9	0	401.3	35.6	0	749.3	134.6	0
Wind speed (m/s)	10.2	5.6	1.0	10.1	5.6	1.2	9.7	5.6	1.6	10.2	6.0	1.8	9.4	5.1	0.8
Atmospheric press. (Pa)	1023	1019	1015	1023	1019	1015	1022	1017	1013	1026	1021	1016	1029	1022	1016
WBGT	20.6	14.0	8.6	10.7	4.8	-0.6	2.5	-1.1	-4.8	1.4	-3.2	-7.6	7.0	2.1	-2.4

## 6. Results and Discussions

The overall average temperature of 21.2°C was recorded in the spaces during the fall while the overall temperature of 20.5°C was observed in winter. Concerning the average temperature in the spaces during office hours (8am-5pm), 20.6°C was reported as the average temperature in the fall. In winter, the average temperature of 20.9°C was recorded in similar spaces during office hours (Table 2). Likewise, mean temperatures of 19.9°C and 20.0°C were measured in the spaces during non-office hours (that is, from 6pm-7am) in the fall and winter respectively. The results showed the average temperatures recorded in the spaces during the office hours and non-office hours were slightly higher in the winter than the fall. The results showed heating of the spaces might be a contributing factor to higher average temperatures measured in the spaces during the office hours than the non-office hours. The results showed the mean temperatures did not exceed the threshold for comfort temperature (23.9°C) in the spaces in the fall and winter. However, mean temperatures fall below the baseline for comfort temperature (20.3°C) in the main hall in the fall especially during office hours as well as non-office hours. The results showed that occupants might experience thermal discomfort within the space in the fall.

The average dew-point temperatures of 9.3°C and -1.9°C were observed in the spaces during the fall and winter correspondingly. The mean relative humidity was 50.7% in the fall. In winter, the average RH was 23.9%. Also, the average air velocity measured in the spaces was 0.1m/s. At different seasons and periods considered in this study, higher temperatures were recorded in the office space than the classrooms and the main hall. The more extended hours of the occupation of the users in the office space and the frequent use of control (such as heating) may contribute to the higher temperatures recorded in the office space. Moreover, the orientation of the office space (south facing) and its location on the ground floor, which can help reduce various temperatures swing, may have also contributed to the higher temperatures recorded in the space than other spaces in the building. On the contrary, the double-volume, large floor area, as well as regular use of the entrance doors of the multipurpose hall, which are manually operated by people, may

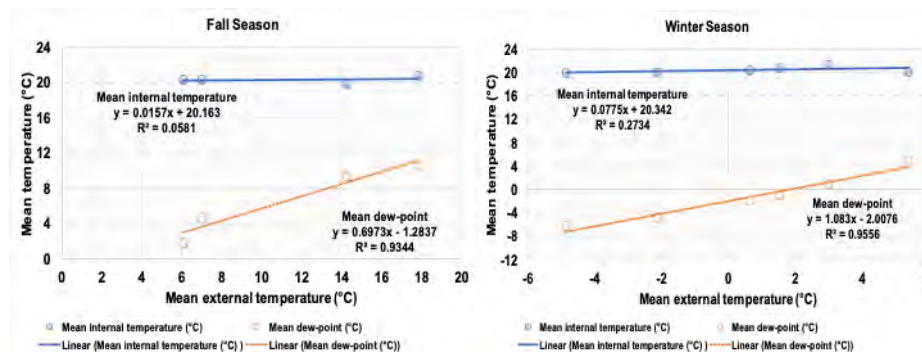


contribute to the lower temperatures reported in the main hall. For the classrooms, some parts of the spaces were used as laboratories. This factor may contribute to the lower temperatures measured in the classrooms. Also, a higher CO<sub>2</sub> level was measured in the spaces during office hours than the non-office hours. The results also revealed higher dew-point temperatures and higher relative humidity were measured in the main hall than the classrooms and the main office in the fall and winter as well as the different periods (office hours and non-office hours). The maximum, minimum, and mean values of the parameters recorded during the field surveys in the fall, winter and different periods are presented in table 2 below.

*Table 2 Maximum, minimum and mean values of parameters recorded in the fall and winter*

Spaces/ parameters	Fall season (October – November 2017)									Winter season (December 2017 – February 2018)								
	Max. temp (°C)	Min. temp (°C)	Avg temp (°C)	Max. dew-point (°C)	Min. dew-point (°C)	Avg dew-point (°C)	Max. RH (%)	Min. RH (%)	Avg RH (%)	Max. temp (°C)	Min. temp (°C)	Avg temp (°C)	Max. dew-point (°C)	Min. dew-point (°C)	Avg dew-point (°C)	Max. RH (%)	Min. RH (%)	Avg RH (%)
Main hall (ground floor)	26.4	17.6	19.2	16.1	7.7	11.0	76.6	38.5	59.6	30.2	13.6	20.5	20.4	-15.8	-1.9	71.2	7.9	23.9
Classrooms (upper floor)	23.2	12.3	20.3	18.0	-7.3	6.7	78.5	19.0	42.9									
Office space (ground floor)	23.0	18.4	21.0	18.9	1.4	10.1	77.9	32.0	49.7									
Main hall (8am-5pm)	26.4	17.8	19.8	15.8	8.0	11.3	73.7	38.5	58.2	30.2	14.3	20.9	20.4	-15.8	-1.8	71.2	8.2	23.5
Classrooms (8am-5pm)	23.2	13.3	20.7	16.1	-7.3	6.6	71.6	19.0	41.6									
Office space (8am-5pm)	22.9	18.5	21.2	15.5	1.5	9.6	63.2	32.0	47.6									
Main hall (6pm-7am)	20.8	17.6	18.8	16.1	7.9	10.9	76.7	51.5	60.7	24.9	13.6	20.0	15.8	-15.0	-2.0	61.8	7.9	24.2
Classroom (6pm-7am)	22.9	12.4	20.1	18.0	-5.5	6.7	78.5	19.3	43.9									
Office space (6pm-7am)	23.0	18.4	20.9	18.9	1.4	10.4	77.9	32.0	50.9									

On the one hand, a relationship exists between the mean dew-point temperatures and the outdoor temperatures in the fall ( $R^2 = 0.9344$ ) and winter ( $R^2 = 0.9556$ ). On the other hand, no relationship exists between the mean indoor and the outdoor temperatures in the fall ( $R^2 = 0.0581$ ). A relationship is also found between the parameters in winter ( $R^2 = 0.2734$ ). The range of mean indoor temperatures and dew-point is slightly higher in winter than the fall (Figure 2).



*Figure 2 The relationship between the mean internal and the external variables in the fall and winter*

The WBGT values were calculated using Equation 3. The mean air velocity of 0.1m/s (measured) was used for the computation of the WBGT indexes. The results showed the mean WBGT values were higher in the office than the classrooms and the hall during the fall including office and non-office hours. In the winter, the WBGT index for the spaces was higher during office hours than non-office hours. Across the spaces, higher mean WBGT values were computed in the fall than winter. The research revealed the study building users might be subject to slight cold stress in the spaces, especially in winter. Considering, the number of hours above the ASHRAE comfort temperature thresholds for the cold season, the results showed a substantial amount of hours above 20.3°C/23.9°C in the spaces during the different seasons and periods. The investigation revealed that the building users might be subject to discomfort in the cold seasons. By relating the mean WBGT values in this research during the fall (16.0°C) and winter (13.7°C) with the recent study on heat stress in the CLT school buildings (Adekunle, 2018), lower WBGT indexes were computed in this paper than the value (19.8°C) calculated in existing research. Table 3

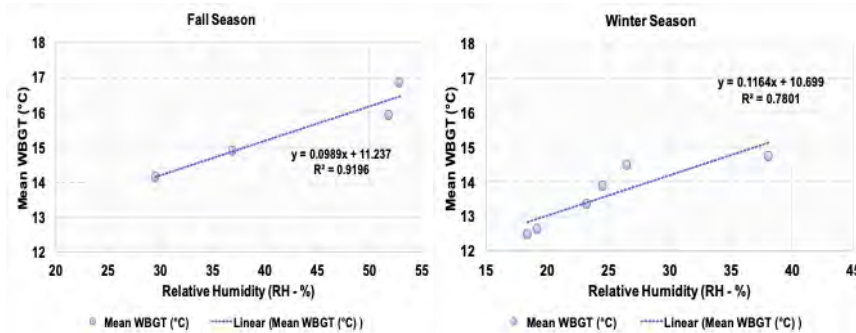
summarizes the mean values for the temperature, RH, WBGT and number of hours above the comfort temperature thresholds.

*Table 3 Comparison of the average values measured with the ASHRAE comfort temperature thresholds*

Spaces/ parameters	Fall season (Oct. – Nov. 2017)				Winter season (Dec. 2017 – Feb. 2018)			
	Avg temp (°C)	Avg RH (%)	Avg WBGT (°C)	No of hours above 20.3/23.9°C	Avg temp (°C)	Avg RH (%)	Avg WBGT (°C)	No of hours above 20.3/23.9°C
Main hall (ground floor)	19.2	59.6	16.0	861/ 0	20.5	23.9	13.7	1162/ 3
Classrooms (upper floor)	20.3	42.9	15.4					
Office space (ground floor)	21.0	49.7	16.7					
Main hall (8am-5pm)	19.8	58.2	16.4	404/ 0	20.9	23.5	13.9	564/ 1.5
Classrooms (8am-5pm)	20.7	41.6	15.6					
Office space (8am-5pm)	21.2	47.6	16.6					
Main hall (6pm-7am)	18.8	60.7	15.7	457/ 370	20.0	24.2	13.3	598/ 1.5
Classrooms (6pm-7am)	20.1	43.9	15.3					
Office space (8am-7am)	20.9	50.9	16.7					

Note - The total hours in the fall – 1464 hours. The total hours in the winter – 2160 hours.

Strong correlations exist between the mean WBGT and RH within the spaces in the fall and winter (Figure 3). The investigation revealed higher humidity values at warm temperatures have a considerable effect on WBGT while higher air velocity at warm temperatures does not have a substantial impact on WBGT.



*Figure 3 The relationship between the relative humidity and the mean WBGT in the fall and winter*

On the one hand, relationships are found between the mean indoor temperature, the mean WBGT and the mean dew-point in winter. On the other hand, low  $R^2$  values were reported between the variables in the fall (Figure 4). Seasonal changes may influence variations in the occupants' adaptation to the thermal environment, which can contribute to the extent to which they use the control to regulate the environment. A combination of variables (temperature, air speed,  $CO_2$  level, RH, dew-point temperature) could influence the cold stress values within the thermal environment. The research showed an increase in the WBGT has an impact on the temperature and dew-point in the winter rather than in the fall. As a result, the WBGT can be applied to determine people's vulnerability to cold stress in CLT school buildings. This paper also highlighted that the WBGT could be explored for assessing cold stress in different thermal environments.

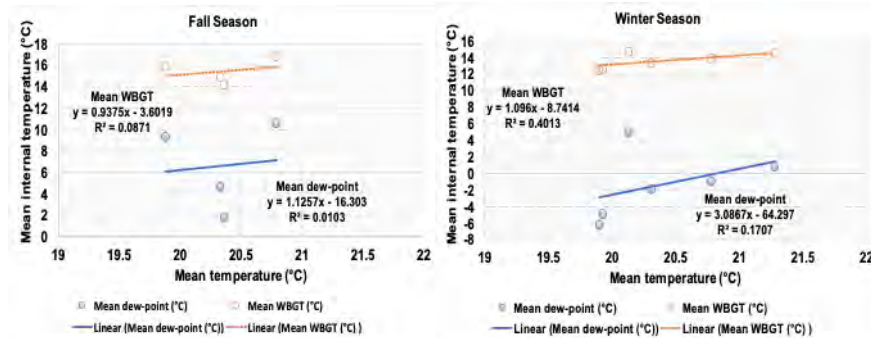


Figure 4 The relationship between the mean WBGT, dew-point and internal temperatures

## 7. Conclusions

The study assessed the occupants' comfort and cold stress in CLT school buildings. The mean temperatures in the office space, main hall, and classrooms varied from 18.8°C to 21.2°C in the fall. The values ranged from 20.0°C to 20.9°C in winter. The overall mean temperature of 21.2°C was reported in the fall while a mean temperature of 20.5°C was recorded in winter. The mean temperatures in the cold seasons (fall and winter) were within the ASHRAE comfort temperature thresholds (20.3°C/23.9°C) for people in cold seasons. The mean RH in the fall was within the comfortable range (30%-60%). However, it was below the range in winter. The office space was found to be the warmest space due to the longer hours of occupation and frequent use of control (heating) to regulate the thermal environment. The hall is the coolest space due to various contributing factors such as its location on the ground floor, double-volume of the space, large floor area which may require additional energy for heating, and frequent use of the large entrance doors which may contribute to constant heat loss within the space during the cold seasons. The opening of the entrance doors should be regulated to reduce heat loss in cold season. The introduction of a transitional space between the entrance doors and the main hall may also reduce heat loss in cold seasons, but the approach may contribute to summertime overheating in the space.

Regarding office hours (8am-5pm), the mean temperatures were 20.6°C and 20.9°C in the fall and winter respectively. The mean temperature during the non-office hours was 19.9°C in the fall, and it was 20.0°C in winter. The temperature exceeded the recommended comfort temperature lower threshold (20.3°C) for about 59% of the time in the fall, and it exceeded the limit for approximately 54% of the time in winter. During office hours, the temperatures exceeded the comfort temperature lower threshold for 28% and 26% of the time in the fall and winter respectively. The temperature did not exceed the comfort temperature's upper threshold (23.9°C) for more than 1% of the time at any season or duration. The lower external temperatures reported during the cold seasons may be a contributing factor to this finding.

The results showed a higher mean temperature, RH and dew-point temperature in the office space than the classrooms and the main hall during the cold seasons. The users are more likely to experience cold temperatures in the hall than the office and classrooms. By considering the WBGT mathematical model, lower cold stress indexes were calculated in the hall than the classrooms and office space in cold seasons. The average WBGT ranged from 15.3°C to 20.0°C in the fall while the average WBGT varied from 13.3°C to 13.9°C in winter. Overall, the research proposes a WBGT of 14.9°C as possible cold stress index for the vulnerable people in CLT school buildings during the cold seasons. The study showed higher RH have a considerable impact on the WBGT.

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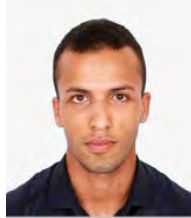


## **GREEN BUILDING**



# DATA MANAGEMENT USING COMPUTATIONAL BUILDING INFORMATION MODELING FOR BUILDING ENVELOPE RETROFITTING

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## Summary

Computational Building Information Modelling (BIM) is a design paradigm grounded on the use of BIM-based rules and algorithms for data extraction and management to meet the design objectives and user need. This design approach has been applied in many aspects and disciplines within building industry such as spatial, geometrical and structural design/optimization, building energetic performance analysis, acoustical optimization and more.

This article discusses the application of computational BIM for data management within the scope of a research project entitled the retrofitting of existing buildings through BIM (RBIM). The main goal of this project is to optimize the overall thermal transfer value (OTTV) of building envelope of existing buildings against the cost of investment. OTTV criteria have been adopted by several green rating tools in different countries to evaluate building envelope thermal performance, hence to assess buildings' cooling loads. Building envelopes design under OTTV requirement often requires cumbersome data collection process and complex design decision-making regarding building envelope component selection.

In the RBIM project, Dynamo was used as the computational BIM design software to create scripts for the automation of data extraction and data push back from/to the BIM model. Meanwhile, MATLAB was used to perform multi-objective optimization of the OTTV/Cost using the data extracted from the BIM model as an input.

This paper focuses only on the data management part of the RBIM project. Thus, the development process of the Dynamo scripts is explained and limitations are discussed. Moreover, delicate tasks during the development of the scripts such as automating the detection of building envelope elements orientation are further explained. For validation purpose, the whole RBIM workflow was implemented on a case study building (BIM model), where the applicability of the developed Dynamo scripts for data management was demonstrated and tested.

The finding shows a great potential of the implemented workflow in automating data extraction for building envelopes performance optimization, as well as reducing working time. Besides, pushing back the optimized data to the BIM model using Dynamo scripting seems to be applicable.

**Keywords:** retrofitting, OTTV, optimization, Revit, Dynamo, visual programming, MATLAB, sustainability

## 1. Introduction

A huge investment is devoted globally for environmentally friendly buildings that can provide both high performance and long-term cost saving (Jrade and Jalaei, 2013). In order to efficiently guide the design and construction of green buildings, several green building rating systems (GBRS) have been developed around the world such as LEED (US), BREEAM (UK), Green Mark (Singapore) and GreenRE (Malaysia). When a project team is seeking for a green certification under these rating systems, often design decision-making become very time consuming due to the fact that collecting, managing and documenting the relevant data is a very labour process (Wu, 2010; Wong and Kuan, 2014; Jalaei and Jrade, 2015; Ilhan and Yaman, 2016; Lim et al., 2016; Seghier et al., 2018)we are looking at not just buildings' certification but sustainable practices that go beyond ratings to satisfy our social responsibilities. The construction industry in general will benefit from an integrated tool that will help optimize the selection process of materials, equipments, and systems at every stage of a proposed building's life. Building information modeling (BIM. Accordingly, architects and designers tend to rely on their previous experience outcomes to make "what they think it is the best design decision". These issues can occur during the design of a new building as well as the retrofitting of existing ones. It has been argued by Biswas et al (2013) that taking the appropriate steps to automate the process of gathering the necessary information for building environmental analysis is very crucial.

Building Information Modelling (BIM) design process is based on one data-rich digital model that can be used to perform numerous analyses through building life cycle. It has been argued by many scholars that BIM can support design Decision-Making and sustainability analysis in the very early design stages (Azhar et al., 2011; Jalaei and Jrade, 2015; Ilhan and Yaman, 2016)we are looking at not just buildings' certification but sustainable practices that go beyond ratings to satisfy our social responsibilities. The construction industry in general will benefit from an integrated tool that will help optimize the selection process of materials, equipments, and systems at every stage of a proposed building's life. Building information modeling (BIM. Though, BIM is still not being effectively utilized in improving the sustainability of existing buildings, such as building retrofitting and refurbishment activities. *"While the use of BIM for asset management has been acknowledged by researchers and practitioners, BIM is still not being effectively utilized for refurbishment activities"* (Alwan, 2016). Additionally, Computational BIM tools (i.e. Dynamo, Grasshopper) have broadened opportunities for design optimisation and increased the automation of data management throughout the building design process. Several studies have implemented computational BIM tool for building performance analysis such as Energy Efficiency and daylighting optimization (Asl et al., 2011), structural analysis (Makris et al., 2013), acoustical analysis (Andrea Vannini, 2015) and building envelope performance assessment (Seghier et al., 2017).

In new green building design and existing building retrofitting, heat gain or loss through buildings envelop is usually controlled by specific standards and regulations. For instance, the overall thermal transfer value (OTTV) is one of the mandatory requirements under several green building certifications and standards of several countries including Malaysia, Indonesia, and Singapore. It has been developed in order to guide project teams during the process of building envelope design, thus cut down on the external heat gain and hence, reduce the cooling load of the air-conditioning system (BCA, 2008). It is a mandatory requirement for both new and existing buildings. The complexity of OTTV assessment resides in the process of collecting the required data to perform the required calculations (Inhabitgroup, 2016; Lim et al., 2016; Seghier et al., 2017). In the Malaysian context, OTTV computation is based on the methodology specified in the Malaysian Standards (MS-1525) (Department of Standards Malaysia, 2014). The equation of OTTV applied to commercial buildings is given as follows:

$$OTTV_i + 15 \alpha (1 - WWR)U_w + 6 (WWR)U_f + (194 \times OF \times WWR \times SC) \quad (1)$$

Equation 1 OTTV equation

Where:

WWR is the window-to-gross exterior wall area ratio for the orientation under consideration;

$\alpha$  is the solar absorptivity of the opaque wall;

$U_w$  is the thermal transmittance of the opaque wall (W/m<sup>2</sup> K);

$U_f$  is the thermal transmittance of the fenestration system (W/m<sup>2</sup> K);

OF is the solar orientation factor; as in Table 1; and

SC is the shading coefficient of the fenestration system.

SHGC is solar heat gain coefficient where  $SHGC = SC \times 0.87$ .

This paper aims to develop a computational BIM-based data management workflow for building envelop retrofitting. This workflow is implemented within a research project called RBIM which focuses on the optimisation of the thermal performance of existing building envelopes. Different from the existing workflows which are often based on the usage of Industry Foundation Class (IFC) format, this workflow relies mainly on Dynamo visual scripting and the embedded information within the BIM model components. Thus, three Dynamo scripts are developed to extract automatically the required data from the BIM model in order to be used as an input during the optimization process. Finally, the optimisation output is pushed-back to the BIM model through another Dynamo script developed for that purpose. Accordingly, the BIM model is updated automatically with the optimised design option based on two criteria; OTTV performance, and cost of investment. In this paper, first, the overall RBIM framework is explained then, the development process of the Dynamo scripts is discussed and its usability is demonstrated through case study building.

## 2. RBIM Framework Overview

The RBIM workflow is mainly established to optimize the OTTV of an existing building against the cost of investment. As shown in figure 1, the RBIM framework is developed to perform a cycle of data starting by extracting the relevant data from the BIM model using Dynamo. Dynamo scripts are designed according to OTTV requirement and its assessment procedures, which are stipulated in the Malaysian Standards (MS) 1525:2014. Accordingly, all OTTV data requests were interpreted to rules for data management, these rules are compatible with Autodesk Revit and Dynamo current functionalities. Following the extraction of OTTV related data from the BIM model, this data is exported to MATLAB for optimization purpose. Finally, the optimization output data is pushed back again to update the configuration of the building envelope automatically.

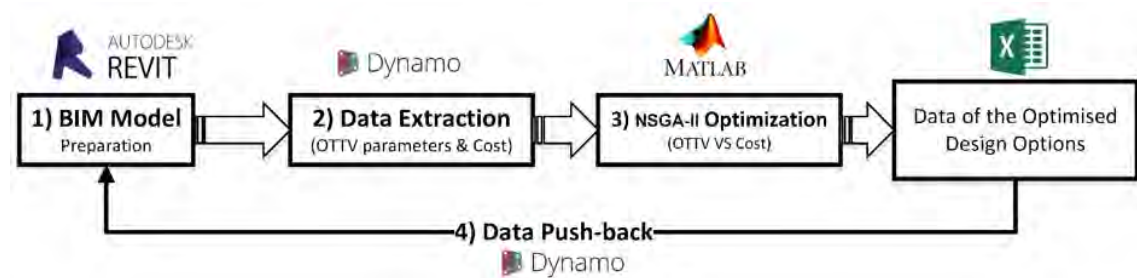


Figure 1 Logic workflow of the RBIM framework for OTTV/Cost optimization

Technically speaking, the first stage focuses on the preparation of the BIM model for data extraction. The preparation process requires having a BIM model of the building in question. In the case where no BIM model is available, it is required to remodel the existing building (at least the envelope) based on its CAD drawings using a BIM authoring tool (i.e. Autodesk Revit). The choice of selecting Autodesk Revit software in this study is because it is a widely used software in both BIM related research and the practice, adding to that its availability as student version and its integration with Dynamo (open source visual programming platform for computational BM).

The BIM model should be modelled correctly, for instance, the exterior walls should be directed to the outside of the building. Moreover, all building envelop elements (walls and windows) should contain all the required parameters for OTTV assessment such as U-value of wall and windows' glazing and cost. As a result, it is recommended to have a BIM model with a level of development (LOD) equals to 300.

On the other hand, data management in the RBIM project is mainly performed using Dynamo scripting. Similar to the other visual programming tools, Dynamo scripting is accomplished by combining the different nodes available in Dynamo library in order to create a logic flow for data management according to OTTV requirement. The first stage of data management consists of extracting the relevant OTTV data from the BIM model, as well as the data related to Revit library which contains walls and windows types. Following the data extraction process, the extracted data is hosted in an Excel template designed for that purpose. Next, this data is used as an input during the optimization process which uses a Non-Dominated Sorting Genetic Algorithm II (NSGA II) customised using MATLAB to perform Multi-objective optimisation of OTTV against the cost of investment. Finally, another Dynamo script is developed to push back of the optimised data (MATLAB output) to the BIM model. Thus, updating the BIM model automatically with the optimised design option configurations. It is worthy to note that the RBIM framework is open for customisation; the user can add additional types of elements to the library and create constraints to the optimization output according to its need.

At the end of the development process, the RBIM workflow was tested and demonstrated on an actual existing building (BIM model), and the generated optimization results were compared to manual calculations for validation purpose. Though, in this paper, the demonstration part focuses only on the applicability of the developed Dynamo scripts to extract the relevant data and push back this data to update automatically the BIM model with optimum design option (MATLAB output).

### **3. Dynamo Scripting Development**

Data management scripts in the RBIM framework are classified into four categories as follows:

- Script A1: Auto data extraction for opaque walls,
- Script A2: Auto data extraction for glazing (windows),
- Script B: Data extraction for Revit library, and
- Script C: Data push back.

Script A1 and A2 are developed to extract building envelop data related to OTTV requirement. This data is mainly related to the exterior opaque walls and exterior windows of the project. It covers the data request of OTTV equation, which includes windows and walls U-value, windows and walls area, windows and walls orientation, shading coefficients (SC1, SC2), wall pitch angle, WWR (%) and the solar correction factor (OF). Script B is designed to extract the library data of Autodesk Revit (Walls and windows elements). This data will be used to create the new design alternative during the optimization process in MATLAB. In order to get accurate optimisation results, the Revit library should contain different types of walls and windows of different sizes and a variety of thermal material properties. More importantly, the cost parameter of each element in the library and the case study model should be assigned with its relevant value. This is because the RBIM framework is basically developed to optimized building envelop OTTV against the cost of investment (cost of the new design option). Script C has been developed to push-back the data of the optimum design option (MATLAB output) to the BIM model in Autodesk Revit. This will update automatically the BIM model with the new solution which consists of the best design alternative in term on OTTV performance against cost investment. It is important to mention that the scope of this paper includes only the development of script A1, A2, and C.



### 3.1. Data Extraction

As shown in Figure 2, the process of extracting building envelope's data goes through multiple rules and functions which have been created and embedded within two Dynamo scripts (A1 and A2) based on OTTV requirements. It is important to note that OTTV is applicable only to air-conditioned buildings with an air-conditioned space  $\geq 1000 \text{ m}^2$ . Since one building could contain both air-conditioned (AC) spaces and naturally ventilated (NV) spaces (i.e. store, toilet, corridors) in the meantime, it is crucial step to automate the detection of only the building envelope elements that enclose air-conditioned spaces during the assessment process of OTTV. This has been implemented by adding a new shared parameter called "Is NV space" to the rooms' category within the Revit template. Then, the Dynamo script was developed to filter only the rooms with unchecked "Is NV space" parameter (see Figure 2, a-b-c). The next part (c-d-e) of the script was created in order to select all the wall elements of the air-conditioned rooms. Then, only the exterior walls were filtered from this selection by using the function parameter of the wall elements as a Boolean parameter (Exterior = 1, interior = 0). Moreover, this part included the addition of some new shared parameters to assist the user in excluding manually the walls that do not belong to any room in the project (i.e. walls in the staircases).

The orientation of building elevation has a direct impact of the final measure of OTTV. This occurs because several coefficients in OTTV equation such as solar orientation factor (OF), shading coefficient of shading devices (SC2) varies according to the orientation of each building elevation. Thus, it is crucial, in the preliminary stages to automate the detection of building elements orientation of each elevation of the building envelope in order to automate the whole assessment of OTTV. In Autodesk Revit, each wall has a vector perpendicular on its exterior surface. This vector is called "the normal", it is used as a key element in the automation of wall orientation in this study. As shown in the central part of figure 2 (part; e-g, e-f), script A1 detects the normal vectors of the envelope walls in the project. Then, the normal vectors coordinates (x, y) are assigned with conditions related to the angles defined by the cardinal and intermediate directions (N, E, S, W, NE, NW, SE, and SW) of the design environment of Autodesk Revit. For example, West direction is defined by a normal vector which belongs to an angle that ensures the following condition;  $67.5^\circ \geq \text{angle} \geq 112.5^\circ$ . Therefore, when executing script A1, each wall element is automatically assigned with its specific orientation parameter; walls with the same parameter value (same orientation, i.e. North) are grouped together to defined the gross area of each elevation. On the other hand, one of the fundamental modelling rules related to window modelling in Autodesk Revit is that each window should be hosted in a wall element. Based on this rule, data extraction script for windows (A2) has been developed to assign the orientation parameter of each window based on the orientation parameter of its host wall (assigned using the previous process). For instance, if a window is hosted in a wall oriented north, automatically the orientation of the window will be assigned as north as well, and vice versa. Next, in the f-h and g-h parts (see figure 2), all the relevant walls and windows are categorized according to their orientation parameter, and all the required parameters are extracted. Finally, the list of the extracted data is exported to an Excel template (h-i) which in turn will be used as an input in MATLAB to perform the optimization of OTTV against the cost of investment (i).

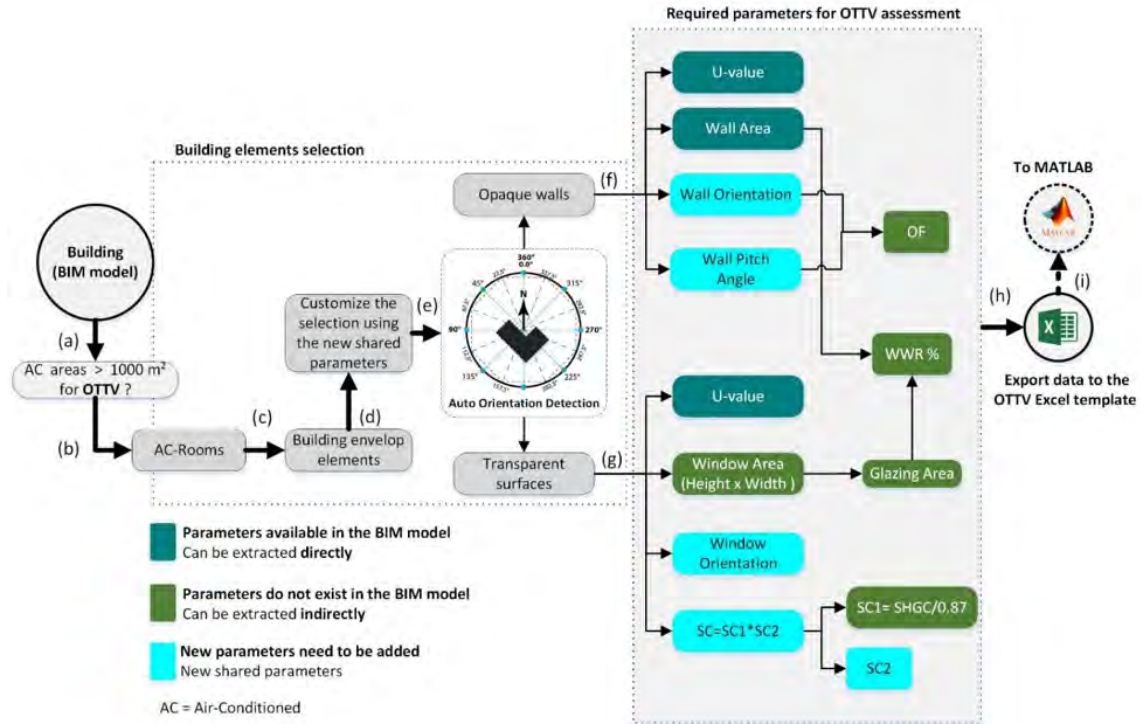


Figure 2 Data extraction logic flow for OTTV requirement (wall and window)

### 3.2. Data Push Back

Data pushback is another key step in the RBIM framework, it opposes the data extraction process discussed previously. In contrast, data pushback consists of feeding the BIM model with the optimized data that will ensure an optimized building envelop design in term of OTTV performance and cost of investment. As shown in figure 3, the data output of MATLAB optimization is exported to an Excel template (a-c). This data is pushed back to the BIM model using Dynamo script C, which was developed for that purpose. Script C will select the optimized design alternatives of walls and windows using their ID parameter (d-f). This selection is performed by reading the available data within the green columns of the Excel file (MATLAB output), see figure 3. It is worthy to mention that all the design variables generated by MATLAB are linked to the library of Autodesk Revit (b). In the meantime, script C will select the existing walls and windows of the building envelope using their ID parameter (e-f). Finally, after reading both data of the existing and optimised building envelop elements, script C (f-g) will replace each existing wall/window element with the optimised option based on their ID parameter. As result, the model will be updated automatically to the optimum design configuration based on MATLAB data output.

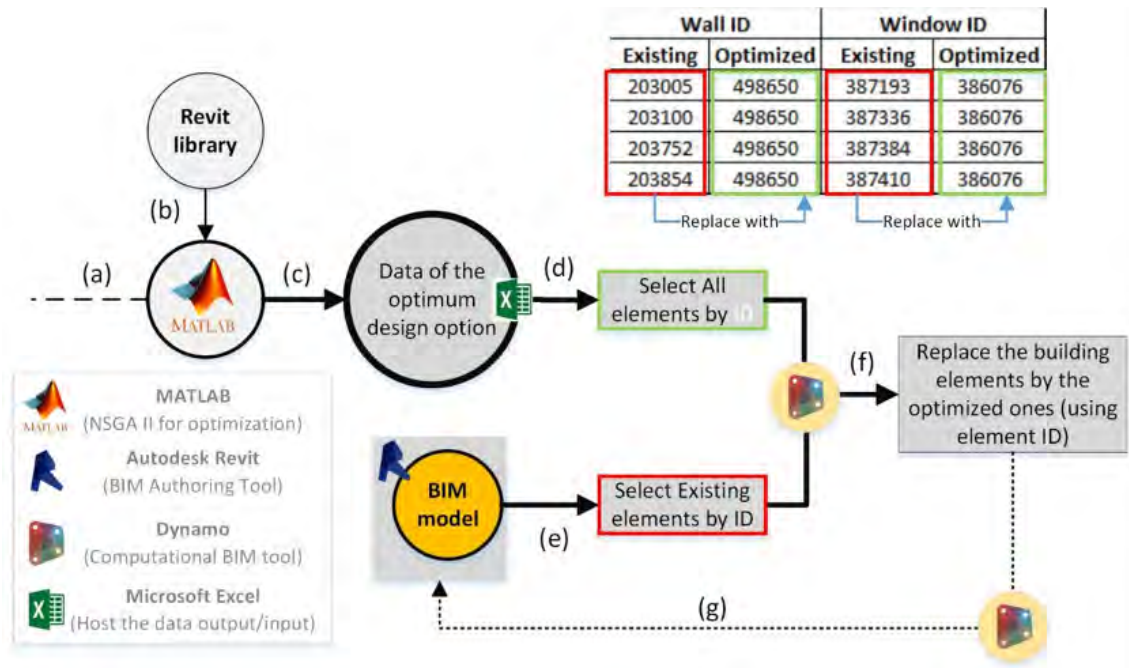


Figure 3 Logic workflow of the data push-back script

#### 4. Case Study

The whole RBIM framework applicability is tested and demonstrated through case study building (BIM model), though in this paper the validation will focus only on the implementation of Dynamo scripts (A1, A2, and A3).

The selected case study consists of an existing office building of four levels with a gross floor area of 7500 m<sup>2</sup>. This building is located in the Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia (UTM). The BIM model of this building was modelled using Autodesk Revit based on CAD drawings. As shown in figure 4, the building has four facades (NW.NE.SW.SE); each façade consists of opaque walls built using single brick material and transparent surfaces that consists of windows with single glazing.



Figure 4 Case study building for the RBIM framework testing; (a): photo, (b): BIM model

The RBIM was tested on the case study building through three optimisation scenarios as follows: optimization which considers only window elements (scenarios one), optimization for both Wall and window elements (scenarios two) optimization using an additional constraint for window area (scenarios three). All the different scenarios have shown a significant reduction in OTTV,

however, the cost of investment varied from case to another. In this paper, only the second scenario and the North-East elevation are of the case study are taken as an example.

The optimization process starts by running the data extraction scripts (A1 and A2), which takes only 35 seconds to extract all the required data. The extracted data consist of two lists of data related walls and windows, these lists cannot be presented in this paper because of their length. At this stage, to prevent including wrong walls, any walls included in OTTV optimisation are assigned with a specific colour according to the elevation orientation in the BIM model (i.e. orange colour for North-East orientation). Next, the extracted data is exported to MATLAB to run the multi-objective optimisation. The optimization results have shown a reduction in OTTV value from 49.47 to 25.96 W/m<sup>2</sup> (19.91% of reduction) with an additional cost of investment related to building materials that equals to RM 92832 (the cost of the initial building envelop design is RM 101291.95). The data of the optimised design option is then pushed back to the BIM model using script C. At this point, the BIM model of the initial building is updated automatically with the optimised data generated through MATLAB. It is worthy to mention that the time of data push back took around 3 minutes, however, this period may vary dependently on the BIM model size and its design complexity. Figure 5 illustrates the status of the BIM model before and after optimization. It can be seen that the element types of building envelop have been changed to new types which have more thermal performing materials. For example, windows with single glazing (U-value= 6.7 m<sup>2</sup>.k) have been changed to new window types with double glazing (U-value= 3.12 m<sup>2</sup>.k) meanwhile single brick walls have been changed to double brick walls with additional insulation layers. As mentioned previously, these optimisation results are highly dependent on the possible design options available in the library, and the constraint under of the second scenario.

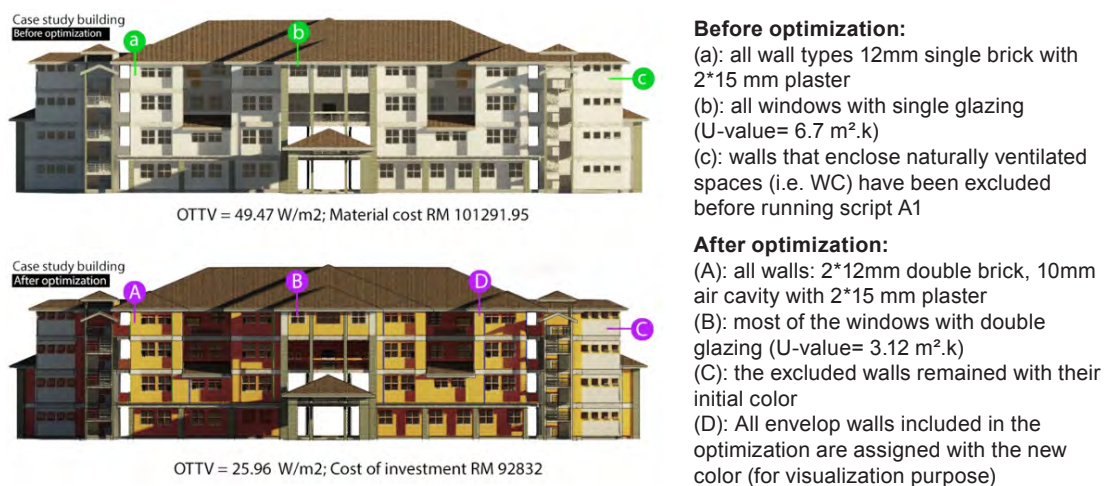


Figure 5 Case study building (North-East elevation) before and after optimization

## 5. Discussion and Conclusion

This paper has presented the development of a computational BIM-based workflow for data management using visual programming (Dynamo). This workflow has been implemented within a research project called RBIM which seeks for the optimization of existing building envelop thermal transfer value (OTTV) against the cost of investment. Two main Dynamo scripts able to extract/push back data automatically from/to the BIM model were developed for this purpose. The results of the case study have shown a great potential of using Dynamo to automate data management (extraction and push back) for building envelops optimization. Data extraction process using script A1 and A2 took only 35 seconds to extract the required data. On the other hand, data push back of the optimized data to the BIM model took 3 minutes. More importantly, heat transfer of building envelop (North-East elevation) has been reduced by 19.91% with an additional cost equals that to RM92832.



Despite these achievements, this study is only a preliminary investigation of the usage of Dynamo to automate data management within the RBIM project. Further investigation on how the transparent curtain walls data can be integrated to the developed scripts is required. In addition, an assessment model for shading coefficient of shading devices (SC2) has to be integrated. Finally, in order to make the developed scripts more user-friendly, exploring how the developed scripts can be developed further as a Revit plug-in is recommended. It is believed that the RBIM framework and data management scripts in this study can be adapted to optimize other sustainability criteria such as Co2 emissions and building material selection.

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## TOWARDS SELF-RELIANT DEVELOPMENT: CAPACITY GAP WITHIN THE BUILT ENVIRONMENT OF MT. ELGON RURAL INHABITANTS

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### Summary

Rural communities in many developing countries show a socially inclusive, resilient and self-reliant model for their built environment, despite the lack of individual capacities. However, due to scarce opportunities many people move to the cities often landing again into challenging conditions. As a result, both urban and rural inhabitants struggle to reach the desired living standards and well-being. This article explores general capacities of rural inhabitants in Kenya and identifies what shortages prevent inhabitant well-being within their built environment. Outcomes of the interviews performed on 200 families (4 communities) evaluate if the different communities still build by themselves; if they would like to continue this 'self-reliant model' or would prefer to change it. Conclusion indicates that inhabitants would prefer to build themselves and expose why these communities change to 'external', dependent solutions. Showing alternatives, which lie within their capacities play a crucial role in sustaining the communities' self-reliant built environment.

Keywords: Self-reliance, inhabitant capacities, inhabitant-led development

## 1. Introduction

Existing informal rural (vernacular) architecture offers a flexible model based on locally available (renewable) materials and building methods. This model often evolved over centuries, passed down to every new generation. Due to the nature and character of the vernacular archetype, extensive maintenance is often needed. Even though the maintenance is considered inconvenient, the continuity allows the community to practice its execution. This makes them highly resilient towards change, Nel and Binns (2000). The circular sustainable model is still widely used among many rural African communities. Rural communities have been trying to improve the living quality, however the change introduced industrialized materials and construction methodologies. In practice, this means, despite that durability and maintenance have improved, the process created significant external dependency in material, construction and skills (labor). Causing unsustainable, non-circular and climatic undesirable solutions. What is equally important, it diminishes the community's self-reliance<sup>1</sup> towards their built environment (Smits, 2014). The reasons are manifold for rural inhabitants to improve the quality of the existing vernacular housing. In most cases they are restricted to only use local, natural materials and traditional construction methods.

In an effort to change the existing housing model, they now often use materials and techniques that lay outside the inhabitants' knowledge sphere. If these communities are to continue the self-reliant model, they need a way to upgrade the model (extend durability, lower maintenance) without damaging its qualities: self-building practice, climatic orientation and renewable materials. To sustain both self-reliance and house qualities it is vital to evaluate inhabitant capacities<sup>2</sup> and use them in decision-making (Smits, 2017). However, inhabitant capacities often seem to contradict the ones necessary to build their desired house. Inhabitants are aware of the house they would like, however, lack the capacities (materials, knowledge, skills and finance) to build the house by themselves. Therefore, this study investigates the conditions in which inhabitants are living in right now and how they would prefer to live. The rural area of Mt. Elgon proves a representative study area<sup>3</sup> in which communities with various levels of 'capacities' can be found. Exploring general capacities of rural inhabitants and identifying what shortages are preventing them from improving their built environment.

For this purpose, over two hundred families participated in a survey conducted in February 2017. Due to the sensitive context of the survey a questionnaire was combined within an interview. Here the interviewer had the opportunity to answer any questions and explain the interviewee's privacy rights (informed form). To have a representative sample of the Mt. Elgon area, four communities with different levels of income, housing and ownership were targeted. To have a representative sample per community (around 50% of the population) communities were targeted of approximately 100-120 households. Moreover, did one male and one female researcher investigate every community, sampling 25 females and 25 males from various households.

This article will focus on the type of house most of the rural inhabitants of Mt. Elgon live in right now, which one they desire and what their capacities are. This will help expose the discrepancies between what the inhabitants have and desire. This article will elaborate the executed study on Mt. Elgon in four steps. Firstly, explaining the context of Mt. Elgon and relevance of the targeted communities. Secondly, describing the methodology and consecutive execution of the study in February 2017. Thirdly, elaborating the most important outcomes of the study. Fourthly, describing the conclusions and restrictions to the study. This article will conclude the importance of assessing and incorporating inhabitant capacities towards their build environment, which the author coined: "capacity informed decision-making". As this article will show the communities on Mt. Elgon area have a shared notion of their desired house. This shared image is studied in detail, including: size and materialization. However, almost half of all the participants of the presented study estimate that they won't be able to afford the desired house. Resulting in a large part of the

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1 Self-reliance: to which extend a person or family can rely on their own capacities.

2 Capacities: collection of all available resources, tools, knowledge and skills.

3 Representative study area: the level of 'development' in the area is representative for many others.

population remaining in challenging conditions: 75% of the studied communities almost all live in mud-based houses. Indicating a need for alternative solution(s) for a large part of the community.

## 2. Mt. Elgon area & targeted communities

Over 70% of the built housing worldwide, is built informally and often by the inhabitants themselves (UN-Habitat, 2013). South Asia and Sub-Sahara Africa will have one of the most significant shifts from rural to urban in the upcoming decades (UN-Habitat, 2015). This shift has posed a great threat to the wellbeing of vulnerable families in the past and can only predict the problems ahead. In Africa, projections are that over half of the urban population (61.7%) lives in slums and by 2050, Africa's urban dwellers are projected to have increased from 400 million to 1.2 billion (UN-Habitat, 2015; United Nations., 2012). It is needless to say that it will be vital to understand one of the largest contributors to the urbanization, namely: rural-urban migration (Tacoli, Mcgranahan, & Satterthwaite, 2014). Therefore, this article aims at understanding the current living situation of rural inhabitants on Sub-Sahara Africa as it contributes to the fastest urbanizing areas on the continent. With 20-25% of the countries' population urbanizing in the next 20-30 years (World Bank, 2016) Kenya proves to be representative case.

In particular West Kenya has a large number of growing cities Kisumu, Eldoret, and Nakuru (World Bank, 2016), which is also called the 'western hub'. In the left image of Figure 1 this urbanization is projected. Here, Mt. Elgon is one of the rural areas that potentially hold rural-urban migrants.

In this area four communities were sought to analyze their current and desired housing. Considering the available resources for this study, a total of 200 inhabitants could be interviewed. Based on this scope several criteria were chosen to identify the communities: firstly, to have a substantial, representative sample, at least 40-50% (Thompson, 2012) of each population had to be included in the study. Therefore firstly, four communities of around 100-120 families were sought in Mt. Elgon area. Secondly, to prevent a subjective representation, communities with variable levels of income were selected (only selecting poor communities would support the claim that capacities do not meet the desired housing). The communities on the North-eastern slope of Mt. Elgon have varied levels of income (areal employers include: Mt. Elgon Orchards, ADC Japata and ADC Suam) good schooling and healthcare. Thirdly, a mixture of housing quality had to be identified. It was crucial to show that the mismatch between capacities and desired housing are present amongst different levels of income and quality of housing.



Figure 1 (left to right): Urbanization index (World Bank, 2016), location of Mt. Elgon in Western Kenya and location of selected communities (source: Google Maps)

Four researchers from Nairobi University and a local social worker deliberated with village elder and areal chief for suitable communities in the Northeast area of Mount Elgon. Here, twelve rural communities were evaluated according to previously mentioned criteria. The considered communities were (estimated inhabitants): Chepchoina (70), Cherubai (200), Habitat (94), Japata (90), Kaisheber (150), Kaptega (50), Koronga (550), Nabeki (420), Njoro (300), Sokomoko (100),

Vamia (150) and Wangu (30). Finally four communities in proximity to each other were selected and grouped:

2. No/low income, doesn't own plot, mainly renting/self-build houses
3. Low/regular income, doesn't own plot, mainly/self-build renting houses
4. Low/regular income, owns plot, mainly self-build houses
5. Regular/high income, owns plot, mainly commercially build house.



*Figure 2 Map of the selected communities on Mt. Elgon (source: Google Maps)*

The Japata settlement near Kaptega river was selected as group 1 (figure 2: red marker). This community of approximately 70 households, was allowed to temporarily settle themselves as farm workers and since independence (1963) have been living there. They do not own the plot they live on, are not allowed to build permanently, and have low/non-existent incomes.

Chepchoina village was selected as group 2 (figure 2: green marker). This community of approximately 110 households lives around the Chepchoina village market. The plot is privately owned; most of its residents rent a house in this area. The families have a mixed income and often combine small business with farming, generating a low/regular income. This community has its own marketplace and bus stop, which influences landownership.

Vamia was selected as the group 3 (figure 2: blue marker) consisting of approximately 120 households. The plot belongs to the inhabitants and they mainly have a regular income combining a commercial position with farming their lands. The Habitat community was selected as group 4 (figure 2: orange marker). Consisting of 94 households owning their plots. The majority works fulltime for a commercial farm and have a regular/high income.

With the four communities selected, the next section will elaborate on the methodology used to interview the communities and consecutive questionnaire.

### **3. Survey, mixed methodology: interview & questionnaire**

Studying inhabitant capacities on their housing, involves both quantitative and qualitative aspects. Quantitative capacities consider measurable aspects such as: income, size of family, ages, etc. Where, qualitative capacities consider why and how they live at the moment, moreover, understanding their housing preferences. For this purpose, a mixed method was used, where both questionnaire and structured interview are performed in a survey framework (Creswell, 2013; Fowler, 2013). The questionnaire was used to register quantifiable answers, closed questions and later on to compare the 200 outcomes. The structured interview was used to address open questions and help to understand motives. A structured interview is chosen to ensure that the interviews follow the exact same procedure. The questionnaire supports the structured interview to ask the same questions in the same order amongst all 200 participants of the survey.



### 3.1. Interview context

The survey was performed in a vulnerable environment where many of the participants have difficulties to sustain a living (below international poverty line: \$1.90 p.p.p.d.). Moreover, many participants live in a traditional house and conservative relation between man and woman. Therefore, it was essential to take preliminary precautions. As the community elder, chief and a local social worker were already involved, they were also aware of the survey and informed the communities. To get a balanced perspective all households, 100 surveys were conducted with women and 100 surveys with men. To prevent social/cultural dilemmas two female and two male researchers were hired. Sophie E. Kibuywa, is head of a local organization (Desece: development education services for community empowerment) and has decades of experiences in conducting local researches. She recruited the researchers and instructed them for the survey. Evaluating the experiences within the four selected researchers Pauline was appointed as team leader (she was the most experienced).



*Figure 3 (left-right): B. Sawenja, K. Humphrey, S. Kibuywa, P. Nabalayo and A. Nyangugu (source: Author)*

During the survey the researchers were staying separately (men/women) in the middle of the targeted communities. Two communities were next to their place of residence and two communities were in a short travelling distance (max. 5 minutes on motorbike). There was an office arranged at the local hospital where they were able to work.

### 3.2. Interview instruction & guide

To prevent any inconsistencies in executing the surveys, a questionnaire instruction sheet (see attachment) was prepared for the researchers. The instruction explains step by step how the survey should be performed and what the points of attention are. It starts by explaining the context, in which the survey is positioned, gives the objective and aim; continues by introducing the composition (targeted age and such) and explains the practicalities of the questionnaire: location, recruitment of the participants, picture/audio recording, venue, breaks and ethical issues. Ensuring that: the surveys were taken in a safe environment, with the participants of appropriate age and gender and not invading the privacy of the participant. The interview guide has a similar purpose to the instruction. However, it gives the exact questions that need to be addressed during the interview. The guide was written according to the advised structure of an interview guide by: Qualitative Research Methods (Hennink, Hutter, & Bailey, 2010). It starts by introducing the research purpose and explains the attached consent-form (see attachment). The researchers are asked to read the consent form and answer any questions of the participant. When all of them are answered the interview can be conducted. The questions are divided in three sections: general information, questions about current house and questions about the desired house.

Section 1: The general information questions are closed quantitative questions that are relatively easy and comfortable to answer. Questions are meant to evaluate: family size, occupations, ages, financial capacities and landownership. The answers will help understanding the extent to which these capacities enabled the current and desired type of housing.

Section 2: The questions on current habitation aim to understand the house people live in. The questions emphasize ownership, amount of structures, house size, in/outdoor functions, used materials, self-build practice, help by community members, satisfaction, maintenance and the reasons for not realizing desired housing.

Section 3: Questions in this section focus on the participants desired housing. The closing questions in this section emphasize if they would be able to afford<sup>4</sup> the desired house based on their existing capacities. Moreover, if they would prefer to build the house by themselves, helped by their community.

The questionnaire was available via Google-sheet, accessible by smartphone (all researchers had one). All interviewers had a printed version of the questionnaire, interview guide and instruction with them.

### 3.3. Pilot & Adjustments

On the 30th of January 2017 the first pilot was run amongst the researchers. Here they were requested to test the survey (using the printed English questionnaire, making audio recording and pictures) on each other. The team concluded that there was a necessity of translating the questionnaire to Swahili as it was too difficult to do this simultaneously during the interview. The cross-cultural survey guidelines of Mohler et al. (2010) provide with an appropriate team translation model that suited the requirements of this study. Also called The Team Translation Model Procedures (TRAPD). The group researchers was divided in two teams and separately made their translation. In the review session they compared their translations, discussed the differences and made a concept translation. The results were reviewed by Sophie E. Kibuywa and returned to the team. They had a second adjustment session when they debated the review and made a final translation.

### 3.4. Executing the survey

The survey started with one research team in the Japata ADC and one in the Habitat community. Every time locating one household that had a mother present and another that had a father present. According to the set target every team conducted between 8-10 interviews per day. The researchers used the physical print to write down the answers of the participants and their phones to make the audio recordings. After each survey the researchers took a picture of the participants. Afterwards they were given one kilogram of sugar per household as compensation. At the end of the week the researchers used three days to digitalize the 100 answer sheets and upload the pictures and audio recordings.



Figure 4 (top to bottom): Samples of the Japata ADC & Habitat community (source: Google Maps)

4 Afford: to what extend the capacities enable or disable a realization

On February 16th the survey continued in the Vamia and Chepchoina communities, following the same procedures as the Japata ADC and Habitat community. The research teams were able to finish the second round of 100 surveys by February 24th.



Figure 5 (top to bottom): Samples of the Vamia & the Chepchoina community.

## 4. Outcomes survey

In the following sections the outcomes of the survey are compared between the four communities. In each consecutive part of the questionnaire the most important findings are shown and explained.

### 4.1. General information questions

Table 1 projects shared income, income stability and the family size, between the communities. Although the Habitat and Chepchoina community have a higher average income, the majority of inhabitants (>50%) earns up to 25000 KsH (roughly \$250) per month. Considering that the majority of the community has between 0-7 children this leaves the households with \$4 per person per day (2-person household), \$1,6 in a five-person household and worst-case \$0,8 in a nine-person household. With income fluctuating in at least 70% of the households in three out of four communities, questions arise if the families are able to sustain basic life necessities (as they are far under the international poverty line: \$1,90). It is important to state that Japata has a considerably lower average income.

Table 1 Shared income, Income stability & Family size

5. How much is your shared income?				
	Japata	Chepchoina	Vamia	Habitat
<1000	0,0%	4,7%	5,9%	0,0%
1000 to 2499	9,1%	4,7%	2,9%	2,0%
2 500 to 4 999	20,5%	9,3%	17,6%	3,9%
5 000 to 7499	40,9%	16,3%	17,6%	2,0%
7 500 to 9 999	13,6%	16,3%	5,9%	21,6%
10 000 to 2 4999	15,9%	37,2%	32,4%	60,8%
25 000 to 49 999	0,0%	9,3%	5,9%	7,8%
50 000 to 99 999	0,0%	2,3%	0,0%	0,0%
100 000 to 500 000	0,0%	0,0%	11,8%	2,0%
6. Is this stable, or does fluctuates seasonal or occasional? income?				
	Japata	Chepchoina	Vamia	Habitat
stable	18,4%	28,9%	19,5%	64,2%

fluctuates	81,6%	71,1%	80,5%	35,8%
<b>8. Amount of children</b>				
	<b>Japata</b>	<b>Chepchoina</b>	<b>Vamia</b>	<b>Habitat</b>
from 0 to 3	42,9%	69,4%	36,6%	32,1%
from 4 to 7	38,8%	22,4%	43,9%	58,5%
from 8 to 11	18,4%	8,2%	17,1%	3,8%
12 and more	0,0%	0,0%	2,4%	5,7%

Table 2 Questions on: Farmland, Ownership and the contribution to livelihood.

<b>12. Do you have a farmland (shamba)?</b>				
	<b>Japata</b>	<b>Chepchoina</b>	<b>Vamia</b>	<b>Habitat</b>
Yes	38,8%	54,2%	80,5%	94,3%
No	61,2%	45,8%	19,5%	5,7%
<b>13. Do you own this farmland?</b>				
	<b>Japata</b>	<b>Chepchoina</b>	<b>Vamia</b>	<b>Habitat</b>
Yes	0,0%	34,7%	70,7%	84,9%
No: company land	79,6%	0,0%	0,0%	1,9%
Unknown	20,4%	22,4%	17,1%	1,9%
Family land	0,0%	12,2%	9,8%	7,5%
No	0,0%	24,5%	0,0%	3,8%
Rented	0,0%	6,1%	2,4%	0,0%
<b>14. Does it generate income?</b>				
	<b>Japata</b>	<b>Chepchoina</b>	<b>Vamia</b>	<b>Habitat</b>
Yes: Grow crops for family	36,7%	28,6%	63,4%	66,0%
Yes: Grow crops for family and Selling	2,0%	18,4%	14,6%	18,9%
Unknown	59,2%	22,4%	22,0%	1,9%
No	2,0%	30,6%	0,0%	13,2%

Table 2 shows that although most households did not state that they are farmers (<15%) three out of four community has a majority that has a farmland (>50%), which contributes to their daily livelihood. Current capacities in the communities show that some of the households have been able to secure a stable and substantial income. However, the vast majority of the households have a daily budget below the poverty line and the income in most cases fluctuates often. It makes the households highly vulnerable and indicates that making means to an end is difficult. In relation to their built environment that in most cases the financial capacities for materials and labor are marginal. The next section reflects on how these capacities relate to current habitation.

#### 4.2. Questions on current housing

Ownership in the communities differentiates substantially: see figure 6. The government owns the land on which the Japata community lives, inhabitants are mainly workers of the Japata ADC farm. Japata has an almost equal ownership and renting division. However, as they do not own the land it is questionable to what extent they are allowed to live there. Chepchoina has almost solely renting residents (>95%) and therefore the majority has no land rights. The opposite is

happening in neighboring Vamia. Here, the majority (>70%) owns both land and house. Despite the differences in all three mentioned communities, the vast majority (>90%) of their households live in mud-based houses. This occurs despite the fact that Chepchoina and Vamia on average have a much higher income than Japata. Even renting does not seem to enable households with an average higher income to live in an 'improved house'. Which can be explained by two factors: availability of brick houses and fluctuations in income. The latter explained by the 70-80% of households in these communities have seasonal/unstable jobs. The Habitat community stands quite the contrary to the other three communities. Here, the land is individually owned, however, via a collective. Considering the height and the stability of their income they are the only community who could afford a brick house.

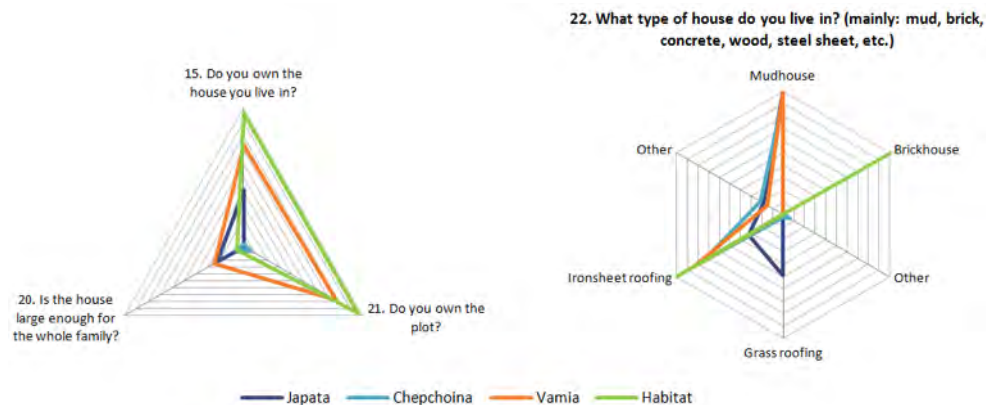


Figure 6 Left: House ownership and Land ownership, Size suitability; right: Type of current house.

However, it seems that in none of the communities the current capacities have offered sufficient living space for the whole family (Figure 6). With the majority of the households having between 0-7 children in a house between 5,7 to 13,7 square meters this problem can be explained.

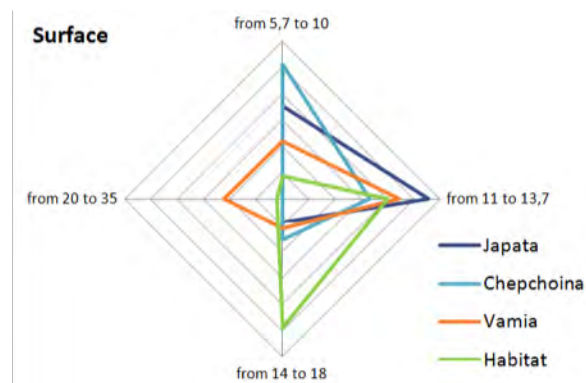


Figure 7 Surface of current house

In the case of Japata and Vamia the majority of the materials (75-100%) are not bought but collected. The only costs involved are to cover transportation. Table 3 shows the large amount of natural materials used in constructing houses, which makes the materials affordable, especially amongst the communities with a low income.



Table 3 Material cost & availability

If yes: a. Did you have to pay for the materials or are there other ways of collecting/ acquire these materials				
	Japata	Chepchoina	Vamia	Habitat
Pay	14,8%	0,0%	0,0%	100,0%
Free	7,4%	14,3%	0,0%	0,0%
Collected	14,8%	4,8%	0,0%	0,0%
Collected and paid for transportation	63,0%	19,0%	100,0%	0,0%
N/A	0,0%	61,9%	0,0%	0,0%
<b>25. Are those materials local natural resources (e.g. mud or straw) or Manufactured (e.g. cement, iron sheet)?</b>				
	Japata	Chepchoina	Vamia	Habitat
Natural	100,0%	78,3%	90,0%	0,0%
Industrial	0,0%	21,7%	10,0%	0,0%
Both	0,0%	0,0%	0,0%	100,0%

Looking at the self-built practice (Figure 7) especially in Japata and Vamia this influences the maintainability of the house. The opposite happens in the Habitat community where more than 90% is not able to maintain the house by themselves. A more worrying trend seems to be the ability to afford maintenance in case income becomes low or stops altogether. The Japata community actually has the most positive score in this section. Here, over 65% of the households think they will be able to pay for the maintenance on the house, due to the availability of materials.

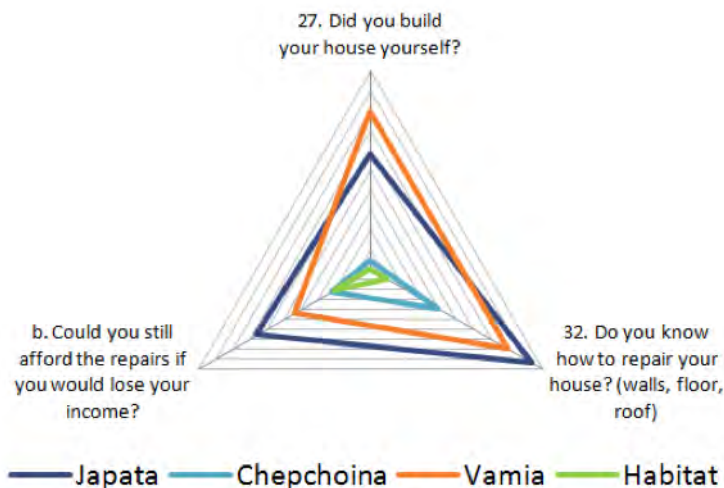


Figure 8 Self-build practice, repair ability and affordance

Although the capacities and living situations differ strongly, they all seem to result in an opinion of dissatisfaction on the house (Figure 8). The Habitat community shows a little more content with the existing house, however, >80% still prefers to build the house differently. When asked why, the majority answered: due to the lack of funds, which most likely is linked, to the type of materials they would have preferred to build with (>80%). Moreover, when asked if they would know how to build this house by themselves, more than 64% of all respondents do not think they are able to do so.

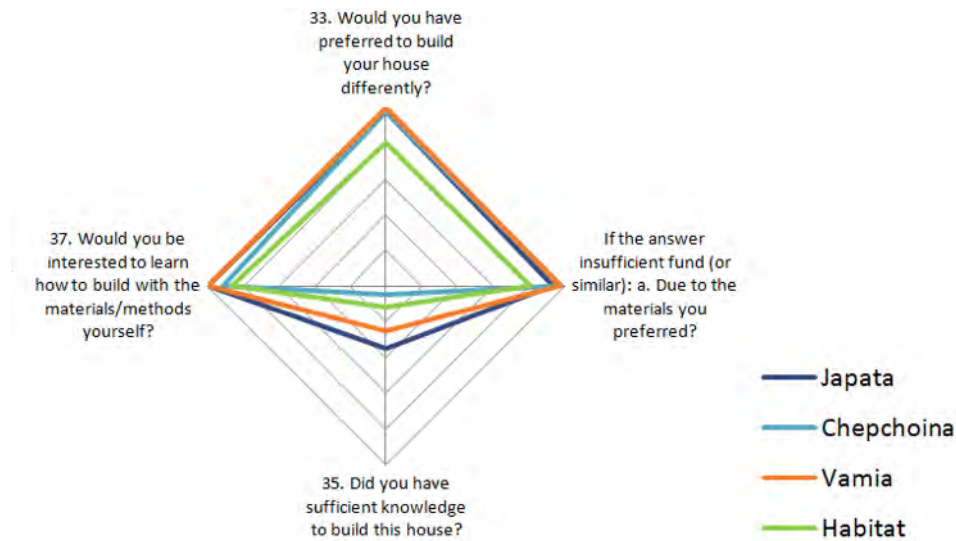


Figure 9 House preference, sufficiency funds, building knowledge and willingness

The last question on the existing house inquires if the inhabitants would be interested to learn how to build their desired house. What they most likely do not consider is the knowledge, skill level and training needed to build such a house. Building such a house would actually require extensive professional knowledge, skills and training, such as: mason, steelworker, carpenter, etc. Those types of trainings would either take many years in training or could be learned on the job. Indicating not only a problem in comprehending the needed requirements but also that there is a considerable knowledge, skill and training gap between the currently used and desired building technique. In the last section on the results this topic will be further explored.

#### 4.3. Questions on current housing



Figure 10 (left to right): roofing sheet Chepchoina, thatched roof Vamia (source: author)

Based on a previously made observation in the area: the houses built with thatch in comparison to roofing sheets, seem to be cooler during the day and warmer during the evening. When it rains the roofing-sheets produce a lot of noise in comparison to the thatched roof. To better understand if the inhabitants had similar observations and how they reflected on material suitability, a short section was included in the survey. Figure 10 shows the results on the existing house (left image). With the majority of the communities having roofing sheets (Japata >32%, Chepchoina, Famia & Habitat 75-100%) they have sufficient experience to reflect on the effects of the roofing sheet.

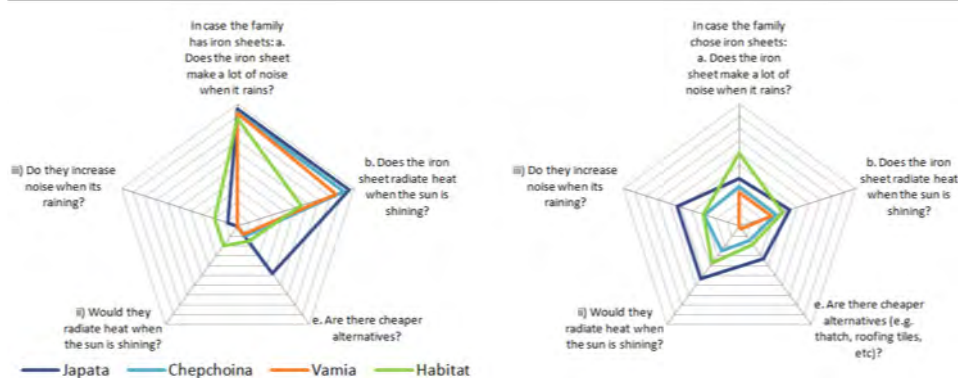


Figure 11 Left: Opinion about existing roofing sheet; Right: Opinion about desired roofing sheet

Results show that the majority of the households find the roofing sheet radiating heat when the sun is shining (>90%) and makes noise during rains (50-95%), confirming the initial observation made in the communities. Despite these disadvantages the majority still uses roofing sheets. Moreover, does the majority not know any cheaper alternatives (50-90%). The rest of the respondents do point out thatched roof as existing alternative. Respondents admit that those alternatives would react better to sun (50-90%) and rain (80-100%), indicating that there are no cheaper alternatives, however, they have better characteristics than roofing sheets. Which indicates a possible knowledge gap of alternative roofing solutions within the communities.

The same questions were asked after households stated their preferred type of house. Here, between 70-90% of the households (figure 10, right image) answered that they prefer using iron sheet roofing. When asked if the iron sheets made noise during rain or radiate heat when the sun is shining, the answers were quite the opposite to their current housing. Here, the majority of the households (rain noise: 40-70% & sun radiation: 55-70%) stated that the iron sheets do not have this effect. In the interviews many households stated that the main reason there are no cheaper alternative is the difficulty they have to find grass locally. Due to this shortage people started to sell grass as a building product. The available 'free' grass has to come from such a distance that the transport costs are almost equal to buying roofing sheets. Moreover, in their opinion the grass roofing requires more maintenance and leaks more often. Other reasons for preferring roofing sheets, are: fire resistance and insect-proof. It seems that these reasons influence their perspective on the disadvantages of the roofing sheet.

#### 4.4. Questions on the desired house

The questions in the third section of the questionnaire focused on desired housing. In the Japata and Chepchoina community respondents would all prefer to own both the house and land. Among all the communities 95%-100% of all the households would prefer to own their house and the land they live on (Table 4).

Table 4 Desired house/land ownership.

39. Would you prefer to own or to rent the house?				
	Japata	Chepchoina	Vamia	Habitat
Own	98,0%	100,0%	100,0%	100,0%
Rent	2,0%	0,0%	0,0%	0,0%

44. Would you prefer to own a plot or rent a plot?				
	Japata	Chepchoina	Vamia	Habitat
Own	100,0%	97,9%	100,0%	100,0%
Rent	0,0%	2,1%	0,0%	0,0%

When asked which materials they would prefer to build their desired house from (see Fig.12) the majority chose bricks (45%-75%) and iron sheets (70%-95%). Most households state that the preferred materials are expensive (see Table 5).

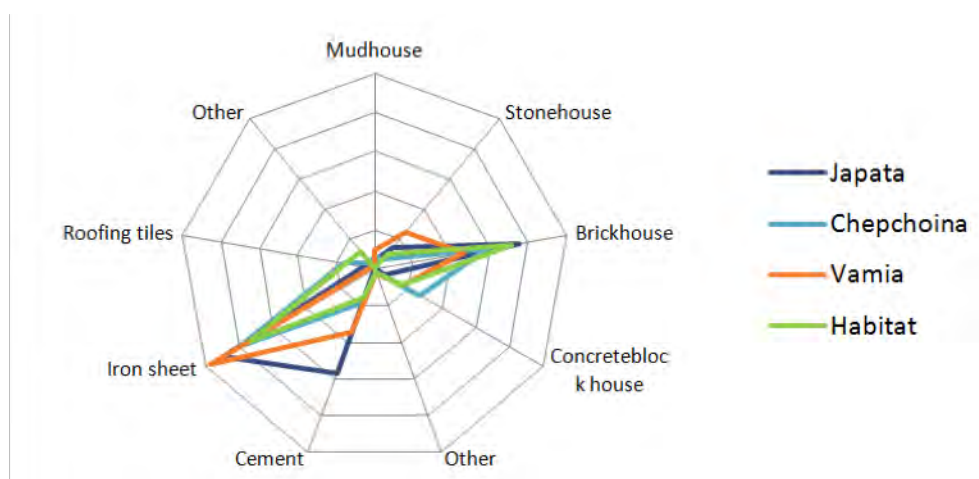


Figure 12 Preferred materials, material costs

Table 5 Material costs

47. Are those materials expensive or cheap?				
	Japata	Chepchoina	Vamia	Habitat
Expensive	81,6%	63,0%	87,8%	56,6%
Cheap	18,4%	37,0%	12,2%	43,4%

Figure 13 shows that they prefer to build the house by themselves (75%-95%) and if they can't or won't build the house themselves that they will need to hire labour (90%-100%). Japata and Vamia think that their community would help most of them in building the house (>95%), which in Chepchoina (mainly renting) and Habitat (formed community) is quite the contrary. It could be argued that these communities are differently organised and therefore inhabitants are reluctant to help each other. This, in the Habitat community is strange considering the fact that they own the land communally. What is most worrying, is that three out of four communities will not be able to make house repairs when they lose their income.

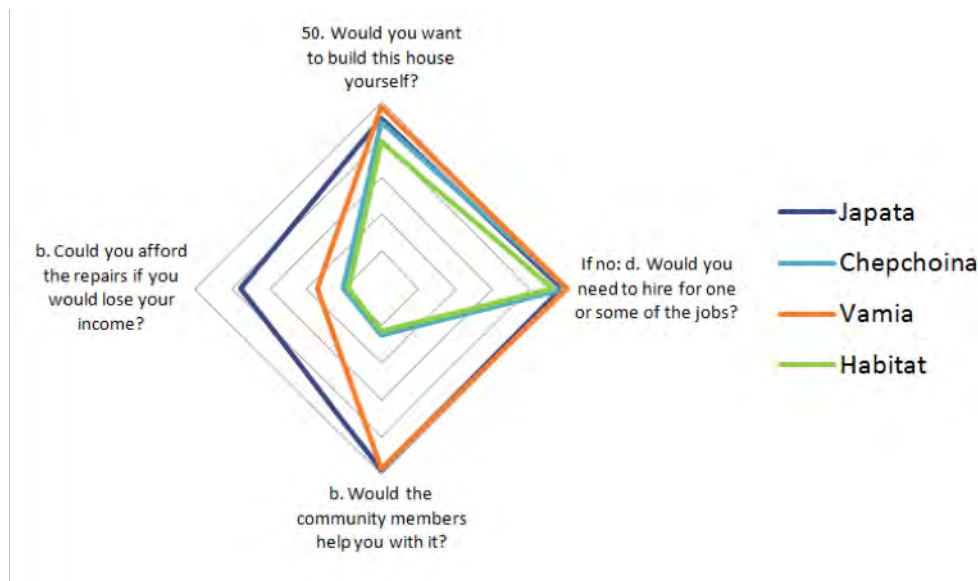


Figure 13 Self-build preference, community help and affordability

The willingness to learn how to build the desired house is very strong (Fig. 13) amongst all households: 95%-100%. Indicating that self-build practice is preferred. Although in some communities there are doubts if community members would be willing to help build a new house. However, almost all households are willing to help (95%-100%) a community member if they can learn how to build in return, indicating there is a strong willingness to learn by helping each other. What might be even more interesting is that again the vast majority of the households are willing to help constructing public building to learn how to build in an 'improved' way.

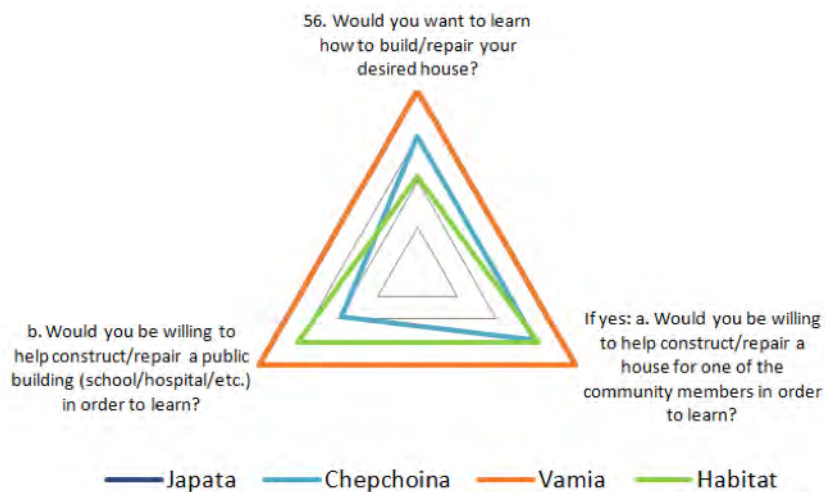


Figure 14 Repair preference house, help of community members and willingness build community infrastructure

## 5. Conclusion

This study proves that the majority of the interviewed households are living in challenging conditions. These living conditions are in most cases in mud-based houses often too small for the entire family. Although the households living in these conditions have an idea how desired housing, they lack the capacities to realize such housing. Landownership is an important restriction



for households in achieving better housing. The Japata community lives on government land and is not allowed to build an improved house. The Chepchoina community mainly rents and is therefore very vulnerable to changes in income. The Habitat community has severely restricted land rights and is not allowed to make any extensions/additions. The Vamia community has the most households owning their land and house. With an acceptable and stable income, it is unclear why they were not able to build desired housing.

The problem seems complex. However, it revolves around two elements: current capacities and the capacities needed to build the desired house. The majority of the interviewed households have more than sufficient capacities to build a house by themselves. This 'traditional' way of building is a shared practice within the family and the community. This practise suits all their capacities: local/natural/free materials, local/available tools, financial and skills. However, it is clear that almost all households prefer a different way of housing. Looking at what those preferences would require it is clear there is mismatch between what inhabitants have and what they want. The lack of locally available alternatives in typology, material and building methodology, limit the scope in which the households consider alternative options. Moreover, is their understanding of materials and skills limited on what possible harm they inflict.

Moreover, are possible alternatives difficult to articulate without a substantial knowledge base. This makes the formulation of a possible alternative 'desired' house by the inhabitants themselves difficult. However, integrating their current capacities into alternative solutions will play a vital role to its success and implementation. As shown in this study, considering alternative solutions that do not meet the inhabitants' capacities is simply not viable. The study proves that there is a high willingness to build by oneself, help each other and help to build community infrastructure. This sense of community could be fundamental in advising rural communities how they can improve their living environment without losing their self-reliance. In a consecutive article the methodology developed for analysing inhabitant capacities will be explained. Furthermore, it will show how these capacities can be used in what the author calls: capacity-based decision-making.

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## MAINSTREAMING *REAL* SUSTAINABILITY IN ARCHITECTURE

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### Summary

The popularity of sustainability has grown significantly in the last decade with new buildings, cars, furniture and other consumer goods all carefully wording their *sustainable* marketing approach to appeal to the consumer. The reality, however, is that most of these products tend to over-sell their commitment to sustainability in their relevant fields. In the built environment, for example, this is due to many interconnected problems: “a failure to take issues of sustainability seriously enough, incoherent ESD [Ecologically Sustainable Development] policy, the predominantly aesthetic agenda of architecture and the assumption that certain technologies in themselves will deliver sustainability.” (Willis, 2000). At EME Design, we believe that a shift in the approach and processes driving architecture and the built environment needs to occur in order to create sustainable and resilient buildings, communities, and cities.

Keywords: Passive House, sustainable, architecture, energy, comfort, resilience

## 1. Introduction

Why has 'sustainable' architecture become so popular in recent decades? And is it even understood completely? Unfortunately, most architecture firms use this as a marketing technique and *real* sustainability is not well understood by the general public. We are being lied to about what *real* sustainability is and people are led to accept less than optimal and bolt-on solutions that depend on high-performing and expensive technologies. As we will discuss later in this paper, we define *real* sustainability in architecture as; beautiful, educational, positively impacting (environmentally, energy, materials, etc.), comfortable and healthy, and with a multi-disciplinary approach to problem solving and design.

"Architecture is a very dangerous job. If a writer makes a bad book, eh, people don't read it. But if you make bad architecture, you impose ugliness on a place for a hundred years." (Luscombe, 2011). More relevant today, we would argue that "ugliness" in this quote be replaced with something along the lines of *if you make bad architecture, you impose an energy intensive and fragile built environment on a place for a hundred years*. Renzo Piano, one of the many *starchitects* with limited commitment to sustainability really puts things in perspective for us here. Architecture has become an issue in aesthetics rather than something that should be concerned with the wellbeing of people and the built and natural environment.

Architecture has become too reliant on technologies and consultants to achieve an acceptable level of indoor comfort in what would be considered a poorly performing building. Silos have been created between professions limiting the dialogue of process and exchange that result in an in-depth understanding from all involved professions.

Architects used to play King when creating buildings from their wildest dreams and imaginations. But with more complexities in the profession evolving, consultants such as engineers (and more recently ESD consultants) have been brought in to ensure the architect doesn't have to be an expert in every field. They handballed their responsibilities to other experts, and while this was a great move forward in developing multiple professions and specialties, it generated silos that segregated professions which made total understanding and deep collaboration redundant. While there are some professionals and practices that take a multi-disciplinary approach to building design and construction, the majority are still dependent on the expertise of others, without fully comprehending what is going on.

We believe that a fundamental shift needs to happen in the education system in order to produce holistically sustainable buildings in our ever-changing built environment. There needs to be more focus on multi-disciplinary approaches to improve understanding and the flow of knowledge through projects and systems.

EME Design's approach to sustainability is one that involves and educates the client, builders, contractors, neighbors and the wider community in the entire process. This is what we call the Elastic Loop Process of the project which aims to ensure a more informed and holistically sustainable approach. Rather than a bolt-on, fake 'sustainable' building, the Elastic Loop generates results which create large energy and waste reductions and savings, as well as improved year-round comfort, and air quality - all while not sacrificing beauty. The Elastic Loop Process is by nature one that is more permeable and open to accepting positive influence. It is founded on a process which depends on dialogue and exchange of knowledge and learnings. The process embraces the challenge of harmonizing the pragmatic fundamentals (the physics of super-efficient buildings) with the poetics of space and light. It is interested in real outcomes and involves detailed post occupancy analysis to ensure the reality is measured against the rhetoric (something sadly missing in most architecture today, for a reason). Shifting the profession and industry will require a multi-faceted approach starting with universities, government and professional bodies.

## **2. Elastic Loop Process**

Since 2000 the Elastic Loop process has been developed and adapted by EME Design. It consists of three main phases which allow a project to continually evolve and adapt over time to improve the overall benefits and gains. The process, by its nature, ensures that the system and approach continuously evolve and improve.

### **2.1. Exploration/Gathering**

This first phase (like all other phases) can be revisited and re-viewed multiple times throughout the elastic loop process. It involves clients and other parties to engage in the process of gathering information to understand the local and broader context. This initial phase is very much focused on self-education where all parties become educated to shift their focus (and thus the project brief) into a holistic and sustainable approach. It is about mapping the potentials (energy, materials, climate, movement, beauty, etc.) to see how they can be exploited and (potentially) quadrupled in the manifestation phase (Roggema, 2009).

### **2.2. Harmonizing/Aesthetic**

The information collected from the exploration/gathering phase then informs decisions made in the harmonizing/aesthetic phase to “form an “armature”, the backbone of the design response. This is tested and must be found to have stability when challenged.” (Middleton, 2009). The client’s perceived norms are challenged in this phase as the design progresses through the problem-solving period.

### **2.3. Manifestation**

This phase brings in people from other fields – builders, tradespeople, to create a dialogue between clients, contractors, science, media, etc. This results in the final project, but previous stages can be constantly re-visited to evolve and improve the final and future manifestations.

### **2.4. Post-Manifestation**

After the physical manifestation of the project is completed, the Elastic Loop Process does not stop. Projects with a complete Elastic Loop approach are then monitored post-occupancy to ensure the building project is performing as expected or exceeding expectations. This collected data then allows future projects to share the obtained knowledge to continually improve and evolve building techniques, processes and outcomes.

## **3. Elastic Loop Process and Passive House**

As our process and experience at EME Design has developed and improved over time, just like our approach to building projects, we have moved towards the Passive House approach. The Passive House approach was developed in Germany and is a voluntary method of certification which results in an extremely energy efficient home (or building) with high quality indoor air, improved health and year-round comfort (Passipedia, 2018). Its five basic principles to achieve this are (figure 1);

2. Thermal Insulation
3. High Performance Windows and Doors
4. Mechanical Ventilation with Heat Recovery
5. Airtightness
6. Thermal Bridge-Free Design



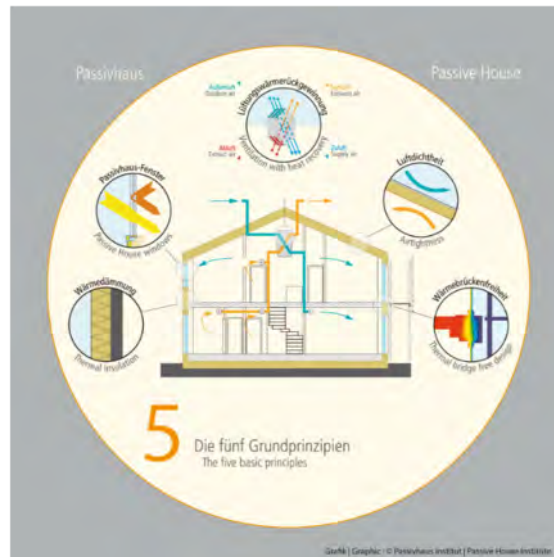


Figure 1 The 5 Basic Principles of Passivhaus (Passive House Institute), <<https://passipedia.org/basics>>.

## 4. Key Principles of an Elastic Loop Process

### 4.1. Comfort

When people talk about a Passive House, the first thing that comes to mind is the energy efficiency. But there is so much more to a Passive House than this. They are extremely comfortable to live in with a radiation temperature asymmetry less than 5°C. This means that two internal surfaces will never have a temperature difference of more than 5°C in a Passive House which vastly improves the internal comfort levels. Draughts from glass surfaces do not occur as they do in most conventional homes, so no cold spots are created. Overheating occurs less frequently, too (maximum allowed for a certified Passive House is 10% of the time annually, but most are much less than this), reducing the need for air conditioning. Internal temperatures of Passive Houses have a very low diurnal range and are required to stay within 20°C - 25°C for increased comfort year-round.

The controlled stable temperature is only achieved with a rigorous approach which challenges the typical methods of design and construction. It results in an airtight building that removes uncomfortable draughts and while still providing constant filtered fresh air through the Mechanical Heat Recovery Ventilation unit at a controlled rate and temperature. With this improved quality of indoor air and thermal comfort, the health of the occupants is also significantly improved.

### 4.2. Health

Most typical constructions are prone to mold growth and unhealthy air quality due to high levels of VOC's (volatile organic compounds) and carbon dioxide from poor ventilation and badly designed building materials, furniture, and even toys (to name a few of the culprits!). Think about lead paint in homes or asbestos. How many years were we constructing with these materials until we realized they were bad for us? And how many homes around the world are still occupied by these toxins? Too many to count. Passive House, on the other hand, is a scientific approach which focuses on the health of the occupants and removes harmful toxins from the built environment – a focus where too many *sustainable* certification systems fall short.

### 4.3. Post-Occupancy Monitoring

While the Passive House Institute does not require building monitoring to be conducted, we believe that it is an extremely important part of learning that contributes to the Elastic Loop process. From real data, we are able to analyze and compare predicted results of a building's performance with real results. We are able to use this gained knowledge on future projects and to expand and improve on systems and approaches. The post-occupancy monitoring works like an open source for people wanting to understand more about Passive Houses and their efficiency. It works as an educational tool that is continually growing and developing over time.

## 5. Passive House Case Study #1 – Passive Butterfly

The Passive Butterfly (figure 2, figure 3) is a heritage renovation project that holistically upgrades a cold and draughty home into a 21st century sustainable and comfortable home. Passive House principles were applied to create an exemplary home that exceeds minimum building standards worldwide. Pioneering projects such as this don't eventuate without complete passion and collaboration from all parties. We were lucky to have an enlightened and educated client whose vision of a healthy and carbon positive world perfectly aligned with EME's ambitions. The client was also the perfect example of an actively engaged client involved in the process of dialogue and exchange enabling greater understanding and knowledge sharing between all.

The Elastic Loop process of the Passive Butterfly continues even today with the client actively involved with the Passive House Institution, and other sustainable organizations such as the ATA – Alternative Technology Association. Multiple papers and studies have been conducted on the performance of the Passive Butterfly (see figure 4, 5 & 6), and all this information is openly shared as a resource to learn from.



*Figure 2 South-facing elevation of Passive Butterfly. Photography by Amorfo.*



*Figure 3 Rammed earth walls at Passive Butterfly. Photography by Amorfo.*

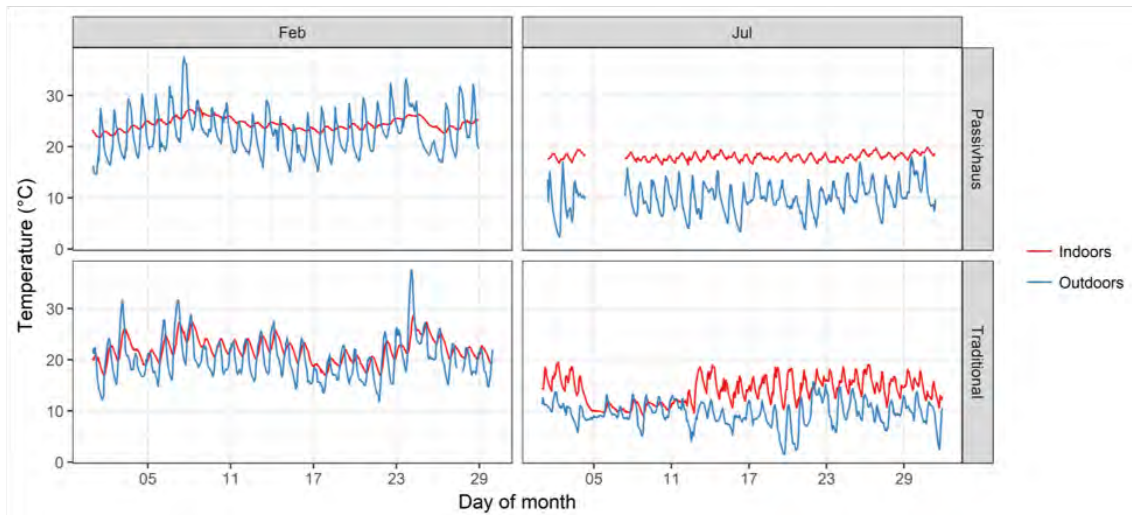


Figure 4 Comparative temperature performance between Passive Butterfly (Passivhaus) and a typical Australian home (Traditional)

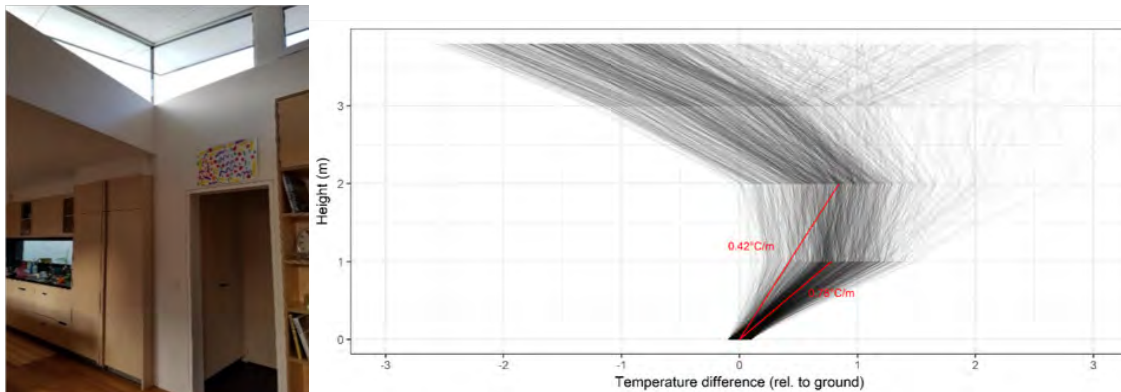


Figure 5 Temperature stratification: Living room. Line of measurement shown in red on photograph.

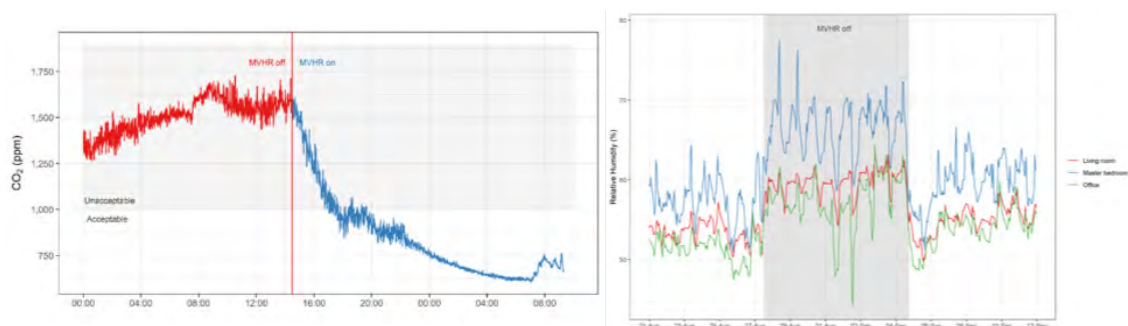


Figure 6 CO2 and Relative Humidity Data from Passive Butterfly. Showing how the humidity increases significantly when Mechanical Ventilation Heat Recovery unit is switched off.

The above diagrams indicate performance testing conducted at the Passive Butterfly post-occupancy. Figure 7 shows how the CO2 levels and relative humidity are controlled and stabilized through the Mechanical Ventilation Heat Recovery unit. As soon as the unit is switched off, CO2 and relative humidity rise to levels that are uncomfortable and unhealthy to live in causing mold growth as well as increasing the risk of asthma. Once the unit is switched back on, a low volume

of filtered fresh air is brought in to constantly provide 100% fresh air and healthy levels of CO<sub>2</sub> and relative humidity.

## 6. Passive Hybrid Case Study #2 – The ‘MM-House’

This home was designed a hybrid, following both Australian passive solar design together with Passive House design principles (figure 9). It was pressure tested during construction achieving 0.6 ACH (\*), and is currently being monitored for comfort, performance, air quality. The home is a testing bed for other embedded design systems that EME have experimented previously. This project will be part of an on-going education and dissemination program actively pursued by EME.



Figure 7 MM House



Figure 8 MM House

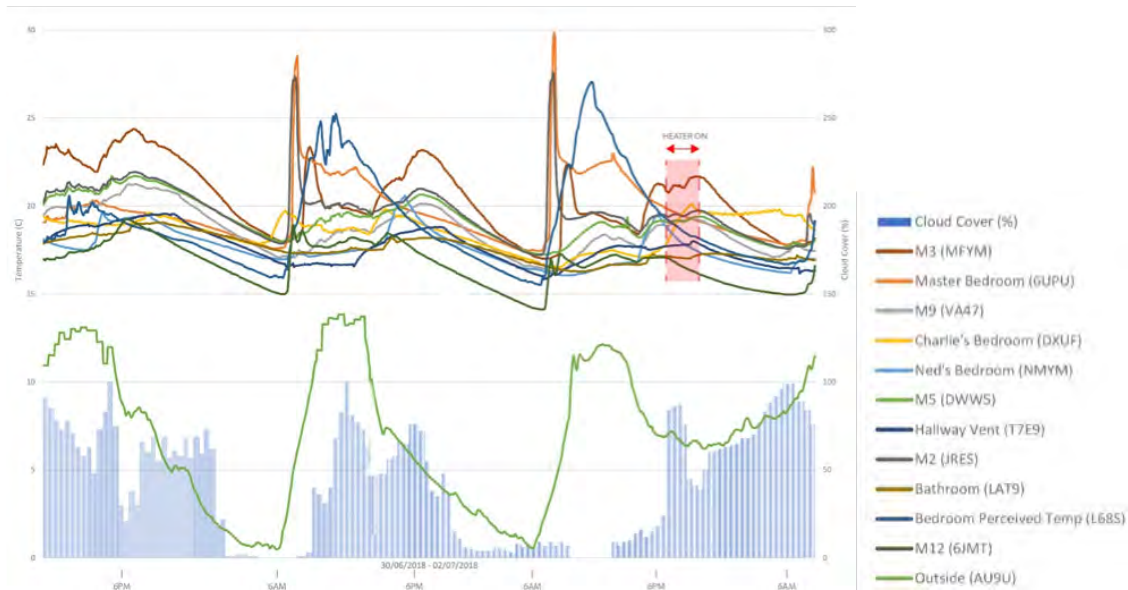


Figure 9 MM House temperature monitoring. Minimal supplementary heating 3 hrs x 4Kw = 12kw over 3 days with very low ambient temperatures

This temperature monitoring graph of MM House shows a comfortable internal diurnal range, while external temperatures range 0.6 - 13°C.



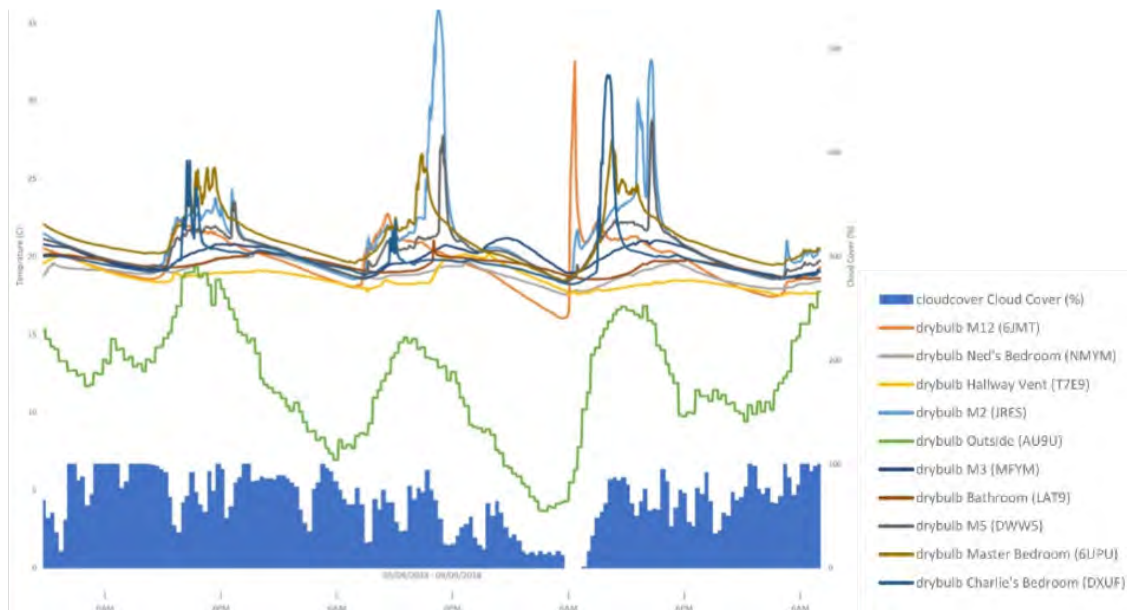


Figure 10 MM House temperature monitoring (no heating)

Spikes in the internal temperature in the above graph are due to direct solar heat gain. This was a deliberate strategy to better monitor the direct solar gain on thermal mass.

## 7. Exponential Energy Saved

The Passive Butterfly, being the first Passive House project we embarked on, is the beginning of a new Elastic Loop period where new clients will be educated on the positive change they can make with a Passive House standard home. Two of our most recent projects – Passive Butterfly and MM House were both designed and built with passive house principles in mind. They're prototypes for us to learn from, and with continual performance monitoring, we're able to share with others how that knowledge approach and process can produce a building that is holistically sustainable (see table 1).

Table 1 Energy Saved

PROJECT	YEAR	ENERGY GENERATED	ENERGY CONSUMED	EXTRA ENERGY	ENERGY CONSUMPTION PER M2
Passive Butterfly (143m2)	2017	7,855	3,947	3,908	27.6
MM House (197m2)	2017	7,785	4,485	3,300	22.7

\*energy is shown in kWh/year

\*Average electricity consumption = 5,730 kWh/year

Based on 15.7 kWh/household/day average (Ausgrid, 2018)

## 8. Positive Changes

Steps have been taken gradually to improve policies and building standards both Australia-wide and internationally. The minimum green star rating, for example, was introduced in 2005 to require a minimum of 5 green stars for residential projects. The problem with this process, however, is that it looks at the "designed" "theoretical performance, rather than the performance during occupancy. The other concern with this system is there is limited understanding on how



the calculations are made and what assumptions are made in terms of comfort levels (i.e. the tolerance internal temperature).

Other government initiatives, such as the Zero Net Carbon homes, for example, are happening not just in Victoria, but all-around Australia. The Zero Net Carbon homes initiative's objectives are to improve the supply of Zero Net Carbon homes, increase the consumer demand for Zero Net Carbon homes and pilot As-built Verification (ABV) methodologies, standards and skills development through a collaborative approach with industry (Sustainability Victoria, 2018).

While these initiatives are great, and more of these need to be executed, there still needs to be a greater shift in architectural education and approach to prevent aesthetic-obsessed buildings that depend on expensive bolt-on 'sustainable' solutions. No more sustainability as minimum standard imposed on BAU design solutions – a quantum shift in the benchmarks and the approach to design.

## **9. What still needs to be done**

### **9.1. Education**

The core issue is education. We need to engage others in the understanding and critical engagement of what *real* sustainability is and what a viable solution is (and isn't). There is a real issue in understanding and explaining to people working in industries outside of the built environment what a *real* sustainable building is. Unfortunately, big name architectural firms with the most media coverage are where they're getting the message from. This message is typically a non-holistic and bolted-on approach to sustainability that results in poor building performance, comfort and lifecycle. Butera (2005) sums up wonderfully how the built environment lies to us about *sustainable* buildings "Ferraris are beautiful cars, a perfect balance between advanced technology and beauty; but never they have been sold as ecological cars. The same should apply to fully glazed buildings: some of them are outstanding for beauty and for technological innovation; they are the Ferraris of modern architecture. But please, do not sell them as sustainable buildings."

### **9.2. Image**

This point goes hand-in-hand with 10.1 Education as it focuses on developing a *real* representation of what sustainable architecture is. The marketed image of a beautiful million-dollar home in the middle of a forest is not sustainable just because it's situated in a natural environment. And a glazed office tower is definitely not sustainable just because it has solar panels on its roof and uses rainwater for flushing the toilets.

In fact, "Anyone can build a net zero house by slapping enough solar panels on the roof; it can still be drafty, have too much glass, inappropriate orientation, ineffective shading and in efficient planning. Alternatively, anyone can build a sort of comfortable house by throwing enough radiant flooring and ground source heat pump air conditioning and other high tech gizmo green at it. [...] comfort can also be achieved simply by design" (Alter, 2014).

Another issue related to image is that *real* sustainability has also not yet reached a level of market appeal to attract the masses. It's *cool* to be *sustainable*, but as it's not understood from a holistic perspective, this '*cool sustainability*' is typically a bolt-on solution like putting solar panels on your roof and claiming you're now living a sustainable life.

### **9.3. Cost**

There is also a misconception about the price of sustainability. People believe it comes at a cost that outweighs the benefits substantially. Typically, when using a bolt-on sustainability approach

where everything is an afterthought, this might be the case. But when an approach like the Elastic Loop Process is utilized from the beginning of the project, overall lifecycle and running costs are significantly reduced. We also believe that the benefits of truly sustainable architecture can never be reduced to a price tag. How can you possibly put a price on comfortable, healthy, energy efficient and beautiful buildings? Especially when they're creating a positive impact and significantly reducing our footprint.

#### **9.4. Approach**

As discussed earlier, we believe that following the principles of the Elastic Loop process both enable and ensure that a shift in focus towards a resilient and sustainable built environment occurs. The Elastic Loop process, by its nature, is focused on education and knowledge sharing to create systems of positive feedback loops.

#### **9.5. Policies**

While we have seen positive steps taken towards incremental improvement in building performance, there is still so much more we can do to challenge the minimum requirements. Another problem is that these rating systems are also based on designed/theoretical, not the as-built performance.

The Passive House certification standard, for example, is completely voluntary, but we have seen a positive growth in popularity it has had in the last decade – especially in Australasia. Improvement in mandatory requirements are resisted by powerful interest groups thereby hampering dynamic and substantive policy change. We would like to see professionals as the leaders of change. Leading by example, setting new standards of architecture that are rigorously tested. The rhetoric has gone unquestioned too long.

We believe that it is vital that public and high-profile projects and projects that are published should be tested to ensure that the right message, knowledge and lessons are being communicated. After-all these are the projects that are effectively being held up as exemplars in their field, and more likely to be referenced by others, both professional and general public.

We feel industry professionals have an ethical responsibility to ensure they are communicating a genuine message. Implementing rules and regulations to ensure that the real-life outcomes of these high-profile projects, that gain more attention in the public eye, will have an exponential effect on lifting public knowledge and awareness. These regulations will also highlight the benefits of projects with holistically sustainable approaches (rather than bolt-on solutions) and will also increase understanding and awareness of what is sustainable and what isn't.

To combat the issue of *fake* sustainability or untested sustainable rhetoric, we suggest auditing of built projects to check their sustainability to compare the claims and the actual operation. All high profile projects will be obligated to publish the real results during their operation. This will measure will motivate positive change simultaneously at many levels. Genuinely sustainable projects will clearly shine above ones that have a superficial sustainable approach. The general public and industry peers will enjoy the benefit of better understanding what designs have real sustainability embedded in their design process. Developers and governments will be accountable for all the outcomes of their high profile projects. The implementation of these measure will prevent design professionals from making misleading statements, thereby, motivating them to really practice what they preach.

High profile projects to be audited would include;

1. Public projects (government, etc.)
2. High profile award-winning projects
3. Real sustainable projects

4. Projects published in mainstream and industry publications.

We suggest the following new policy to be implemented;

1. All projects that fall within the criteria listed above would be required to be rigorously tested with details post-occupancy audits. All results of the audit must be published widely and extensively (to the same level as the publicity gained by the project prior to comprehensive testing). The publication of the results will be accompanied with a plain English commentary to ensure the interpretation of the results can be understood by the wider public as well as industry professionals.
2. A register of these high profile projects will provide historic bench-marking to enable comparisons to easily be made. .

## **10. Real Sustainability**

So what is this talk of *real* sustainability, and what does it all mean? For us, we define *real* sustainability by the following criteria (in no particular order);

### **10.1. Beautify and delight**

Real sustainability gives beauty and brings delight. If a building is not beautiful, it will not be appreciated and there will be no desire to build it (or, much less desire than other aesthetic-driven architecture). As aesthetics is what preoccupies people most (typically) about architecture, we need to ensure that sustainable solutions are still beautiful ones – if not more beautiful than non-sustainable solutions.

### **10.2. Educational**

Once education is re-calibrated to portray *real* sustainability to the general public, and through the teaching of architecture (and all other involved professions), only then can the image of sustainability and its benefits be properly represented and understood.

Performance monitoring of built projects will also allow real data results to be shared and used as an educational resource and tool. It can also weed out those projects that claim to be sustainable but do not live up to the claim.

### **10.3. Positive impact**

This goes hand-in-hand with the core of sustainability. It is about making a positive impact on the environment by reducing energy consumption (or even better, making an energy contribution), using sustainable, recyclable and reusable materials, and being a generator for positive change.

### **10.4. Multi-disciplinary approach**

The Elastic Loop process is all about learning and sharing knowledge between disciplines to achieve a holistically sustainable project.

### **10.5. Comfortable and Healthy and resilient**

Comfort and health are key. A sustainable building provides both – with almost no inputs from bolt on technical/mechanical devices. A building that is robust and efficient at its core – providing shelter, comfort and a healthy environment to its occupants.

## 11. Conclusion

In our rapidly progressing society where a focus on sustainable solutions is key, new approaches to architecture are crucial in order to improve our built environments and reduce our footprints. Following the typical business as usual approach is not going to cut it anymore and a holistic approach such as the Elastic Loop is well needed to attack multi-disciplinary issues. Architecture can no longer only focus on the aesthetics, but instead needs to create a positive outcome and take a stance that focuses on sustaining our environment. "The requirement for architecture to contribute to social and environmental sustainability now charges architects with responsibilities that go beyond the limits of an autonomous brief." (Butera, 2005). Our approach to sustainable architecture and communities relies on a significant shift in the way all professions, stakeholders, governments, and private developments undertake their processes. Only through the process of critical engagement and re-assessment of our typical approach to design and procurement, will we be able to achieve a quantum shift to rapidly improve our built environment's resilience.

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# GREEN BUILDINGS IN AUSTRALIA: EXPLAINING THE DIFFERENCE OF DRIVERS IN COMMERCIAL AND RESIDENTIAL SECTOR

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## Summary

Green Building (GB) projects can positively affect society, economy and the environment. They are being adopted by different sectors of the building industry including the office and residential sectors. As each building sector has a unique development environment, GBs in each sector are developed with particular drivers. Understanding the different drivers of GB development and the differences across sectors of building industry and the reasons for those differences should give greater insight into how GB development might be promoted.

An investigation of the GB development related drivers is conducted in Australian context with a focus on commercial-office and residential sectors. Interviews are conducted with Australia-based GB experts. These interviews are qualitatively analysed and explained. Overall, experts agreed that the commercial-office sector is highly driven towards GB development, while the residential sector lags behind in this regard. Some prominent GB drivers in case of commercial-office sector in Australia are found to be the high commercial value and marketability of these office spaces, regulatory requirements imposed by local authorities, health and well-being, energy efficiency, and the organizational Corporate Social Responsibility (CSR). In residential sector, the main drivers are the sustainability awareness of the client and energy efficiency. Along with the drivers, the paper also presents the attributes of development environment in each sector, which are the core reasons for difference of GB development across the two sectors. These attributes discussed in this paper include the regional context, business case of GB development, risk driven motivations, ownership structure, as well as organizational and individualistic thinking.

The understanding of GB development-related drivers across residential and commercial sector can provide support to the policy frameworks involving these sectors. In the paper, only a comparison of residential and commercial-office sector is provided. Future research should also provide comparison across additional sectors of building industry, for instance retail, health care, hospitality, and educational sector.

**Keywords:** Development environment, Green Building, drivers, commercial-office, residential sector



## **1. Introduction**

Different sectors of the building industry have unique project development environments. These development environments involve different stakeholders, stakeholder relationships and project expectations. The knowledge of the development environment of a building sector can be critical when different sectors are being compared. Such understanding can also help rationalize the difference in GB development across different sectors.

Sustainability is currently an important aspect of the building industry and a research relating the drivers for Green Building development can significantly contribute to our understanding of factors which strongly influence GB development. While acknowledging the value of GB driver-related research for understanding of sustainable development, it is important to note that the research on this topic needs to thoroughly explore the difference in drivers resulting from the respective development environments of different building sectors. Investigating development environment is particularly important as drivers for achieving a goal are highly dependent on the context in which the goal is being achieved.

The residential and commercial-office sector are significant and should be compared. The importance of considering these sectors is that they respond to the two important routine matters of an inhabitant (i.e. living and working) and both these sectors have a significant environmental footprint. For instance, in Australia where the 94% of energy is generated from non-renewables, the residential sector accounted for 7.5%, while the commercial sector accounted for 5.6% of Australia's energy use in 2015–16 (Ball et al., 2017). Both these sectors have significantly different development environments, and while the office sector in Australia has significantly embraced sustainability, the residential sector significantly lags behind. An inquiry in this regard can have a significant role in theory and practice related to GB development. The inquiry presented in the paper highlights the drivers which contribute towards sustainability in these sectors. Further, this inquiry draws a comparison of the development environment of individual sectors, the intrinsic differences within their environment, and the drivers which suit the environment of each individual sector.

The aim of this paper is to investigate the underlying reasons for a difference in Green Building drive in the residential and commercial-office sectors in Australia.

## **2. Literature Review**

Research has previously been conducted to discuss the drivers of GB development in Australia, at different levels of detail. Some prominent insights in this regard are by Wilson and Tagaza (2006) who discussed financial risks, construction risks, and regulatory environment in terms of GB-related drivers and barriers; and Li Ang and Wilkinson (2008), who investigated the role of social agenda in driving sustainable development of real estate in Melbourne, Australia. In another study by Bond (2011), a household survey was conducted to identify householders' lifestyle choices influencing energy use in homes and the people's motivation to conserve energy.

While the mentioned studies contribute to understanding factors which drive GB development in the commercial and residential sectors in Australia, no previous study provided a comparison of the GB development in residential and commercial sector. Furthermore, the previous studies within Australian context are also limited in terms of investigating the attributes of development environment, which can affect GB development.

## **3. Methods**

This paper reports some of the findings of semi-structured interviews conducted with GB experts in Australia. While interviews in Melbourne were conducted in-person, the interviews in other cities of Australia were conducted over the phone. The interview participants included design

consultants, sustainability consultants, project managers, and developers. The interviews included a key question, i.e. *‘What are the differences of GB development in Australia across the residential and commercial-office sectors?’* This paper reports the findings from 14 interviews. Some of the research findings relating the difference in a household’s and an organization’s decision-making for GBs are explained using the constructivist research paradigm.

The interview data is categorically classified as prevalent drivers of GB development, and development environment attributes which result in a difference of GB drive across the residential and commercial sectors. It is recognized that even within the commercial sector, the office and retail projects have different GB drivers. Keeping this in consideration, this paper only reports the findings relating office projects in the commercial sector and the term ‘commercial’ is exclusively used for commercial-office projects.

The results section first presents the views of interview participants relating the development status of GB projects in residential and commercial sector. Subsequently, the drivers related to GB development are explained. Afterwards, the development environment attributes resulting in a difference of GB development across the two sectors are explained. Following the results section, the discussion section explains the interrelationships among different development environment attributes and different drivers of GB development.

## **4. Results**

In general, it is agreed that in Australia, the GB development is highly focussed towards the commercial sector and residential projects have received relatively much less attention in this regard. As an interview participant (Int-13) said, *“residential sector as compared to commercial sector has taken longer to embrace sustainability.”* The lack of GB development in the residential sector is owing to the lack of demand in this sector and the developers’ perception of low demand. As an interview participant (Int-6) put it, *“from residential clients there is almost a non-existent request to develop sustainably.”* While addressing this issue another interviewee (Int-11) stated, *“in the Australian residential sector, it is hard to identify the drivers which lead to Green Building development. There are some occasional residential projects which opt for sustainability, but overall the residential sector seriously lags behind the other sectors when it comes to sustainability. Although in Australia, there seems to be people who want to live in eco-efficient homes, the developers don’t seem to listen to them and argue that there is no market demand for sustainable homes.”*

As compared to residential sector, the commercial-office sector has aptly embraced the GB development practices, as according to an interview participant (Int-12), *“sustainability is not a novelty anymore for the commercial market [in Australia]. If your project is not sustainable anymore, then its regarded as more uncommon these days.”*

### **4.1. Drivers of Green Building development**

Some prominent drivers of GB development in the office sector include marketability, high commercial value, better working environment, energy efficiency, and regulatory requirements. Further, many business organizations need to occupy GBs, as it is part of their Corporate Social Responsibility (CSR). In general, CSR means that the corporations take responsibility of the social implications of their activities. While reflecting on this, an interview participant (Int-10) stated, *“marketing is the key factor when it comes to commercial-office buildings. The top tier buildings go for certifications with the green rating tools.”*

While the regulatory requirements may also apply in the residential sector, in most cases these are minimal and do not act as a driver. The drivers prevalent in case of GB development in residential sector include the sustainability awareness of the owner, and energy efficiency. While stating client’s awareness of sustainability as a driver, a participant (Int-3) stated, *“in case of*

*Queensland, the drivers for sustainability in residential buildings are basically from the clients who understand the benefits of sustainable development. There are minimal compliance requirements for sustainability in residential buildings in the region.”* Energy savings is also recognized by residential clients as a benefit of sustainability, as an interviewee (Int-8) stated, *“in residential buildings, people are mostly driven towards sustainability to help realize better living environment and savings from energy efficiency.”* According to another interviewee (Int-6), *“for the clients of residential projects, energy is the major consideration. They want to get the value for their money.”*

#### **4.2. Development environment attributes contributing to variations in GB development**

Attributes related to the development environment contribute to a lag of GB development in residential sector as compared to the commercial sector, are discussed in this section. These attributes are often the regional priorities, business case of projects, stakeholders’ ownership of projects, and difference of individualistic and organizational thinking.

##### **Regional context**

In Australia, the building efficiency and sustainability requirements are governed by two separate regulatory systems as discussed by some interview participants (Int-13; Int-8; Int-9). Nationally, the building code of Australia imposes some requirements. In parallel the local councils impose special planning requirements for building projects within their regional jurisdictions. While there are plans for significant efficiency-related updates in the national building code in 2019, the national building codes lag behind the planning requirements which the inner city councils in Australian metropolitans have enforced. A project merely meeting the national building codes, cannot qualify as a GB. Planning requirements for the local councils however, vary significantly. While some inner city councils in Australian metropolitans have strongly embraced GB development in their regulations, the other councils have not considered sustainability in much details. According to an interviewee (Int-7), *“primarily, the drive for sustainability in commercial buildings is for town planning requirements. If the building size is greater than 5,000 m<sup>2</sup> then the Melbourne City Council requires an informal Green Star rating for the project. Although, this consideration varies from council to council, Melbourne City Council has the majority of office buildings in the region so many office projects are bound to follow the sustainability regulations. Other than this, the clients also require sustainability in their projects for marketing reasons. However, the predominant driver is from the town planning requirements.”*

Since a significant number of commercial-office buildings lies within the jurisdictions of inner city suburbs and a majority of residential development is within the jurisdictions of outer city suburbs, a difference can be observed in the GB development-related regulatory focus towards residential and commercial sector. According to an interviewee (Int-5), *“often the developments in countries [including Australia] are such that the commercial buildings are located in the city centres where the governments have much stronger control and have more ability to influence development. Residential sector on the other hand is spread out and often placed in different suburbs, therefore requiring more work from a government to be regulated in terms of sustainable development.”*

Hence, a major reason for the variations in GB development across residential and commercial sector in Australia, is the non-uniformity of regulatory requirements across different regions. This is due to the geographical differences in the building stock, i.e. the commercial buildings majorly lying in the inner city and the residential buildings majorly lying in the suburbs.

##### **Business case of Green Building development**

The building industry is highly driven by decision-making frameworks in which economic benefits are often a high priority. For a developer, the economic benefits are paramount as an interview participant (Int-1) pointed out, *“a developer is not much concerned about the climate change*

issues, etc. To him [her] what matters is that, whether developing a building as a Green Building would help him [her] sell it better.” In a project, sustainability considerations like any other aspect of the project, are subjected to cost benefit comparisons and are deemed feasible if the benefits are comparable with costs spent. As an interview participant (Int-1) pointed out, *“whether it is the residential or the commercial sector, the developer performs a cost benefit analysis before undertaking a Green Building project.”*

In the commercial sector, sustainability has become a widely accepted project attribute and is thought of as a ‘must have’ value in projects. Therefore, the sustainability aspect becomes a source of market competition for these projects. According to an interview participant (Int-13), *“green development has become an industry standard especially in the office sector. As a developer, you are interested in competitive development and sustainability is one of the areas to compete in.”* In case of commercial buildings, a higher demand for sustainability exists from the side of the occupants and they are willing to pay extra for these projects, which acts as an incentive. Commenting on this aspect, an interview participant (Int-6) said, *“there is a lot of evidence of the [high] value of green commercial buildings and the [high] amount a tenant would pay to lease it. Such an evidence that the occupiers pay more for a sustainable house, does not exist in case of the residential sector.”*

In the residential sector, however, the prevailing competition is to develop projects at low costs. Owing to the mutually contradicting relationship of capital cost with sustainability, the competition for lower costs restricts the introduction of sustainability initiatives. According to a participant (Int-8), *“.... the general trend of sustainable projects in Australia is quite bad. This is particularly so, in case of residential projects as in those it is all about saving the bottom dollar.”* According to another GB professional (Int-6), *“from a residential point of view, in developing a Green Building the developer thinks that, is there a benefit to the customer in doing so? It is very difficult for a developer to embed anything in the development in case it has no clear benefits for the customer and this is because of the already very high costs of construction in Australia.”* Regarding this issue another interviewee (Int-5) stated, *“..... in residential sector, sustainability initiatives impact the cost of dwellings. Due to these reasons there is reluctance in developing residential buildings as green buildings, particularly in the first home owner market. For the potential home owners, the challenge is to whether pay premium for a well-furnished kitchen and an extra bedroom, or to pay for the solar panels.”*

A product can only become competitive in a particular aspect in case the added value is appreciated among the customers (Anderson and Narus, 1998). In the commercial sector, sustainability is a value appreciated by tenants and owners, while affordability is a value appreciated by home owners in residential sector and consequently both these sectors compete in this regard. These findings can be compared with a Melbourne-based study (Li Ang and Wilkinson, 2008). Although some (3) respondents in the study were found to support Ecologically Sustainable Development (ESD) unconditionally without economic considerations, most (13) of the study participants in support of ESD stated that in case of a drop in profit margins on a project they would have to reconsider supporting ESD. These study findings highlight that beside some exceptions, in the majority of cases, the decision-making in projects is driven by economic considerations.

### **Risks related to non-GB development**

The business case of GB development is in-part driven by risk-related motivation. Since an office building incorporates sustainability features for attracting high profile tenants, the GB development can be considered as risk driven, as this helps the developer to avoid the risk of losing premium clients. In the residential sector, owing to lack of GB demand, a developer may not confront the risk of losing tenants or potential buyers. According to an interviewee (Int-4), *“the clients for green office buildings are the government agencies or private investors. The clients in case of these projects go for sustainability because they want to improve their assets’ value. They also do it for risk mitigation in terms of climate change. The people aware of it understand, that the tenants will pay more for a building which performs better. So, the key drivers for the sustainability in office*



*buildings are about risk and money.” According to another interviewee (Int-4), “once you start talking about legalities, risks etc. then people start to take notice and now that we have found a new language to talk with business people, people are beginning to understand that merely maintaining a building is not good enough, they have to step up and improve it and future proof it, so that they won’t be sued by future occupants for under-performance. Once the conversation is in that direction, the building owners are much more likely to understand and work on it.”*

Hence, in commercial-office building projects, GB developments are in-part driven by the developers who avoid the risk of losing good tenants, and by tenant clients who avoid the risk of low staff productivity and absenteeism. This is discussed by an interviewee (Int-14) stating, *“high-end clients want their staff to know that they are living in or using Green Star facilities.”* According to another interviewee (Int-9), *“... drivers [of green office buildings] are also the increased health and well-being of occupants and increased productivity.”*

Similar risks do not prevail in the residential sector, as a significant number of home owners may not relate GBs with health and well-being. According to an interview participant (Int-6), *“housing customers are much driven towards economic benefits of sustainable development rather than social benefits. They don’t tend to associate social aspects with sustainability. Health and well-being is not considered by customers as a part of sustainability.”*

### **Ownership structure**

The ownership structure of a building can have a significant contribution to the motivation for developing a GB. The difference in prevalent ownership structure of the two types of development is a significant reason for the difference in adoption of sustainability in residential and commercial sector. For the speculative project developments and the GBs being developed to be sold, the developers have little interest in sustainability. A difference in sustainability motivation can be seen in two sectors, as in many cases, developers sell the housing units, yet keep the ownership of office buildings once developed.

*“The commercial and residential projects have different types of clients. In commercial projects, the clients have different business reasons to get the formalized sustainability certifications in their projects. This can help them to charge better rents. It also matters in such projects, whether they are owner-occupied or they are developed to be sold. The developers who plan to sell the property, don’t care a lot about sustainability. They are likely to get the formal certification and move on. However, if the developer is someone who is also going to occupy the building, he will make sure that the commissioning and tuning are performed well and the operational energy performance is, as expected .... In case of the town house developments, the developers move on once the projects are completed, so they have little interest in sustainability.” (Int-7)*

*“A reason for the limited drive of residential sector towards sustainability as compared to the commercial sector is owing to the interest of the developer. In case of residential projects, the developer sells the property to the individual buyers, and resultantly the relationship of developer and the final user is for a very short term. However, in case of commercial buildings, the developer mostly owns the building and leases it to different tenants. In such a situation, the developer has an emphasis to reduce the costs of energy and water, as it is in his interest to do so. In commercial projects, as the developers are mostly owning the building and leasing it to tenants, it is in their interest that the value is continuously created for such projects through the benefits offered by sustainable development.” (Int-2)*

*“In case of residential projects, the developers who work on speculative projects are not genuinely interested in sustainability and they stick with the bare minimum requirements.” (Int-3)*



These interview findings corroborate with a Melbourne-based study (Li Ang and Wilkinson, 2008), which through a survey of property developers, revealed that incorporation of ESD was most probable for projects undertaken by owner-occupier clients, and was least probable in case of 'speculative projects'.

### **Individualistic and organizational approach towards sustainability**

There seems to be a difference of perception of the workplace and the living place in terms of environmental performance. According to an interview participant (Int-10), *"there is not a close correlation between working in a green building and living in a green building. While one may think that someone working in a green office, would end up buying a green home, it may be true for a small percentage, but not a reliable assumption. Our concepts of work and living are quite different."*

A client's wilfulness for sustainability in commercial and residential context can be explained by constructivist research paradigm. In short, constructivism is a theory about how people learn. It says that by experiencing things and reflecting on those experiences, people construct their own understanding and knowledge of the world (Bereiter, 1994). This theoretical paradigm explains the change in aspirations and wilfulness for sustainability as the role of a person changes from a corporate to a residential household. Both the home and office have a significantly different socio-cultural context and accordingly the person learning from a particular context acts differently.

One of the reasons for an organization to partake in sustainability initiatives more than an individual, can be the accountability for actions. As far as the accountability of the environment-related actions is concerned, organizations may be more exposed to it than individuals. As an interviewee (Int-5) stated, *".... the people occupying these [green office] buildings also have a corporate responsibility and sustainability policy. If the company is ASX listed, it has to report for sustainability every year. So the ball has been rolling for a long time, and the commercial-office building market is quite mature in Australia, though not much in Western Australia."*

At the organizational level, sustainability can become part of the corporate social responsibility therefore motivating business firms to either develop, own, or lease GB projects. This leads to a high commercial value for GB office projects and therefore, even in the absence of government regulations there is still sufficient motivation for development of such projects. Therefore, business aspirations lead to commercial demand, which consequently leads to development of GB offices. Contrary to this, the ownership of a house is an individual choice rather than an organizational decision, which means that even though someone is aware of the need of sustainability, s/he may decide to opt for non-sustainable alternatives. As an interview participant (Int-10) reflected on this aspect, *"the commercial sector is more evidence driven to certify buildings with popular Green rating tools, while the residential sector is more lifestyle driven."*

In an organizational and a person's approach towards GB development, awareness for sustainable development plays a very important role. As an interviewee (Int-13) mentioned, *"in office projects, the tenants over the years have become more sophisticated in their understanding of sustainability. They understand what sustainability means to their staff, and what it means to the operations of the building and the ongoing costs."*

The standard way of GB development prevalent in commercial sector, is majorly driven by unified organizational thinking, for instance within the developing, owning and leasing client organizations. Resulting from organizational thinking and understanding of sustainability, CSR policies are formulated which eventually lead to development, occupation and operation of the buildings in sustainable ways. While the clients in commercial sector have adopted standard approaches of perceiving sustainability, it is not the same case for residential projects. Relating this, a design consultant (Int-4) mentioned in the interview, *"most of the clients who come to us for developing sustainable residential buildings, want their buildings to perform well. They want buildings which touch the ground lightly. These clients are well-educated and have a different*

*understanding of the sustainability word. Since sustainability can be a very broad area, so for each client we go through the process of ascertaining what the sustainability means to them and what are the key elements they want. In this way, there is a back and forth process involved in which we educate each other.”*

This points to the fact that commercial-office developments have standardized GB development, which is not the same case for residential projects. While green office buildings are inclined to get green certifications, owners of green residential buildings do not acknowledge the need for these certifications.

## 5. Discussion

Different factors resulting in varying levels of GB development in residential and commercial sector are well connected (as shown in Fig. 1). Further, these factors also explain the drivers for GB development in the two sectors.



*Figure 1 The interrelationships among the GB drivers and reasons of differences in GB development*

Overall it can be stated that as a result of non-uniform regulations across different regions in Australia, regulatory requirements for commercial-office sector are stringent as compared to residential sector. Some aspects need to be collectively considered for understanding the difference of GB development among commercial and residential sector. First, individuals as compared to groups (i.e. organizations) think and act differently, which is also realized in a study by Kugler et al. (2012). Secondly, residential buildings have a different ownership structure than office buildings, as houses are owned by individuals while office buildings are mostly owned by developers and leased by business organizations. As organizations think differently than individuals, they decide to own or rent workplaces which support their CSR, and result in higher productivity and well-being of their employees. Once the demand for GBs is established, this results in a better business case for GB office development. These findings are also corroborated by a study (Eichholtz et al., 2010) stating that there are both the economically tangible and intangible benefits related to certified commercial GBs.

It can be stated that majority of key stakeholders are directly benefitted from development and operation of a Green office building. The occupants are more productive, and feel better in a GB; the business organization can fulfil its CSR and avoid the risk of high utility bills, low performing staff, and high staff absenteeism; and the developer in case owning the building, is paid higher rents. Once, the high market demand for commercial GBs is coupled with high regulatory requirements, the development of such projects becomes unavoidable.

However, in the residential sector, the focus of a typical house buyer is towards amenities. While an individual may like to have sustainable features in the building, s/he does not appreciate the house being unaffordable. As the sustainable features relate with higher initial investment, a typical house buyer prefers affordability over sustainability. Since an individual and not an organization, is the decision-maker in buying a house, the individual's personal choices prevail. Consequently, the business case for a green residential building becomes unfeasible for majority

cases and the developer avoids partaking in such projects. Once the low market demand for residential GBs is coupled with low regulatory requirements, the development of such projects is seriously impeded. These findings are partially corroborated by a study (Pinkse and Dommisse, 2009), which discussed that in the residential sector, the principle-agent problem prevails to some extent. This is because the energy efficiency benefits of a GB development are for the end-user and not the home builder.

## 6. Conclusion and Recommendations

This paper is part of a study aiming to develop a framework of factors affecting sustainability performance in GBs. The paper highlights the importance of development environment attributes in understanding the drivers of GB projects across different sectors. By using the development environment attributes in explaining the difference of GB development across residential and commercial sector in Australia, this paper establishes the importance of context specific research for GB projects. Particularly, it highlights that the previous research studies relating GB drivers in particular regions, are limited in terms of rigour, because not only the GB drivers vary across different regions, they also vary across different sectors of the building industry. An important contribution of this paper for practice is that it demonstrates the need of context specific initiatives to enable a trend of GB development.

This paper has established the differences in drivers among the residential and commercial sector and the reasons of those differences. It is argued that both these sectors are significantly different in their contexts and the drivers in one sector may not be applicable in the other sector. Although a significant gap exists among the sustainability drive of two sectors to date, this gap can be filled by increased regulatory focus towards residential sector. Some aspects which ease the GB development in commercial sector include the ownership structure and the business case. In case innovative ownership structures and business cases for residential projects are used in future with a particular consideration of increasing stakeholders' interest in green features, then it can also increase GB adoption. Furthermore, the relatively high drive in commercial sector for GBs can be expected to increase the adoption of GBs in residential sector as well. First, because of the high demand of GBs in office sector, construction industry has significantly matured in delivering such projects. This maturity will benefit the GB development in residential sector by providing adequate skillset, reliable technology, and relatively lower costs of green features. Second, GBs in office sector will also act as education hubs for building users. People will begin to notice the difference of GBs from traditional buildings, and they may like to imitate this in their houses to benefit from the privileges of a GB.

The study is limited in terms of comparison across different sectors as only the residential and commercial sector are the subject of investigation. Even within the commercial sector, office projects and retail projects often have a different development environment. Further research needs to be conducted along these lines to enable a broader understanding of the optimal practices of GB development.

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**CONSTRUCTION**



# CHALLENGES TO THE IMPLEMENTATION OF SUSTAINABLE WASTE MANAGEMENT PRACTICE IN THE CONSTRUCTION INDUSTRY

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## Summary

The South African construction industry has a high generation of construction and demolition waste and low diversion of construction and demolition waste trend. In addition, there is rampant illegal dumping and recent studies have shown a positive correlation between the quantity of waste generated on site and the cost of construction projects.

The aim of the study is to improve prevailing waste management practices and to reduce the contribution of the construction industry to South Africa's already existing waste problem to ensure environmental sustainability. The data was collected using structured questionnaires distributed to construction professionals comprising of construction project managers, construction managers, site managers (CM / CPM / SM), quantity surveyors (QS) and architects employed in Port Elizabeth.

The salient findings conclude that more than half of construction firms do not have a waste management policy and do not evolve a waste management plan prior to construction. The majority of construction firms utilise landfill disposal as the main means of waste disposal whereas recycling and re-use measures are rarely used. Furthermore, construction professionals generally have positive attitudes and behaviours towards illegal dumping when questioned however illegal dumping still occurs. It was also evident that rework, as well as poor material and waste handling have an effect on cost of building projects.

Based upon the findings, the paper concludes that sustainable waste management requires co-operation and commitment of all construction professionals from a design, planning, and management stages of a project and top-down commitment in construction firms. Moreover, government can play a role in creating incentives for good waste performance and penalties for inadequate waste performance. Also stronger penalties can be an effective measure to curb illegal dumping.

Keywords: Construction & demolition waste; Waste minimisation; Waste diversion; Illegal dumping

## **1. Introduction**

Construction related activities consume 32% of the world's natural resources. These natural resources are used during the construction process which generates excess unwanted material output known as 'waste' (Poon, Yu & Jaillon, 2004). The waste by product of the construction process has negative consequences for the environment and public health (Alam, Eskicioglu, Hewage, Sadiq & Yeheyis, 2013). Yet construction waste management has so far been largely ineffective in dealing with the waste enigma of the construction industry (Ajayi, Akinade, Alaka, Bilal, Owolabi & Oyedele, 2014).

High rates of waste generation and low rates of waste diversion within the construction industry is a worldwide dilemma. For instance, in the United Kingdom, construction and demolition (C&D) waste was the largest waste generated in the region in 2010, 2011 and peaking at 120 million tons in 2014 (UK Department for Environment Food and Rural Affairs, 2017). The United States of America produced 534 million tons of C&D waste in 2014 with 166 million tons from buildings (US Environmental Protection Agency, 2016). Hong Kong produces 57547 tons of C&D waste and landfills 3942 tons of C&D waste per day (Hong Kong Environmental Protection Department, 2015).

In South Africa, the same global trend is evident. C&D waste generated by the construction industry in 2011 was 4 725 542 tons and of that, only 756 087 tons was recycled. The C&D waste generated accounted for 20% of all the general waste produced in the country (SADEA, 2012). For example, in the Gauteng province, 25% of the waste landfilled is C&D waste and contributed to the diminishing air space in landfills (Gauteng Department of Agriculture Conservation and Environment, 2009). The government of the Republic of South Africa planned to invest R870 million towards public sector infrastructure over three years beginning in 2016 (South Africa. Department of Finance, 2016). Growth and development requires suitable waste management strategies that will ensure environmental sustainability. Therefore, sustainable waste management practices that promote waste minimisation and diversion is a vital concern to construction and the environment (Mwanaumo & Okorafor, 2013).

Given the aforementioned, the objectives of the study reported on are to:

- Identify the factors influencing the occurrence of C&D waste during construction and improve prevailing waste minimisation practices within the construction industry;
- Identify whether contractors have dedicated measures to divert C&D waste away from landfills;
- Identify effective ways of reducing illegal dumping of C&D waste, and
- Determine the impact that ineffective material and waste handling methods may have on construction costs.

## **2. Review of the Literature**

### **2.1. Waste in the construction industry**

According to Damci, Gurgun, Polat and Turkoglu (2017), identifying the most critical causes of C&D waste generation is the first key step in the successful implementation of waste management plan. The main causes of C&D waste can be categorised into seven factor groups. These are: design and construction documents; procurement; handling; storage; workers; site management and supervision, and external sources of C&D waste. Moreover, worker and management problems may lead to a higher generation of C&D waste such as poor communication and poor quality work (Adlan, Aziz, Hassan & Johari, 2015). As Poon et al. (2004) noted, managers lack waste monitoring systems that leads to ineffective implementation of waste management plans and workers lack waste minimisation awareness and it is viewed as a low priority activity. For example, an error in design may lead to an error in procurement and construction, which will ultimately lead to waste generation. As depicted in Figure 1, this is known as the interplay effect

of the causes of waste. Thus, the waste causative factors have a dynamic relationship which may compound the amount of waste generated on project sites (Ajayi et al., 2014).



Figure 1: Interplay of waste causative factor categories (Ajayi et al., 2014).

The most common C&D waste material comprises of bricks, nails, wood, reinforced cement concrete, lime concrete, mixed earth, electrical wiring and steel bars. C&D waste also consists of hazardous substances such as lead and asbestos (Chatterjee, Ghosh, Ghosh & Halder, 2016). The quantification of such material waste generated may be useful in compiling a waste management plan and environmental management systems for construction firms (Porrás-Amores, del Río Merino & Villoria Sáez, 2015). According to Ajayi, Akinade, Alaka, Bilal, Owolabi and Oyedele (2017), there are two main schools of thought regarding waste management. Firstly, the reduction of waste landfilled through recycling and re-using and, secondly, the prevention and minimisation of waste before and during the construction process. The first approach to waste is re-active given that waste is viewed as necessary by-product of the construction process that cannot be eradicated. The second approach to waste is pro-active and is more effective.

Ameh and Daniel (2013) were of the opinion that there is a significant relationship between building material waste on construction sites and cost of a project. The general improvement of waste levels on construction sites can have a cost saving benefit and enhance the construction industry's performance which provides incentives for waste

## 2.2. Waste diversion and recycling

Landfilling and ocean disposal of C&D waste has severe environmental and socio-economic implications including the reduction of landfill space (Alam et al., 2013). Furthermore, Arslan, Kazaz and Ulubeyli (2017) opined that the construction industry will never reach zero waste-status and the current dominant disposing method of C&D waste i.e. landfilling, is not sustainable. Waste diversion measures such as recycling serves as a waste management and material reduction process and reduces the need for landfilling and the use of virgin material thus has a net benefit for the environment (Crossin, Lockrey, Nguyen & Verghese, 2016). According to Jin, Li, Piroozfar, Wanatowski and Zhou (2017), the lack of economic feasibility and viability in recycling

and reusing C&D wastes causes contractors to choose the less economical disposal measures such as landfilling. Additionally, poor communication and co-ordination plays a role in a lack of waste diversion and recycling material tends to be poor in quality and have limited application. Jha, Misra, and Rao (2007) noted that lack of awareness, lack of government support, lack of proper standards, absence of appropriate technology, and lack of appropriately located recycling facilities are barriers to recycling of C&D waste by contractors.

Hao, Lu and Yuan (2013) posited that construction waste sorting results in a diversion of waste to landfills. According to Kang, Lu, Wang, and Yuan (2010), construction waste sorting has a number of benefits for the construction industry such as having an increased rate of re-use and recycling. It also reduces the cost of waste transportation and disposal thus pro-longing the life of landfills and reduces the amount of pollution. Jin et al. (2017) argued that there is reluctance or cultural resistance towards re-use and recycling. A cultural change of the construction industry can be a way to divert the amount of waste landfilled (Ajayi, Akinade, Alaka, Bilal, Kadiri, Owolabi & Oyedele, 2016). Furthermore, Jin et al. (2017) identified recommendations for the improvement of C&D waste management that will promote recycling and waste diversion. These include: applying economic instruments such as tax incentive, penalty and subsidy mechanism; governmental initiatives to increase C&D waste diversion activities; innovations in construction technology and management, and investment, research (e.g., economic feasibility), and development in waste reduction, recycling, and reuse.

### **2.3. Illegal dumping in the construction industry**

Illegal dumping causes aesthetic damage to the landscape of affected areas. Moreover, C&D waste may contain harmful substances which can seep into the ground and cause air, water and land pollution within the natural environment (Hareli, Portnov & Seror, 2014). The sight and smells in an affected area are unpleasant and the value of the property in the surrounding regions tends to drop (Ball, Chalmers, Dunywa, Lovelock, Nkata, Pearton & Smart, 2014). According to Baum and Katz (2010), the causes of illegal dumping include: long transportation distances; high tipping fees; lack of enforcement measures; lack of knowledge on recycling measures, and lack of legal landfilling sites. However, Ichinose and Yamato (2011) stated that the measures to reduce illegal dumping include: intermediate waste management facilities; waste minimisation; strong penalties, and incentives for recycling. Hareli et al. (2014) revealed that vehicle impounding deters truck drivers from illegal dumping. Additionally, continuity and persistence in policies is important for the success of enforcement measures.

## **3. Research Methodology**

The study takes the quantitative approach by analysing and measuring the responses to structured questionnaires. The use of questionnaires is a relatively cheap and efficient way of collecting data. The sample stratum consists of professional construction managers, site managers, construction project managers, quantity surveyors, and architects / designers, that are involved with building construction projects in Port Elizabeth. The respondents were from 15 different construction related firms and the technique of probability (simple random sampling) sampling was employed to select the research participants. 68 questionnaires were emailed or hand delivered to construction professionals in their offices as well as on site. 30 / 68 questionnaires were returned and an overall response rate of 44.12% was achieved. It is worth noting that 47% (14 / 30) of the respondents were construction managers / construction project managers' / site managers (CM / CPM / SM), 30% (9 / 30) were quantity surveyors (QS), and 23% (7 / 30) were architects. The questionnaire consisted of 58 questions of which a combination of open ended and closed ended questions are utilised, including five-point Likert scale type questions. The data analysis technique adopted for the study was descriptive statistical method. Descriptive statistics were used to measure the central tendency such as mode, median and mean, and the

dispersion (standard deviation) of the data. The Likert-scale type questions are discussed based on the mean score comparisons in the following table:

Mean score range	Meaning
$\geq 1.00$ to $\leq 1.80$	Minor to near minor extent
$> 1.80$ to $\leq 2.60$	Minor to a near minor / near minor extent
$> 2.60$ to $\leq 3.40$	Near minor extent to some extent / some extent
$> 3.40$ to $\leq 4.20$	Some extent to a near major / near major extent
$> 4.20$ to $\leq 5.00$	Near major extent to major / major extent
$\geq 1.00$ to $\leq 1.80$	Strongly disagree to disagree
$> 1.80$ to $\leq 2.60$	Strongly disagree to disagree / disagree
$> 2.60$ to $\leq 3.40$	Disagree to neutral / neutral
$> 3.40$ to $\leq 4.20$	Neutral to agree / agree
$> 4.20$ to $\leq 5.00$	Agree to strongly agree / strongly agree
$\geq 1.00$ to $\leq 1.80$	Not at all to least extent
$> 1.80$ to $\leq 2.60$	Not at all to least extent / least extent
$> 2.60$ to $\leq 3.40$	Least extent to some extent / some extent
$> 3.40$ to $\leq 4.20$	Some extent to large extent / large extent
$> 4.20$ to $\leq 5.00$	Large extent to very large extent / very large extent

#### 4. Research Findings

Table 1 indicates the extent to which the following factors contribute to the quantity of waste in construction projects in terms of responses to a scale of 1 (minor) to 5 (major) and a mean score ranging between 1.00 to 5.00 and midpoint being 3.00. It is notable that 7 / 8 (87.5%) factors' MSs are  $> 3.00$ , which indicates that generally the waste causative factors contribute to waste on site more of a major than a minor extent.

As indicated in Table 1, it is worth noting that rework is ranked first in all construction professional fields with a MS of 4.14. Overall, poor handling of materials on site is ranked second (4.07), and poor site management is third (3.90). It is worth mentioning that poor planning on site (3.87) is not too far behind poor site management at fourth. Furthermore, 7/8 (88%) MSs  $> 3.40$  to  $\leq 4.20$ , which indicates that the contribution can be deemed to be between Some extent to a near major / near major extent for the following factors: Inefficient procurement practices, Inefficient design (e.g. design errors and omissions), Poor material handling on site, Poor planning on site, Poor site management, Poor understanding of design drawings, and Rework. However, for contract variations, the degree of concurrence can be deemed to be between near minor extent to some extent / some extent since the MS is  $> 2.60$  to  $\leq 3.40$ .



*Table 1: Extent to which the following factors contribute to the quantity of waste in construction projects*

Factors	Architects		CM/CPM/SM		QS		Overall	
	MS	Rank	MS	Rank	MS	Rank	MS	Rank
Rework	4.00	1	4.33	1	4.00	2	4.10	1
Poor material handling on-site	3.57	4	4.33	1	4.14	1	4.07	2
Poor site management	4.00	1	4.22	3	3.6	5	3.90	3
Poor planning on-site	3.43	6	4.22	3	3.92	3	3.87	4
Poor understanding of design drawings	3.57	4	3.89	6	3.69	4	3.70	5
Inefficient procurement practices	3.85	3	3.89	6	3.42	6	3.67	6
Inefficient design (e.g. design errors and omissions)	3.14	7	4.11	5	3.35	7	3.53	7
Contract variations	2.57	8	2.78	8	3.14	8	2.90	8

Table 2 indicates whether participants have or do not have a waste management policy in place in terms of percentages. It is notable that 5 or more participants ( $\leq 16.67\%$ ) within each construction professional field reported not to have a waste management policy in place.

With respect to architects, none of the respondents' reported to have a waste management policy within their respective firms. With regard to Qs, 5 (16.67%) reported that they do not have a waste management policy and 3 (10%) were unsure whether their firms have or do not have a waste management policy, only 3.33% reported to have a waste management policy in place. Relative to the CM / CPM / SM's, 9 (30%) of them reported to have no waste management policy within their respective firms, on the other hand, 5 (16.67%) do have a waste management policy in place. Overall, it is notable that more than half of the respondents 20 / 30 (66.67%) reported to have no waste management policy. This finding suggests that the lack thereof of waste management policy exacerbates the occurrence of waste during construction.

*Table 2: Number of respondents whose firm has a waste management policy*

	Architects		CM/CPM/SM		QS		Overall	
	Number	(%)	Number	(%)	Number	(%)	Number	(%)
Yes	0	0	5	16.67	1	3.33	6	20.00
No	6	20.00	9	30.00	5	16.67	20	66.67
Unsure	1	3.33	0	0	3	10.00	4	13.33
Total	7	23.33	14	46.67	9	30.00	30	100.00

Table 3 indicates whether or not participants evolve a waste management plan for each project in terms of percentages. It is notable that 5 or more participants ( $\leq 16.67\%$ ) within each construction professional field reported to not evolve a waste management plan. With respect to CM / CPM / SMs, 8 (26.67%) reported to evolve a waste management plan for each project. However, 6 (20%), of CM / CPM / SMs responded not to evolve a waste management plan. Overall, 17 / 30 (56.67%) of the respondents reported that their firms do not have a waste management plan in place for each project.

Table 3: Number of respondents reported to have a waste management plan for each project

	Architects		CM/CPM/SM		QS		Overall	
	Number	(%)	Number	(%)	Number	(%)	Number	(%)
Yes	0	0	8	26.67	2	6.67	10	33.33
No	6	20.00	6	20.00	5	16.67	17	56.67
Unsure	1	3.33	0	0	2	6.67	3	10.00
Total	7	23.33	14	46.67	9	30.01	30	100.00

Table 4 indicates the main means of waste disposal in terms of percentage responses. It is notable that more than half (57.14%) of the participants' main means of waste disposal is landfill disposal. Furthermore, 2 / 14 (14.29%) and 3 / 14 (21.43%) of the respondents' main means of waste disposal is avoidance/minimisation and re-use, respectively. Recycling is the main means of disposal for a minority of participants 1 / 14 (7.14%).

Table 4: Indicates the participant's main means of disposal.

CM/CPM/SM		
	Number	(%)
Avoidance/Minimisation	2	14.29
Incineration	0	0
Landfill disposal	8	57.14
Re-use	3	21.43
Recycling	1	7.14
Other	0	0
Total	14	100

Table 5 indicates the extent to which the participant's firm divert waste away from landfills. The responses are tabulated in terms of percentage responses to a scale of 1 (not at all) to 5 (very large extent) and a mean score ranging between 1.00 to 5.00 and midpoint of 3.00. It is notable that the MS is > 1.80 to ≤ 2.60, which indicates that generally the extent to which participants' firms divert waste is considered to be between not at all to least extent / least extent.

Table 5: The extent to which the respondents firms divert waste away from landfills

Factor	CM/CPM/SM						Overall MS
	Unsure	1	2	3	4	5	
Diverting waste away from landfills	28.57%	0%	28.57%	42.86%	0%	0%	1.86

Table 6 indicates the extent of agreement / disagreement with the following statements regarding illegal dumping in terms of responses to a scale of 1 (strongly disagree) to 5 (strongly agree) and a mean score ranging between 1.00 to 5.00 and midpoint being 3.00 (Neutral). It is notable that 5 / 6 (83.33%) MSs are > 4.00 which indicates that in general the participants agree more than they disagree with the statements.

Table 6: Extent of agreement/disagreement with illegal dumping statements

Statements	Architects		CM/CPM/SM		QS		Overall	
	MS	Rank	MS	Rank	MS	Rank	MS	Rank
Illegal dumping is detrimental to the environment	4.86	1	4.79	1	4.78	1	4.80	1
Illegal dumping causes aesthetic damage	4.71	2	4.57	2	4.67	2	4.63	2
Illegal dumping is a severe offence	4.43	3	4.34	3	4.56	3	4.43	3
The punishment for illegal dumping should be severe	4.42	4	4.00	5	4.44	4	4.23	4
Illegal dumping is a problem within the industry	3.86	5	4.36	4	4.22	5	4.20	5
Convenience is more important than the environment when disposing waste	1.86	6	1.86	6	2.22	6	1.97	6

Overall, 4 / 6 (83.33%) MSs are  $> 4.20$  to  $\leq 5.00$ , which indicates that the degree of concurrence can be deemed to be between agree to strongly agree / strongly agree for the following statements: Illegal dumping is detrimental to the environment; illegal dumping causes aesthetic damage; illegal dumping is a severe offence, and the punishment for illegal dumping should be severe. The degree of concurrence for illegal dumping is a problem within the industry can be considered to be between neutral to agree / agree since the MS is  $> 3.40$  to  $\leq 4.20$ . Notably, the statement "Convenience is more important than the environment when disposing waste" had the lowest MS (1.97). This indicates that the degree of concurrence can be deemed to be between strongly disagree to disagree / disagree with the statement since the MS is  $> 1.80$  to  $\leq 2.60$ .

Table 8 indicates the severity of cost overruns due to poor material and waste handling experienced by the firms of the participants. The responses are tabulated in terms of percentage responses to a scale of 1 (not at all) to 5 (very large extent) and a mean score ranging between 1.00 to 5.00 and the midpoint being 3.00. Notably the MS is  $> 3.00$  which indicates that generally, the severity of the participant's firms cost overruns can be considered to be between least extent to some extent / some extent since the MS is  $> 2.60$  to  $\leq 3.40$ .

Table 8: Severity of cost overruns due to poor material and waste handling

Factor	CM/CPM/SM						Overall MS
	Unsure	1	2	3	4	5	
Severity of cost overruns due to poor material and waste handling on-site	0	7.14%	7.14%	50%	28.57%	7.14%	3.21

Table 9 indicates the extent to which sources of waste contribute to cost overruns in terms of responses to a scale of 1 (minor) to 5 (major) and a mean score ranging between 1.00 to 5.00, the midpoint being 3.00. It is notable that 6 / 7 (85.71%) sources of waste MSs are  $> 3.00$ , which indicates that generally the sources of waste contribute more of a major than minor extent to cost

overruns. Overall, the top ranked factors are poor material and waste handling (3.90), rework (3.90) and poor planning on site (3.87), which indicates that the degree of concurrence can be deemed to be between some extent to a near major / near major extent since the MSs are > 3.40 to ≤ 4.20. Furthermore, it is worth noting that 4 / 7 (57.14%) MSs are > 3.40 to ≤ 4.20, which indicates that the degree of concurrence can be deemed to be between some extent to a near major / near major extent for the following factors: rework; poor material and waste handling on site; poor planning on site, and poor site management. Moreover 3 / 7 (42.86 %) MSs are > 2.60 to ≤ 3.40, which indicate that the degree of concurrence can be deemed to be between a near minor extent to some extent / some extent for the following factors: Inefficient procurement practices, Inefficient design (e.g. design errors and omission), and Contract variations.

*Table 9: Extent to which waste causative factors contribute to cost overruns*

Factors	Architects		CM/CPM/SM		QS		Overall	
	MS	Rank	MS	Rank	MS	Rank	MS	Rank
Rework	3.14	3	4.21	1	4.00	3	3.90	1
Poor material and waste handling on-site	3.29	1	4.14	2	4.00	3	3.90	1
Poor planning on-site	3.14	3	3.93	3	4.33	1	3.87	3
Poor site management	3.00	5	3.93	3	4.11	2	3.77	4
Inefficient procurement practices	3.00	5	3.36	5	3.11	6	3.20	5
Inefficient design (e.g. design errors and omission)	3.29	1	2.79	6	3.33	5	3.07	6
Contract variations	2.86	7	2.57	7	2.89	7	2.73	7

## 5. Conclusions and Recommendations

The construction industry in RSA is no different from other construction industries worldwide with respect to C&D waste generation and diversion. The industry has a high generation of C&D waste and low diversion trend including other problems associated with waste such as rampant illegal dumping and the effect of poor waste and material handling on the cost of building projects. Waste also has wider environmental and socio-economic effects and remains a conundrum within the construction industry. There are multiple sources / causes of C&D waste that can occur prior to and during construction. Design and procurement waste causative factors remain largely unexplored. Moreover, the construction industry in RSA is characterised with low C&D waste recycling and re-using rates, yet the main construction materials in use do have recycling and re-use potential. However, there are still barriers between construction professionals and effective waste recovery.

Construction professionals generally have positive attitudes towards illegal dumping and its effects on the environment. There is agreement that illegal dumping has negative effects on both the environment and quality of life, and that convenience is not more important than the environment when disposing of waste. However, illegal dumping still occurs and there are other factors which may lead to illegal dumping. Rework and poor handling of material and waste was shown to have an effect closer to very large extent than not at all in relation to cost overruns experienced by construction related firms. The benefits of efficient and effective waste management practices have the potential to and play a role in protecting the environment, the economy and the public

health of South African citizens. Thus to achieve sustainable waste management, C&D waste minimisation / reduction diversion is of utmost importance.

RSA is a developing nation and to ensure growth, the government is planning to invest millions of rands into infrastructure, schools, hospitals, and roads as part of the objectives set within the National Development Plan. This will presumably guarantee more construction and more potential waste generation within the country. To ensure sustainable waste management by the construction industry, the following is recommended:

- Construction related firms to evolve a waste management policy that sets out broad principles and intentions with regard to waste reduction and waste diversion;
- Architects playing a proactive role in waste minimisation through the implementation of a waste efficient design;
- Contractors having effective waste management practices on site;
- Construction industry professional bodies creating awareness and emphasis on waste management education and training within the industry;
- Government offering incentives for good waste performance by construction firms and penalties for inadequate performance, and
- Enforce stronger penalties on illegal dumping.

Waste generation rates remain a major problem in South Africa, especially when compared to waste recovery rates. This is largely attributed to inadequate approaches to waste management within several industries; the construction industry is one of those. Sustainable waste management requires co-operation and commitment of all construction professionals from a design, planning, and management stages of a construction project and top-down commitment in construction firms.

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## PRODUCING WORK-READY GRADUATE FOR THE CONSTRUCTION INDUSTRY

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### Summary

While educating building professionals is an essential component of the construction education sector, producing work-ready graduates to meet the construction industry requires greater effort. The factors that influence graduate students' successful transition into the competitive construction environment need to be further explored. This study investigates these factors through a literature review and interviews six experts in academia who have industry experience. The findings of this study show that factors such as 'team-working skills' and 'communication skills' are the two top factors for producing work ready graduates for the construction industry. The findings can help academia to understand the important factors for producing work-ready graduates for the construction industry.

**Keywords:** construction, employability, work-ready graduates

## 1. Introduction

Graduate employability depends on the quality of education. As defined by Brynteson (2012), employability is about skills that can help graduates to find proper employment, in accordance with their experiences and knowledge. Carroll (2011) stated that employability of graduates can be considered as a remarkable benchmark to measure the quality of higher education.

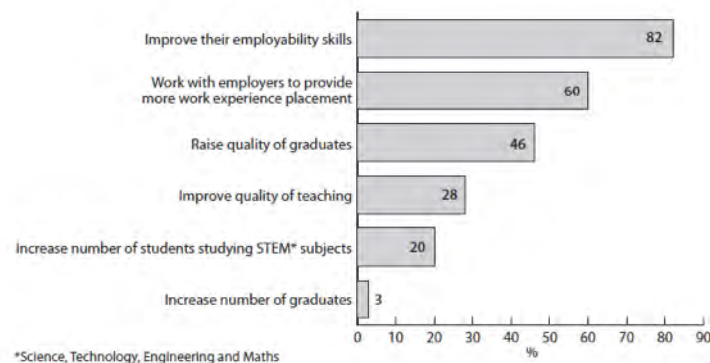
Achieving excellent graduate results depends on producing employable graduates. This is due to the fact that individuals select their tertiary education in order to achieve the skills they need for a rewarding work life. They select what to study because of “what they are capable of and what will get them started on a career” (New Zealand Ministry of Education, 2013). Hence, educational service providers are required by the governments to improve the employability agenda across their organisations, and many of them have attempted to meet this challenge, with varying degrees of success (Culkin & Mallick, 2011).

The response by the educational service providers is not sufficient, as there is a need for a more radical approach that can help in empowering new graduates with the knowledge and skills required for setting up a business rather than focusing on simply ‘getting a job’ (Culkin & Mallick, 2011). Similarly, Herrmann et al. (2008) stated that graduates, in addition to achieving work skills, are required to develop skills that help them to take risks and opportunities, work flexibly, handle complexity, and achieve team-work skills and awareness.

This paper is structured as follows: first, the significance of this study is presented by reviewing the available literature. Next, key success factors for producing work ready graduates, as the basis for conducting a qualitative study, are identified. Following this, the qualitative findings of this study are presented and they are also compared with the literature findings. Finally, the study’s limitations and suggestions for future research are presented.

## 2. Significance of the study

A report by Lambert (2003) provides the UK employer’s perspective on the skills market that educational service providers need to consider in their education curricula. This view was revised and supported by the Confederation of British Industry (2009), which developed Figures 1 and 2 to show the role and responsibility that universities need to consider in providing employability skills. As can be seen from the both figures, educational services providers have a significant responsibility for helping students to achieve employability skills.



*Figure 1 Universities priorities in terms of undergraduates (Source: Confederation of British Industry, 2009)*

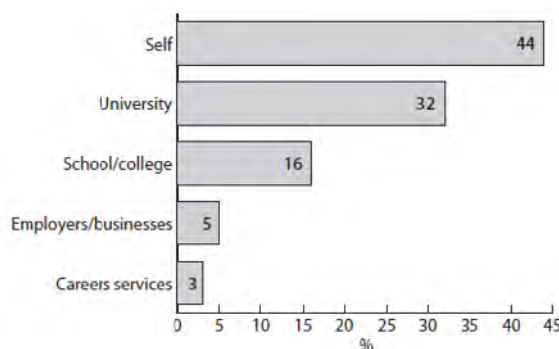


Figure 2 Responsibility for helping students to achieve employability skills. (Source: Confederation of British Industry, 2009)

## 2.1. The economic aspects of graduates' employability skills

Universities in New Zealand are large scale institutions which form an important backbone to the country's economy. For example, they employ around 20,000 full-time staff, have a turnover of more than a \$3.8 billion annually, and they spend about \$960 million on research. They teach around 174,000 at any time and graduate around 43,000 students per year (Universities New Zealand, 2018).

New Zealand universities are not only a growth driver for the New Zealand economy, they also play key roles within the construction industry in the country. The New Zealand construction industry is a small but competitive construction market and very important for the overall economy of the country (Construction Strategy Group, 2015). For example, it contributed 8% to GDP and employed 10% of the workforce in 2015 (PWC, 2016). Despite the importance of the construction sector for New Zealand, its performance is still low in comparison with some other comparable sectors of the New Zealand economy (PWC, 2016), and other similar economies and countries (Constructing Excellence, 2009). According to Building and Economics Research Limited (2003), a 10% improvement in New Zealand construction performance would increase the country's GDP by about \$2 billion. To help achieve this, producing work ready graduates can be considered as an effective approach. Hence, the responsibility for the employability of graduates has been imposed on the government's respective higher education systems. This is aligned with the Theory of Human Capital introduced by Becker (1975), which states that governments are responsible for improving the stock of human capital, as an essential factor for achieving success and performance of knowledge based economies.

Exploring the earnings of graduates helps in understanding the contribution that the tertiary education system is making towards producing work ready graduates. The key findings of a report by the New Zealand Ministry of Education (2013) entitled "looking at the employment outcomes of tertiary education" shows that: "earnings increase with the level of qualification completed; employment rates increase with the level of qualification gained; very few young people who complete a qualification at diploma level or above are on a benefit in the first five years after study; earnings vary considerably by field of study; some qualification types and some fields are associated with high rates of further study; and graduate certificate and diploma graduates have very high employment rates".

## 3. Key success factors for producing work ready graduates

A study entitled 'employers' perceptions of graduate employability' by Eurobarometer (2010) provides insights into the needs of graduate recruiters by assessing the perceptions of employers. In conducting the study, 11 factors such as team-working skills, sector-specific skills, communication skills, computer skills, ability to adapt to and act in new situations, good reading/



writing skills, analytical and problem-solving skills, planning and organisational skills, decision-making skills, good with numbers, and foreign language skills were considered as key success factors for producing work ready graduates. These factors can be determined as instrumental factors which can be considered as a means to an end (Aliakbarlou et al., 2017b), where the end is about achieving a high level of graduate employability. Based on these 11 factors, this paper reports a pilot study which applies the expert interviews method to prioritise the key success factors for producing work ready graduates in New Zealand.

#### 4. Research methodology

This study takes a social constructionist stance where a reality is constructed by individuals activities (Aliakbarlou et al., 2017a). A qualitative research methodology, as used in this study, suggests an in-depth approach to exploring experts' insights about a research question (Aliakbarlou et al., 2018; Mbachau & Nkado, 2004). In the first step, a literature review was conducted to define the main factors affecting students' employability, as well as to develop a basis to prioritise the key success factors from the identified factors based on New Zealand experts' perspectives. In the second step, by focussing on educational organisations as detailed in Table 1, it was decided to conduct expert interviews with individuals who are experts in the particular field that is being researched (Sugar & Schwen, 1995). Hence, selection of the research participants from the educational organisations (10 interviewees) was based on their experience in a university, institute of technology and polytechnic as well as their construction industry experience. Initially, ten organisations were contacted using the researcher's own connections. However, due to, individual availability within the research time frame, six interviewees from five organisations participated in interviews. Selection of the interviewees was based on their knowledge and experience in construction management in New Zealand, Australia and Iran. Table 2 represents the interview participants' details. As Table 2 shows, the participants were senior within their organisations. This helped them to understand what value meant to them from an organisational perspective (Aliakbarlou et al., 2017c). In addition, they had extensive experience and clear ideas about construction employers' recruiting preferences as they had played various roles in construction projects.

*Table 1 Organisations' Description*

Code	Educational Organisation Type	Country
P1	Public – Institute of technology and polytechnics	New Zealand
P2	Private – Institute of technology and polytechnics	New Zealand
P3	Private – University	New Zealand
P4-P5	Private – University	Australia
P6	Public – University	Iran

*Table 2 Interview Participants' Profiles*

Field of expertise	Code	Years of experience
Construction industry experience	P1	30
	P2	10
	P3	10
	P4	8
	P5	20
	P6	5

Field of expertise	Code	Years of experience
Educational experience	P1	10
	P2	20
	P3	20
	P4	15
	P5	10
	P6	10

#### 4.1. Types of questions and structure to address the objectives of the research

The participants were briefed on the research objectives. In so doing, the list of 11 identified factors (as outlined in Table 3) were explained to the participants. They were then asked to prioritise the 11 factors by assigning a range of scores from 1 to 11 to each factor. This method was selected because the data was collected by conducting interviews that allowed appropriate time for the participants to review the factors and to rank them. The interviews helped to achieve insights into participants' experiences (Aliakbarlou et al., 2017d). By conducting the interviews in this study some underlying contextual information was gained regarding graduate employability. Although the number of interviewees was limited, the interviewees were expert in education. Also, the sample of interviewees represents a range of experts with considerable expertise in construction projects. Conducting interviews with experts in their particular field of expertise is recognised as an appropriate method to justify a research finding (Egbelakin et al., 2015). After obtaining the scores for each factor, by calculating the average for the scores given to each factor, the ranks, as shown in Table 3, have been developed based on the average score for each factor.

In addition, the participants were asked to provide explanations as to how the employers perceive value from each of the 11 factors. However, this paper only represents the identified ranks for the factors.

## 5. Findings

A study by Ray et al. (2012), indicated that there is a significant skills gap between graduates and entry-level requirements. "There is an issue with education systems that fail to produce future workers with the kinds of skills required by today's organisations – let alone those of tomorrow" (Ray et al., 2012). In what follows, the key success factors for producing work ready graduates are addressed.

### 5.1. Prioritising key success factors for producing work ready graduates

Table 3 lists the key success factors in rank order, as determined by this study. Reviewing the interview results (with 3 experts from New Zealand), factors such as 'team-working skills', 'communication skills', and 'good reading/writing skills' were shown to be the 3 most important factors for producing work ready graduates for the New Zealand construction industry. Similarly, these 3 factors were recognised as the 3 most important factors by the Australian experts in this study.

The participant from Iran selected 'team-working skills', 'communication skills' and 'computer skills' as the 3 most important factors.

*Table 3 Factors influencing graduates' successful transition into construction market*

<b>Factors</b>	<b>Rank (this study)</b>	<b>Rank (Europe)</b>
Team-working skills	1	1
Sector-specific skills	6	2
Communication skills	2	3
Computer skills	5	4
Ability to adapt to and act in new situations	4	5
Good reading/writing skills	3	6
Analytical and problem-solving skills	7	7
Planning and organisational skills	11	8
Decision-making skills	10	9
Good with numbers	9	10
Foreign language skills	8	11

## 5.2. Comparison between studies

Table 3 shows how the perception of graduate employability in Europe differs from the participants of this study.

### Similarities between studies

Team-working skills and communication skills were identified among the most important factors by both studies. 'Team-working skills' was ranked first by both studies. 'Communication skills' was ranked third and second by the European and this study's participants, respectively. In addition, 'computer skills' and 'ability to adapt to and act in new situations' were regarded as important factors by both sets of respondents, since they were ranked (fourth and fifth) and (fifth and fourth) by European and this study's participants, respectively. 'Analytical and problem-solving skills' was ranked seventh by both sets of respondents. Finally, 'decision-making skills' and 'good with numbers' were ranked (ninth and tenth) and (tenth and ninth) by European and this study's participants, respectively.

### Differences between studies

'Sector-specific skills' was ranked as the second most important factor by the European participants while it was ranked sixth in this study. Also, 'planning and organisational skills' was ranked as the eighth most important factor by the European participants while it was ranked as the eleventh most important factor in this study.

Finally, while communication skills are ranked highly important for both sets of respondents, there is not strong agreement among them regarding 'good reading/writing skills' as well as "foreign language skills'. 'Good reading/writing skills' and 'foreign language skills' were ranked (sixth and eleventh) and (third and eighth) by European and this study's participants, respectively.

## 5.3. Implications of the findings

The study's findings help in better understanding the factors that influence graduates' successful transition into the construction industry. While the findings highlighted factors necessary to achieve successful results for the students and educational services providers, they can also help employers to recruit new graduates who have the skills and knowledge that their organisations

need to succeed (Finch et al., 2013). This is also critical for the growth of the constructing industry which is a knowledge-based economy.

Developing an educational strategy that recognises, prioritises and satisfactorily delivers these factors is essential to ensure that the highest levels of student employability are achieved. For example, as 'team-working skills' and 'communication skills' are the two key factors for producing work ready graduates, promoting collaborative learning cultures gains importance. However, individual assignments and activities are preferred to team assignments and activities by students (Raidal & Volet, 2009), due to, for example, poorly designed assignments and activities with lack of support from the their supervisor, unequal same contributions from team members working on the same assignment, and lack of having an appropriate space (classroom) to conduct a meeting and group activities (Scager et al., 2016). To help this improve, using a collaborative space (instead of a traditional classroom) and a team project task that lends itself to both collaboration and distinct contributions of students is required. This helps students to develop the capabilities and attitudes that are required for their employers. For example, in addition to the two aforementioned factors, achieving 'higher-level reasoning skills', 'accurate and creative problem solving skills', 'willingness to take on difficult tasks', 'intrinsic motivation', and 'ability to transfer learning from one situation to another' are some other key benefits of collaborative learning for students (Johnson et al., 2014), which highlights the significance of collaborative learning for the employability of students (Hayward & Horvath, 2000).

## **6. Conclusion and Further Research**

This study considers employers' views of the factors that are important for employability of graduates. Based on the qualitative findings of this study, 11 employability factors were prioritised based on employers' perspectives. The findings contribute to the existing literature on employability of new graduates. In addition, the study examined how employers' perspectives on significance of the identified factors differ between European's employers and this study's participants.

The findings of this study show that factors such as 'team-working skills' and 'communication skills' are the two most important factors for producing work ready graduates for the New Zealand construction industry. The findings can be used to improve the employability of new graduates, and can be considered by educational services providers when reflecting on employers' recruiting preferences.

By understanding the significance that employers place on key factors for achieving graduate employability, educational service providers can develop curricula based on the development and improvement of important skills that employers look for. Also, it helps graduates to position themselves in the marketplace by highlighting the required factors when they are applying for rewarding work.

An important limitation is related to the scope of the study. The identification of the key success factors for producing work ready graduates in this study is limited, based on the findings of literature and expert interviews. Although the literature review drew on a recognised international source, further interviews and surveys may find that other factors should be added to the list of the factors developed in this study. In addition, this study's findings are subject to the limitations of interview based research. Also, the number of interviewees is small and may not be representative of the views of the wider industry.

Conducting a similar study in other countries is recommended, to determine the adaptability and replicability of the research results in other contexts. Future studies may also identify measurements and benchmarks for the factors in this study. In so doing, the identified factors (and their measurements) can be categorised under 'absolute measures' and 'relative measures' or 'objective measures' and 'subjective measures'. This will help in practical application of this study's findings and bring the graduates closer to the construction industry needs and requirements.

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## CRADLE TO CRADLE BUILDING COMPONENTS VIA THE CLOUD: A CASE STUDY

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### Summary

The paper expands upon 'cradle to cradle carpets and cities' presented by Ness and Field (2003) at SASBE 03, where the notion of providing modular carpets as a service was introduced, and a paper at SASBE 06 where the theme of providing C2C products as a service was further developed by Ness and Pullen (2006). It reports on the outcomes of an ARUP Global Research Challenge Project 2017, undertaken by University of South Australia, ARUP, Prismatic Architectural Research and other partners, under the theme of adapting the circular economy to the built environment. The project addresses the challenge of reusing building components, so they deliver more value over their extended life-cycle, with consequent reductions in resource consumption, greenhouse gas emissions, pollution and waste, coupled with creation of new enterprises and jobs. A universally accessible 'Cloud-based building information management platform' is being developed, which enables components to be identified, reclaimed reused and exchanged multiple times over their lifecycle, within the same or different facilities. A cyber-physical information exchange system was established between physical building components and their virtual counterparts, known as Building Information Models, so that their life cycle information including history of ownership, condition, maintenance history, technical specifications and physical performance could be tracked, monitored and managed. In addition, designers could identify reused components via the cloud platform, and assess their suitability for incorporation in building projects when compared with new products. This research was complemented by an innovative business model, whereby components and products can be provided as a service, with producers retaining responsibility for their repair, remanufacturing and/or reuse over their life cycle. The methodology involved establishing a Cyber-Physical System by connecting a series of existing technologies, including Radio Frequency Identification (RFID) and Building Information Modelling (BIM). Using a case study of a section of a major new hospital for 'proof of concept', information on the history, location, properties and performance of physical components could be exchanged in real-time from RFID tags to a local BIM system and thence to the cloud platform. Complemented by interviews within Australia and Europe with key stakeholders including designers, project managers, manufacturers, owners, investors and facility managers, the research led to the development of a 'products as service' business model and associated business case for the new paradigm. In short, a self-populating relational database that can execute predefined multiple/conditional ownership exchange via a graphical user interface and/or web site front end. The findings are expected to drive increased reuse, adaptation and life-cycle stewardship within the building industry, whereby more value can be derived from built resources, new business opportunities created in the service sector, and adverse environmental impacts reduced. This is consistent with the pursuit of a 'circular economy', where the construction and management of the built environment can exert a major influence.

Keywords: reuse, adaptability, RFID, BIM, products as service, business case

## **1. Introduction**

The paper expands upon themes presented to SASBE 03 (Ness and Field 2003), where the notion of providing modular carpets as a service was introduced, and a subsequent paper to SASBE 06 where the theme of providing “cradle to cradle” (C2C) products as a service was further developed (Ness and Pullen 2006).

It outlines research associated with the ARUP Global Research Challenge (GRC) 2017, under the theme of adapting the built environment to the concept of a circular economy (CE). While the CE is often viewed in terms of recycling, more value can be obtained from buildings and physical components by their reuse, whereby their life cycle is extended and they are kept in circulation, aided by their stewardship and remanufacture to ensure they retain their highest possible performance capability.

The submission for ARUP GRC 2017 was based upon the notion that reuse of building components could be enabled by a) cyber-physical connectivity whereby the location, condition, performance and other properties of components could be identified and monitored remotely via a cloud system, and b) use of a product-service system (PSS) business model that enabled producers to retain ownership responsibilities for products over their life cycle and to provide them to various users as a service. It was postulated that the symbiosis created by integrating these two mechanisms within a ‘Cloud BIM data service platform’ could facilitate a substantial increase in reuse.

Hence, the paper first describes the nature and impacts of present practices, resulting in around 40 per cent of building materials being deposited to landfill, over-extraction of scarce resources, and excessive use of energy and production of GHG emissions. Moves to overcome this challenge are then outlined, within the context of circular economy (CE) principles and practices. Gaps in the literature in regard to state of knowledge and practice are then identified, leading to the expression of the research aims and methodology. The research is then explained, the findings presented, conclusions drawn, and further opportunities and limitations outlined.

## **2. Background**

Whilst global attention has centered on reducing operational GHG emissions, the importance of embodied CO<sub>2</sub> emissions or “capital carbon” has recently gained increased attention (HM Treasury 2013). This has been aided by the adoption of CE principles and policies in many jurisdictions, including the EU and China, and the promulgation of the UN Sustainable Development Goals (SDGs) that include Goal 12: Sustainable Production and Consumption. The construction industry, though, has been slow in the up-take of such approaches, seemingly due to a widespread belief that resources are limitless, and that increased energy efficiency will suffice.

### **2.1. Literature and research**

The notion that parts of buildings may be changeable and/or adaptable is not new. Alex Gordon coined the 3Ls concept – long life, low energy, loose fit – in the early 1970s, N.J. Habraken introduced the notion of ‘open building’ in the early 1990s, while Stewart Brand (1965) developed the concept of ‘layers of change’; these ranged from less changeable, longer-life elements such as site and structure, to more adaptable ‘space’ (fitout), ‘services’ (e.g. lighting), ‘skin’ (e.g. façade) and ‘stuff’ (loose fittings).

ARUP (2016), ARUP and BAM (2017), and the Ellen MacArthur Foundation (EMF 2015) have published guidelines related to a circular built environment, including the role of circular business models. These highlight the opportunity for a platform to be used to track and advertise products and components that are currently ‘locked in’ buildings. Thus, when a building approaches its end of life, these resources could be procured by another development, thus enabling their reuse and

circularity. Baker-Brown (2017, 180) envisaged an online market that tapped into all industries and quantified new material flows as soon as they became available: “Enlightened designers and manufacturers would borrow or lease the material before returning it to the ‘Material Flow Market’”.

EU researchers are active in exploring circular material and product flows in buildings and the role of alternative business models (Geldermans 2016). The BauHow5 group of universities conducted a seminar on *Circular Building Construction*, examining business models involving “material ownership retention by suppliers and delivery of buildings as living, dynamic and adaptable platforms” (Klein 2017). Simultaneously, the Technical University Delft embarked upon *The Façade Leasing Project* in 2016.

One of the most transformative areas of research, which brings together the notions of “open building” and PSS, is the proposition that the changeable, moveable parts of a facility may be provided as a service, which is separate to the base building or real estate. This was first raised by Yashiro (2000, 2004), who sought to disentangle the relationship between skeleton and infill, so that infill could be viewed separately as ‘moveable property’ and provided as an ‘Infill service’. More recently, Zuidema (2015) has sought to elevate thinking on this topic in Europe, recognising that such approaches assisted by “material tracking parameters in BIM” could greatly facilitate open, circular building.

## 2.2. Practices

ARUP introduced what was claimed to be the world’s first ‘circular building’ at the London Exhibition in December 2016. This prototype pavilion incorporated modular and adaptable components with reused content, and employed scanning technologies to identify components and their leasing to enable take-back and reuse. Further prototypes have included the ABN AMRO *Circl Pavilion* in Amsterdam.

With countries such as the Netherlands setting targets for a fully CE by 2050 (Government of the Netherlands 2016), including the construction industry, there has been rapid increase in the introduction of “platforms” such as *Madaster* and *BAMB* (Buildings as Material Banks) to identify and facilitate the reuse of components from existing buildings. Both these initiatives aim to increase and sustain the value of building materials via the “material passport” concept, and pursue the idea that every building is a “material depot”.

## 2.3. The gaps in research and practice

While the above EU initiatives involve platforms whereby building owners may upload digital data on existing buildings as ‘material depots’, they do not enable the real-time identification of reusable components by designers and others, and online interrogation of their location, condition, performance and availability. Although BIM has a capability to capture and maintain the essential knowledge among relevant stakeholders, and enable them to examine the feasibility of reusing building components for projects by importing component models into new designs, research to explore the potential of BIM for improving circularity has rarely been studied (Ness et al. 2015).

The levels of sophistication in the use of RFID, BIM and the Cloud have been uneven (Swift et al. 2015). While some tracking of items by bar or QR codes is practiced as inventory management, this ceases when the items are in-situ and does not extend to their life cycle management.

While the *Madaster* database can be accessed by ‘service providers’, a mechanism does not exist for these providers to remotely monitor and manage their components. In addition, although PSS business models have been applied in other fields, there have been few attempts to introduce these to the construction industry where buildings are normally viewed as long life, immovable entities (as in the French word *‘immeuble’*). Doubts have also been expressed about the efficacy of

providing building and other products as a service. While this has appeared promising in theory, the reality has thrown up a number of barriers. A survey of businesses, government officials and others revealed that low virgin material costs and high upfront investment represented major impediments to adoption of circular business models (Deloitte and Utrecht University 2017). However, a report on the circular phone (Circle Economy 2018) describes legal, operational and financial solutions to unlock the potential of the *Fairphone-as-a-Service* business model. Such approaches have the potential to be translated to the building sector, whereby reusable components are offered as a service (Ness and Xing 2017).

### **3. Research aims and method**

#### **3.1. Aims**

To fill the above gaps in research and practice, the research aims were therefore expressed as: a) Develop seamless interchange of data between physical components using attached RFID tags, BIM and Cloud storage and functionality; b) test the efficacy of a PSS business model for reuse of building components, and c) develop and test a prototype Cloud-BIM data service platform.

#### **3.2. Case Study**

A University of South Australia (UniSA) led research team previously established an integrated agenda for reuse of components enabled by envisaging the connection of a series of well-known digital technologies (RFID, BIM and Cloud-based technology), supported by a PSS business model (Ness et al. 2015). This was followed by a paper to the 'Open Building' session of UIA 2017, which demonstrated that a seamless connection could be made between RFID and BIM (Swift et al. 2017).

This led to the approach for the ARUP GRC Project, which firstly identified via a scoping study and according to Brand's (1995) 'shearing layers of change' – the types of building components with most potential for disassembly, exchange and reuse. These included: framed glazed systems, ceiling systems ('space'); lighting and air handling systems ('services'); and façade systems ('skin'). The *Uniclass* classification system, based on the framework set out in ISO 12006-2: 2015 and able to be assigned to BIM objects, was also used as a typology – with a particular focus on the 'systems' level. Part of the new Royal Adelaide Hospital (nRAH), which incorporated the various system elements, was then selected as a case study. The nRAH provided the most appropriate test site for this project for several reasons: a) It was at the time one of the most extensively documented major building in Australia, hence offered a lot of scope from which to choose a bounded small test site; b) it was accessible to majority of researchers involved in the study; and c) The hospital utilised BIM not only for construction, but also for life-cycle facility management.

Access to the model was negotiated via a representative of BuildingSMART Australasia, also employed by Spotless Facility Management in the ongoing operation of the nRAH project.

Due to the political and commercial implications of making the BIM universally accessible, only a limited number of components were considered prudent to use.

This research on connecting RFID-BIM-Cloud was accompanied by investigations on the viability of providing and reusing these component systems as a service (PSS). PSS enables the performance of a component and its system, such as a framed glazed system, to be managed and optimised by the supplier/service provider over its extended life, such as by regular maintenance, repair or remanufacture as necessary. On the other hand, if a component is continually bought and sold over its life, with no single company able to exercise overall "extended product responsibility", its performance is likely to gradually deteriorate.



The PSS aspect of the research was conducted in collaboration with the Collaborating Centre for Sustainable Consumption and Production (CSCP), Wuppertal, Germany. This involved a series of interviews, within both Australia and Europe, with key stakeholders including designers, project managers, owners, investors, manufacturers and, in particular, a supplier of both internal glazed windows and doors and more complex glazed façade systems.

The supplier was helpful in comparing the economic viability of the PSS approach with business as usual (BAU), using the nRAH for simulating the two scenarios. This comparison was extended to both internal and external glazed systems, with the expectation that a modular, “unitized” and “active” façade system that delivered higher and changeable performance requirements would yield a greater income stream for the service provider.

Finally, the ‘back-end’ RFID-BIM data was integrated with the cloud-based ‘front-end’ user interface that enabled users to identify reusable components, to determine their suitability for alternative application(s), and to procure these either as a service or by purchase.

## 4. Results

### 4.1. RFID-BIM-Cloud data transfer

Using the case study, the research was successful in demonstrating the Cloud-BIM information flow process, as is illustrated in Figure 1.

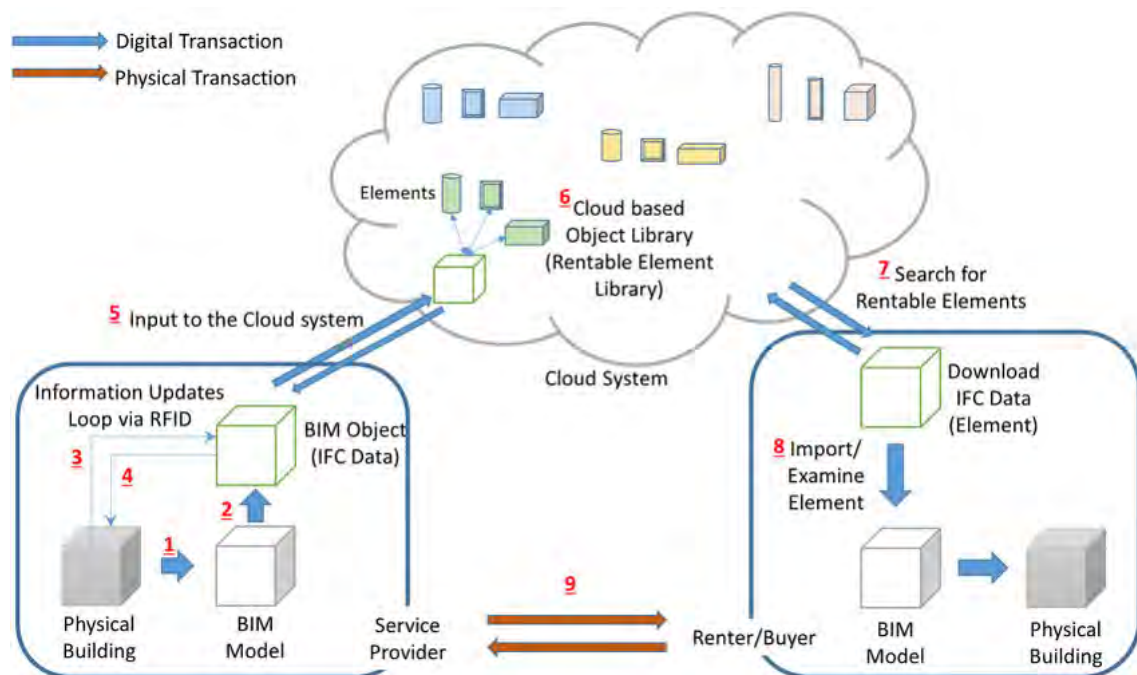


Figure 1 Cloud-BIM information flow

1. A building owner or service provider with an existing building about to be dismantled (or refurbished) could generate (if not already available) a BIM of that building.
2. Once the BIM was completed, it could be converted into IFC format (a universal non-proprietary language) that could be interoperable, regardless of authoring BIM tools such as Revit, ArchiCAD and Tekla (Kim and Park 2018).
3. A RFID tag could be attached (if not already integrated during manufacture) to a physical reusable building component, containing the basic information of the tagged objects and systems: this included the “Uniclass” classification code according to ISO 1206-2: 2015 (ISO

2015), description, material types, dimensions, ownership, life expectancy and geographic location.

4. When changes were made to the tagged object, the updated information could then be recorded within the IFC data and, simultaneously, the information could be updated to the RFID tag. Thus, Step 3 and 4 involved an ongoing periodic update. When the feedback loop was established between the tagged objects and IFC, the IFC data could be uploaded onto the Cloud System in parallel with the full BIM.
5. At this point, the feedback loop was extended to the Cloud System and, finally, seamless information exchange and updates were established between the physical building component and the Cloud System. Consequently, the information feedback loop became a Cloud-based BIM/IFC data system (i.e. Cyber Physical System) underpinned by the AutoID system.
6. Once the information of the reusable elements/components became available via the Cloud system and multiple service providers uploaded their products, a Cloud-based reusable/rentable object library) could be populated.
7. Via the Cloud-based library, it was shown that potential renters/buyers could search via a dialogue based and/or graphical interface for reusable (singular/multiple) objects (products and components).

When a suitable object(s) was identified, a query could be initiated which revealed the dataset associated with that particular component. Due to the limitations of electronic storage space, this full dataset could not be accommodated on the RFID tag, hence the Cloud-based data that includes more visual information such as what it is, its dimensions, materials and ownership to be interrogated, along with other more detailed performance information. For example, exposure to weather could affect the quality and suitability of the object for another application. The query could involve examination of the original BIM model via the IFC data, Cloud-based viewing applications, or using the website searchable interface to conduct multiple parameter-based queries for available building components offered by multiple vendors, or via our software that supplies individual elements. The distance of the reusable component from the destination project could also be ascertained by GPS capability within the search parameters, as this could affect transport and carbon costs.

When a potential user confirmed the suitability of an element, they could download the IFC version of that element via their proprietary modelling package into their model and examine whether it is appropriate for that particular application (8). Therefore, the process from 2 to 8 could be termed as “Digital Inter-Party Transaction”. Once the digital transaction was completed with a confirmation of use of the reusable element, the final step, which is the “Physical Transaction”, could then take place (9).

At this time, due to the physical range associated with writing/reading the RFID tags selected, a hand-held bespoke device would be required to update the data in situ. This process would need to be carried out concurrently with any change of ownership or other variable.

#### **4.2. The product-service business model**

Concerns at the quality and performance of reused components had been raised by stakeholders from various disciplines. The ability to identify, track, monitor and manage reusable components via digital means opens up a number of possibilities to address such challenges. It may not only enable their procurement and reuse as part of traditional purchase-based procurement processes, but also facilitate the addition of various types of services to provide quality and performance assurance.

Multiple buy/sell or conditional transactions could be incorporated into the offerings of available services. These could range from basic services attached to the purchase, such as delivery, warranty and maintenance services, to more advanced services akin to ‘performance guarantee’ coupled with rental/lease options, where the supplier retains ownership responsibilities over the component’s extended life-cycle and licensing its use by customers in appropriate locations

and circumstances. The latter arrangement, although a bigger step for suppliers and service providers, had important benefits. Firstly, it could enable the service provider to defray the initial cost of manufacturing the component, the longer it was used. Secondly, it was more likely to ensure that the performance and value of the component could always be retained (i.e. guaranteed) at its optimum level, as specified and contracted in a 'Service Level Agreement', by regular maintenance and upgrading (Circle Economy 2018). Thus, customers for advanced services could be more confident of the quality and performance of the reused component. Such innovative business models can potentially shift from one-off transactions to a continuing, longer-term partnership. For manufacturers, this creates opportunities to provide an increased suite of services to their customers, with increased profit pools. Meanwhile, customers may benefit from ongoing maintenance and performance support accompanying the products over the term of the contract. In addition to facilitating product recovery and reuse, opportunities also arise for new offerings and profit centres to provide innovative information management services. Installing RFID tags and managing RFID-enabled BIM and life-cycle data can be performed by manufacturers or by third party stakeholders in the supply chain.

With this in mind, the research team explored the various digitally-assisted options with a supplier of aluminium-framed glazing panels. The supplier saw advantages in being able to offer follow-up services attached to sale, such as cleaning and maintenance. However, the greatest opportunity for providing advanced services was with higher-value, modular façades – which could theoretically be disassembled, taken back and reused a number of times. Financial, insurance and other barriers to such a scheme would first need to be overcome, especially the need for additional investment to offset the initial acquisition of the glazed panels and the negative cash-flow at the beginning of the service contract. In this regard, the type of contract and financial arrangement devised for the Circular Phone (Circle Economy 2018) may offer a solution.

#### **4.3. Discussion**

By means of the case study, it has been demonstrated that a well-integrated system comprised of robust individual sub-systems such as Cloud, BIM, RFID and data security systems can guarantee the full functionality of the Cloud BIM based Cyber Physical System by establishing a seamless information and physical circularity of building components. The RFID-BIM-Cloud platform can serve as an information repository and exchange platform, across disciplines and stakeholders, to share and identify the information of reusable building components via utilizing IFC data format, regardless of proprietary BIM software or other system employed by end-users.

The mechanism is aimed initially at new buildings, although it could be extended to existing structures in future. New building systems could be tagged by the manufacturer before delivery to site, with basic data related to the physical dimensions and other information. Enhanced lifetime data could then be added as needed or when re-allocation of ownership occurs. The original tag or "material birth certificate" (akin to the "material passport" concept), if installed by the manufacturer, would improve familiarity and ensure consistency of tag placement, as it would form part of the systematic approach employed as part of the fabrication process.

As the essence of the Cloud-based information exchange system is the 'Universal Accessibility', the security of data related to building components needs to be carefully planned and managed. More importantly, the integrated cyber physical system can only be established properly with a team of multi-disciplinary subject matter experts based on both technical and intellectual aspects, until the system is effectively self-sustaining.

Whilst the cyber-physical exchange system was an important breakthrough towards reuse of building components, its integration with PSS enabled its full capabilities to be delivered. Reusable components could be managed at their optimum performance over their extended life, keeping them in closed loops for much longer period.

## 5. Conclusions and implications

Whilst the research has demonstrated “proof of concept” via a prototype case study and “mock-up” Cloud platform, further research is required to implement the platform and ensure the findings are translated into practice. This is expected to eventuate in a widely adopted, universal and “self-populating” form of eBay, where construction resources are automatically and potentially listed for possible reuse, coupled with their provision as a service and life cycle stewardship.

This phase of the research, however, has confirmed that the Cloud-based Cyber-Physical System, coupled with PSS, is capable of enhancing the circularity of building components, by serving as a platform for capturing, restoring, updating and managing their lifecycle information within the Cloud system. This finding is believed to be an important transformational innovation that has the potential, after further development, to greatly increase reuse and life-cycle stewardship within the building industry.

Using the system, it is expected that designers will be able to assess the condition, reusability, performance and carbon implications of components when considering their suitability for reuse. With the inevitable advent of carbon pricing for new building materials and components, the reuse of existing resources—which makes use of “sunk carbon” is likely to be more financially viable. Reuse will only generate carbon emissions associated with transport, rather than via full resource extraction, manufacturing and production processes – as was shown by a previous case study of structural steel components (Ness et al. 2015).

The successful implementation of the new paradigm can be facilitated by greater adoption of modularization, prefabrication and design for disassembly (Kieran and Timberlake 2004), coupled with increased recognition of the value of building resources, and supportive government policies.

Further investigation is required on the legal responsibilities associated with reliability of data and components procured via the Cloud platform. However, it is expected that responsibility should rest with those who upload data and manage components over their life, whilst the providers of the platform should exercise responsibility for oversight and processes.

Thus, this research is expected to serve as a stepping stone in the era of Industry 4.0 and illuminate a more sophisticated way to manage built assets based on circular economy principles.

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# THE IMPACT OF LEADERSHIP ON INNOVATIVE CULTURE IN THE CONSTRUCTION INDUSTRY

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## Summary

Leadership is an instrument of goal achievement and has been identified as a process that acts on organizational culture and individual behaviors. Effective project leaders require a balance of technical, interpersonal, and conceptual skills. The leadership of innovation enables followers to generate, process, and implement innovative ideas. In this regard, leadership is perceived by many as one of the main pillars of innovation. However, most researchers have studied the innovative traits of the corporate leadership from a rather narrow perspective. There is a need for research that sees innovative leadership from a comprehensive perspective. The aim of this research is to identify leadership skills affecting innovative culture within the construction industry. This study is a literature-based theoretical exploration and a preliminary stage of an ongoing doctoral research. The study findings may inform industry professionals on how the leadership skills can enhance innovative culture in the context of the construction industry to improve productivity.

Keywords: construction, impact, innovative culture, leadership, New Zealand, productivity,

## **1. Introduction**

The construction industry remains dynamic and important for the prosperity of the world. This industry is expected to produce as much as 85% more reaching the figure of \$15.5 trillion by the year 2030 (Global Construction 2030 report). Research results have showed that there is a low level of innovation within the industry and implementing innovation can bring more productivity to the industry ("Pricewaterhousecoopers, 2016). For the building industry to succeed, and find new ways to reach targets, research is required. There is a need of a succeeding, innovative construction industry to bring homes, workplaces and societies which will guarantee a better tomorrow (Ministry of Business, Innovation and Employment, 2013).

Organisations address complex and high-risk business environments by managing change. In order to benefit from more innovative approaches, to further improve their communications and to integrate change quickly, organisations implement change management practices (Project Management Institute. 2013). The market and working environment, should allow innovation to happen and develop. McMeel et al. (2016) state that the leader is also required to guide the construction sector to future technology and should prepare the industry for it.

Leadership is an important part of handling complexity in programs and projects. The following indicate a number of traits which the leader is required to have to guide the program and projects within the organisation: The leader is required to be sponsoring and committed, be aware and highlight key successes of programs and projects within the organisation. The leader is required to be empowering and supportive, aware and goal addressing. The leader is required to be flexible and agile (Project Management Institute. 2014b). The project and program manager have great influence in defining an agile leadership method that could help motivate the program or project team (Project Management Institute. 2014b).

This research, will address the effect of leadership on fostering an innovative environment to the construction industry. The following study aims to provide information on the impact of leadership on innovative culture in the building industry and tries to outline the relevance of the results in the New Zealand construction industry for further research. This topic is under-researched in New Zealand and the results of this study will help professionals and stakeholders understand and practice innovation within their organisations. The findings will inform construction practitioners and industry leaders on how to maximize the impact of leadership towards building an innovative culture. The following study aims to cover the research gap. In this regard, the current study is literature-based and therefore studied the theoretical concepts to view the role of leadership on innovation in the construction industry.

## **2. Literature Review**

Project managers accomplish work through the project team and other stakeholders. Effective project managers require a balance of ethical, technical, interpersonal, and conceptual skills that help them analyse situations and interact appropriately. Important interpersonal skills include: Leadership, Team building, Motivation, Communication, Influencing, Decision making, Political and cultural awareness, Negotiation, Trust building, Conflict management and Coaching (Project Management Institute. 2014a).

Scholars believe that leadership is one of the major abilities of the managers. Leadership can help reach targets, (James et al. 1976) and simultaneously affects the culture of the company and also the behaviour of the employees. (Ostroff, et al. 2003). In this regard, there exists a close relation between organisational culture and leadership (Berson, et al. 2006). Leadership is believed to have a great influence on the culture of the organisation. (Amabile et al. 2004; Damanpour et al. 2006; Peterson et al. 2009). The leader can greatly support a culture of innovation within the organisation. An influential individual within the organisation can define the innovativeness of the organisation. These are the decision makers within the company. They can initiate, manage and improve innovation within the organisation (Barlow, 2000; Tatum, 1989).

## **2.1. Leadership**

It is the leader of the organisation whom is required to take care of the needs. Project managers are conceived as a particular level of leadership. Project management is an important and decisive study. The project manager is conceived to be liaising between the employers and the company goals. The leader should be aware of the opportunities and benefit to the most. Therefore, there is a need for great knowledge and experience and the leader should have an aim towards the future plans of the firm. Building and maintaining the agility of the firm to face new challenges and benefit from them is an important part of the leader's responsibilities (Project Management Institute. 2014a).

In different stances, what makes the difference is in fact the level of preparation and the environment that can foster innovation (Loosemore, 2015). Innovation is in fact a very complex process and it can bring a huge amount of gains for the companies and their beneficiaries. Research demonstrates the importance of leadership in the innovation process and insists that the leadership is more important than having a formal strategy in innovation. It is also important to demonstrate the benefits of doing new things than just talk about them. Without leadership, innovation could not happen and succeed (Loosemore, 2015). In the case of possible tensions as a result of various views of stakeholders, it is the innovation leadership whom can maintain collaboration and resolve issues. (Adner, 2012; Jung et al. 2003).

Research on construction leadership has been very limited (Chan et al. 2005). The current trend on research on innovative leadership is mainly on transformational leadership, power studies, leader's traits, style and behaviour and emotional intelligence of the leader (Chan et al. 2005; Liu et al. 2006; Ogunlana, 2008; Skipper et al. 2006; Wong, et al. 2007; Songer, Chinowsky et al. 2006).

## **2.2. Leadership Styles and Innovative Culture**

Many research results support the acceptance of transformational leadership in construction industry (Limsila et al. 2008). The results also show transformational leadership brings more gains than transactional and laissez-faire leadership. (Ofori et al. 2012). The transformational leadership of the company takes care of the employer's main needs. His charisma, specific focus, and intellectual stimulation can influence his intentions and success rate. (Liu et al. 2017a). On the other hand, the transactional leader takes note of the employee's successes and rewards them. (Avolio, et al. 2004). The leader's ability to use charm and personal abilities to bring the team together is called charisma. Giving rewards, giving focus on individual and simulating intellectually is also important. (Avolio et al., 2004).

The transformational leader encourages the employees towards change while the transactional leader is not similar. Encouraging change has a great impact on innovative culture in a positive manner. (Elenkov et al. 2005; Garcia-Morales et al. 2012; Jung et al. 2003).

Depending on the traits an organisation holds, particular leadership styles are chosen and not every style would be suitable for every organisation. The way a team is motivated by the leader and the internal traits define the ability of the leader (Fiedler, 1972) Some research support the ability of the transactional leader on motivating followers in a given time by offering prizes (Zheng et al. 2017). While other research state the transformational leader is suitable in an innovative environment. Therefore the environment and culture of the organisation should be considered while studying on innovative leadership (Gumusluoğlu et al. 2009). In this sense, there is a research gap to comprehend the results of the previous research and gather the results, so they would be more useful and comparable. A research could look in to the impact of leadership styles on innovative capability of the organisation in regard to the different context and culture of the organizations.

### **2.3. Leadership Skills and Innovative Culture**

Success is susceptible to leadership. (Turner et al. 1993). The nature of the work also defines the success rate. (Zhang et al. 2009) Complexity of the construction industry also affects the success rate. Collaboration is also compulsory for success (Jarad, (2012). Collaboration amongst employees is decisive and to ignite group work, the leader's knowledge and experience is vital. Since the leader defines many variables within the company, the leader becomes the key player within the organisation (Liphadzia et al. 2015). While it is quite impossible to cover the whole literature in one research, this paper studied some of the leadership skills that are required from the leader in an innovative environment. A collection of these attributes is presented in Table 1. The objective of this research is gaining approval from our understanding of decisive attributes through looking at studies around the world. As a result, our existing knowledge will be endorsed.



*Table 1 Leadership skills required from the leader in an innovative environment:*

Title	Leadership and Construction Industry Development in Developing Countries	What makes an "innovation champion"	Understanding the Interplay of Organizational Climate and Leadership in Construction Innovation	Leadership for future construction industry: Agenda for authentic leadership	Relationship between leadership styles and project success in the South Africa construction industry	Role of Leadership in Fostering an Innovation Climate in Construction Firms	Integration and Leadership as Enablers of Innovation in Construction: Case Study
Author	George Ofori and Shamas-ur-Rehman Toor	Natalya Sergeeva	Anita M. M. Liu and Isabelle Y. S. Chan	George Ofori	Muredeni Liphadzia, Clinton Aigbavboa, Wellington Thwalac	Isabelle Y. S. Chan; Anita M. M. Liu; and Richard Fellows	Beliz Ozorhon; Carl Abbott; and Ghassan Aouad
Purpose	Leadership issues in the construction industry	Construction leadership traits	Relationships between leadership, climates, and innovation	Authentic leadership in the context of construction projects	Determine the relationship between leadership styles and project success	Association between leadership and innovation in the construction context	Gain insight on how innovation is achieved within a construction project
Year	2012	2016	2017	2007	2015	2014	2014
Study Area	Developing countries	UK			South Africa	Hong Kong	UK
R1	Vision	Openness to ideas	Charisma	Confidence	Clear vision	Charisma	Customer focused
R2	Hopefulness	Creativity	Intellectual stimulation	Hopefulness	Clarity	Inspirational stimulation	Commitment
R3	Dedication	Self-confidence	Individualized consideration	Optimism	Practicality	Intellectual stimulation	Effectiveness
R4	Tenacity	Self-esteem	Contingent reward	Resilience	Team Attraction	Individualised consideration	Communication
R5	Relationships	Communication		Transparency	Team performance managing		Knowledge sharing
R6		Technical knowledge		Morality/ethical	Collaboration		Change acceptance
R7				Future-orientedness	Performance igniting		Experience
R8				Comprehension of cultural sensitivities	Boundary setting		Advance product provider
R9				High motivation			
R10				Self-awareness			
R11				Integrity			
R12				Deep sense of purpose			
R13				Courage			
R14				Passion			
R15				Skill of leadership			
R16				Technical ability			

Note: R = Rank

The above mentioned indicate the impact of leadership on innovative culture of the construction industry. In other words, the innovative leader brings along the traits mentioned in table 1 for the relating organization, which result in the application and implementation of the mentioned traits for the benefit of the organization and the construction industry as whole. Since the mentioned are mainly positive and beneficial traits, therefore the impact of the innovative leader will be a positive impact. The results of this study, aims to address the existing research gap in understanding the required traits from a leader who takes on the responsibility of addressing the construction industry's need for innovation.

### **3. Research Methodology**

This theoretical research is based on previous literature and looked into leadership traits which could influence the organisational culture towards innovation. The review of previous research results provided an understanding of some of the main attributes a leader requires to guide the innovative goals of the company. National reports, academic journals, textbooks and conference papers were reviewed through databases and search engines. The results were achieved by performing a literature survey and information which were found useful to the topic were concentrated on.

The mentioned research strategy allows for a review of similar work which can add to our knowledge of the field (Cooper, 2010). The results pave the way for further study, fill the research gap and adds to the existing knowledge (Marshall et al. 2011). This research strategy can demonstrate the importance of the topic and can also allow for comparison of previous research results (Cresswell, 2014), therefore gaining detailed results becomes possible. The mentioned is achieved by closely studying theoretical concepts. In this method, the detail and quality of the study should be prioritised against quantity.

Many publications and work of researchers have been chosen by searching many databases like Scopus, Google Scholar, ASCE library and ScienceDirect. The keywords were chosen with special consideration in order to gain access to the relevant data. Keyword combinations of innovation, leader, construction, industry and culture were found to be useful. The publications were provided by International Journal of Project Management (IJPM) Journal of Management in Engineering, Journal of High Technology Management Research, International Marketing Review, Asian Journal of Technology Innovation, International Journal of information, knowledge, and management, Journal of Construction in Developing Countries and etc. The mentioned journals provide the mainstream knowledge areas of project management in construction.

Initially, 410 articles were found to be potentially useful. Following an initial examination, 172 articles were shortlisted depending on their relevance to this topic and were chosen for full review. Amongst them 35 papers were directly used. Measures of criticality, citing and significance in results were engaged to classify and drive the main constructs within the literature. Publication timeline of the reviewed literature was taken into consideration to put emphasize on current literature, while still respecting the importance of the knowledge presented in less current publications. With the use of the process of reduction, attributes of relationship are extracted and categorized (Jones, 2007) Within this method, by applying "de-contextualisation" required parts of text are separated from the chosen articles and a separate meaning is extracted by applying a process of "re-contextualisation" (Richards, 2002).

### **4. Findings from the review of literature**

Reviewing the results of previous literature, (Table 1), demonstrates a number of traits as more frequently occurring. As a result, it becomes evident that these attributes should be more emphasised and built up within a successful innovation leader. The mentioned adds to the current level of information on innovative leadership within the construction industry that can provide an

innovative culture. The results could be adapted and used for further study of the innovative leadership within the New Zealand construction industry.

Also, a detailed look at the results in Table 1, reveals a number of variables as organisational attributes that can greatly affect the innovative culture of the construction industry and have been gathered from a number of contexts. The study highlights the following traits as important for a successful leadership: Vision, Openness to ideas, Charisma, confidence, Hopefulness, Creativity, Intellectual stimulation, Clarity, Inspirational stimulation, Dedication, Individualized consideration, Optimism, Practicality, Tenacity, Self-esteem, Contingent reward, Resilience, Team Attraction, Individualised consideration, Relationships, Communication, Transparency, Team performance managing, Technical knowledge, Morality/ethical, Collaborating, Future-oriented, Performance igniting, Comprehension of cultural sensitivities, Boundary setting, Self-awareness, Integrity, Courage, Passion, Skill of leadership, Technical ability and etc (Chan et al. 2013; Liphadzi et al. 2015; Liu et al. 2017b; Ofori, 2008; Ofori et al. 2012; Ozorhon et al. 2013; Sergeeva, 2016). Among these traits, some could be regarded as more frequently occurring while the mentioned traits could affect the organisational culture depending on the environment and context under study. Clearly, the insight gained through this research is applicable for practice within the New Zealand construction industry. According to the findings, the mentioned traits can empower construction leaders to promote an innovative culture within the New Zealand construction industry.

## **5. Conclusion and Further Research**

The presented research indicates a number of leadership traits as more important and influential for a successful innovative environment. To mention, Vision, Charisma, confidence, Hopefulness, Creativity, Dedication, Optimism, Practicality, Tenacity, Self-esteem, Contingent reward, Resilience, Team Attraction, Individualised consideration, Relationships, Communication, Transparency, Team performance managing, Technical knowledge, Collaborating, Self-awareness, Integrity, Courage, Passion, Skill of leadership and technical ability stand out from the rest (Chan et al. 2013; Liphadzi et al. 2015; Liu et al. 2017b; Ofori, 2008; Ofori et al. 2012; Ozorhon et al. 2013; Sergeeva, 2016). The mentioned will be the base of further research in a pilot study by engaging construction professionals. The results will allow for further understanding of the New Zealand construction industry and the influential variables on innovative culture. The results of an early study indicate leadership, and the structure of the firm as two of the most important factors that enable innovation within the construction industry context (Tatum 1987)

The innovative leader's innovative traits include but are not limited to the traits mentioned in table 1. These traits are mainly considered positive for the benefit of the organisation and the industry. This paper provides beneficial knowledge for scholars for developing scholarly case studies. The mentioned can be achieved by reviewing the details of firms which their leaders practice innovation, benchmarking their success stories and finding similarities with other successful company leaders. This will enable innovation and new ideas and methods to be adapted within the organisational context.

Also, this theoretical research, based on the previous literature, provides practical awareness regarding the attributes that require special attention from the leadership of the company. This will promote the required innovative culture. Leaders, professionals and other stakeholders can focus on innovations and benefit from the added productivity that could be achieved.

This paper is seeking to improve the leader's ability in decision-making process of the construction industry especially the New Zealand construction industry. This research will attempt to help the leaders of the construction industry in taking up approaches towards improving the value of innovation within the construction industry.

Research outcomes will support professionals within the construction industry to embrace change and to understand what effective innovative solutions and approaches mean for our 21st

century lives. This research will endeavour to improve the productivity of the practices within the construction industry.

By improving the results of this study, a tool for innovation, specifically for New Zealand construction industry is intended. The tool will allow for better and faster uptake of innovation within the construction industry.

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**PERFORMANCE**



## TOWER BLOCKS IN DIFFERENT CONFIGURATIONS - ASPECTS OF DAYLIGHT AND VIEW

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### Summary

The groupings of buildings can be made in different regular geometric patterns or in more irregular arrangements. In the PLEA-study “Urban Form, Density and Solar Potential” Cheng et al. (2006) tested some alternatives with uniform/random heights and patterns. The research team concluded with pointing out the advantages of randomly positioned buildings compared to repetitive patterns with respect to daylight access and solar potential. In our opinion the conclusions about random layouts should be interpreted in terms of specific variations. This suggests that there may be strategies for patterns and heights - not simply random arrangements - which this new study clearly confirms. Although the authors of the 2006 study underlined the need for further studies, as far as we know, no research of building groupings has been done.

In this research a series of geometrical patterns of tower blocks was developed to examine daylight conditions. Some are already used in practice while others seemed to be very promising. The choice of evaluation criteria was based on the discourse in the scientific community on daylighting and on practical experience in urban planning. The view was also included as in the new EU standard. The study is carried out for an assumed FAR (Floor Area Ratio) of 1,12 with buildings of seven floors. Advanced computer based daylighting simulations and calculations of view parameters have been done for seven different designs of building groupings of equal density.

All seven groupings have good daylight conditions with Vertical Sky Components over 40%. The six alternatives to the quadratic reference model have higher sunlight radiation on façades, especially on lower floors, due to their less perpendicular orientation to the surrounding blocks. The same alternatives have sightlines up to 3-7 times longer than in the reference model. These advantages depend on the oblique, triangular and scattered configurations as well as the different shapes of the ground floor area. The quadratic group is the most common pattern for tower blocks. Unfortunately it also has the worst possibilities for view with a perpendicular view of 30 meters compared to 50,7 to 93,3 meters for the alternatives. Local conditions as well as technical requirements must – as always – influence layouts. However, the six alternatives can still produce tangible consequences thanks to considerations of daylight and view.

Keywords: Daylight, Views, Urban Morphology, Tower Blocks.

## 1. Introduction

Urban geometry can be created in many different ways. Mark DeKay worked on the evaluation of different forms of a city quarter to find out which has the greatest potential for daylight autonomy by asking: “What would the form of the city be like if we were to take seriously the provision of daylight to all buildings?”(2010). He developed different geometries of quarters and verified daylight availability. Following this, Peter Andreas Sattrup and Jakob Strømman-Andersen made energy simulations to calculate the total energy consumption and the daylight autonomy for six different building patterns (2013). Simulations examined how density ratio in urban blocks affects solar gains and daylight autonomy. Of all studied patterns the results were best for free standing tower blocks.

A previous study by Vicky Cheng et al. (2006) focused on differences between uniform groups of tower blocks (equal height and repetitive parallel patterns) and groups with variations in height and position. The research team pointed out the advantages of randomly positioned buildings of different height compared to uniform groups with respect to solar potential, but concluded there was a need for further research. The present study goes deeper into this topic and broadens the investigation to include views.

This paper presents a study of seven different groups of tower blocks which evaluates the solar radiation on façades and plots, the daylighting accessibility (vertical and standard sky factors) and the potential views. In this paper only a part of the study is presented, i.e. alternatives where all blocks are of equal height. The evaluations have been done with computer simulations. We will continue the tower block research and also comment on the present study in detail, especially with respect to strategies and “random” solutions. This ongoing project will also include other settlement configurations e.g. perimeter blocks.

The basic geometries in the modelled alternatives are simplifications of common modern examples together with some new patterns. The patterns of similar buildings in existing urban settlements are usually grouped in one of two typical patterns, parallel, P or oblique, FO, see figure 2. Even in smaller groups such as 4-5 buildings along a street the same strategies are common. Regarding the interior and the exterior qualities for daylight and view based on practical observations this study confirms that the oblique pattern is the best. A third type, an irregular grouping, is used mainly in some low density developments in order to adapt to the terrain.

The oblique positions can be fully rotated 45°, Full Oblique, from the parallel as well as to other angles as in the illustration below with half that rotation, SO. In a current report focusing on urban structures and energy, that pattern is also mentioned by Philipp Rode, et al (2014). Here we classify the pattern as Semi Oblique. It is sometimes used on a small scale.

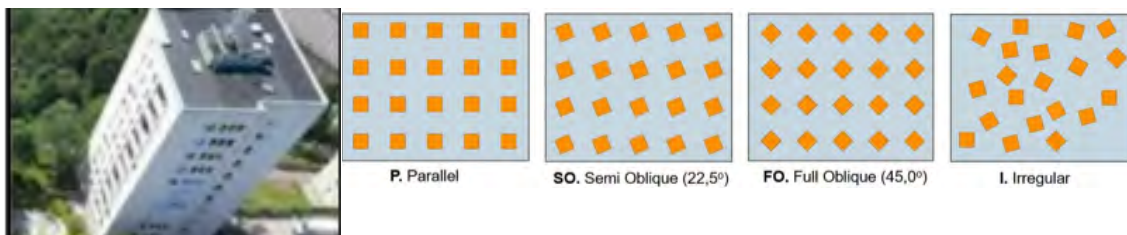


Figure 1 A Typical Tower Block (©2017, hitta.se)

Figure 2 Four groupings of tower blocks.

We regard six important parameters in the urban morphology of tower blocks. This ongoing study deals with all of them;

1. Block heights.
2. The shape of a single block, especially the plan form of the built ground area – the urban foot print, and the proportion between the height and the foot print dimensions.

3. Orientation of the single block in different compass directions. In Trio, alternative 4 in section 2 below, every building in each group is orientated in a different direction.
4. The shape of the area for the whole group.
5. The patterns of the groups of the blocks.
6. Orientation of the groups of blocks in different compass directions.

## 2. The Alternatives

The developed alternatives represent both existing settlements and new proposals (4, 5, 6 and 7 are developed within this project). It is possible to mirror alternatives 2 and 5 to improve their adaptation to local conditions. The alternatives have been developed in Sketch Up-drawing, see figure 3. The intentions for each of the seven alternatives are stated below.

The blocks in the three “*pattern*” alternatives have variations according to the following:

1	QUADRATIC	blocks are grouped in a quadratic pattern. This simple and very typical alternative is used as a reference.
2	SEMI-OBLIQUE	the Quadratic alternative with every block obliquely positioned - rotated 22,50°.
3	FULL-OBLIQUE	the Quadratic alternative with every block obliquely positioned - rotated 45,00°.

Both groups in the two “*courtyard*” alternatives are orientated around a courtyard:

4	TRIO	blocks of three are grouped in a triangular pattern.
5	OBLIQUE-FOUR	blocks of four are grouped in an “oblique pattern”. This alternative is similar to TRIO but the buildings are orientated according to a rectangular grid, so it is easier to adapt them to a quadratic street grid.

The tower blocks in the two alternatives with different “ground forms” are arranged to develop better light and sight conditions than in the usual rectilinear layout:

6	HEXAGON	hexagon-shaped blocks in a pattern of hexagonal plots. It is important that the blocks are rotated clockwise 30,00 in order to improve the sight and the light perpendicular to the windows.
7	DECAHEDRON	polygon-shaped blocks (ten façades) in a pattern of rectangular plots. All façades are orientated in order to improve the sightlines and the light perpendicular to the windows.



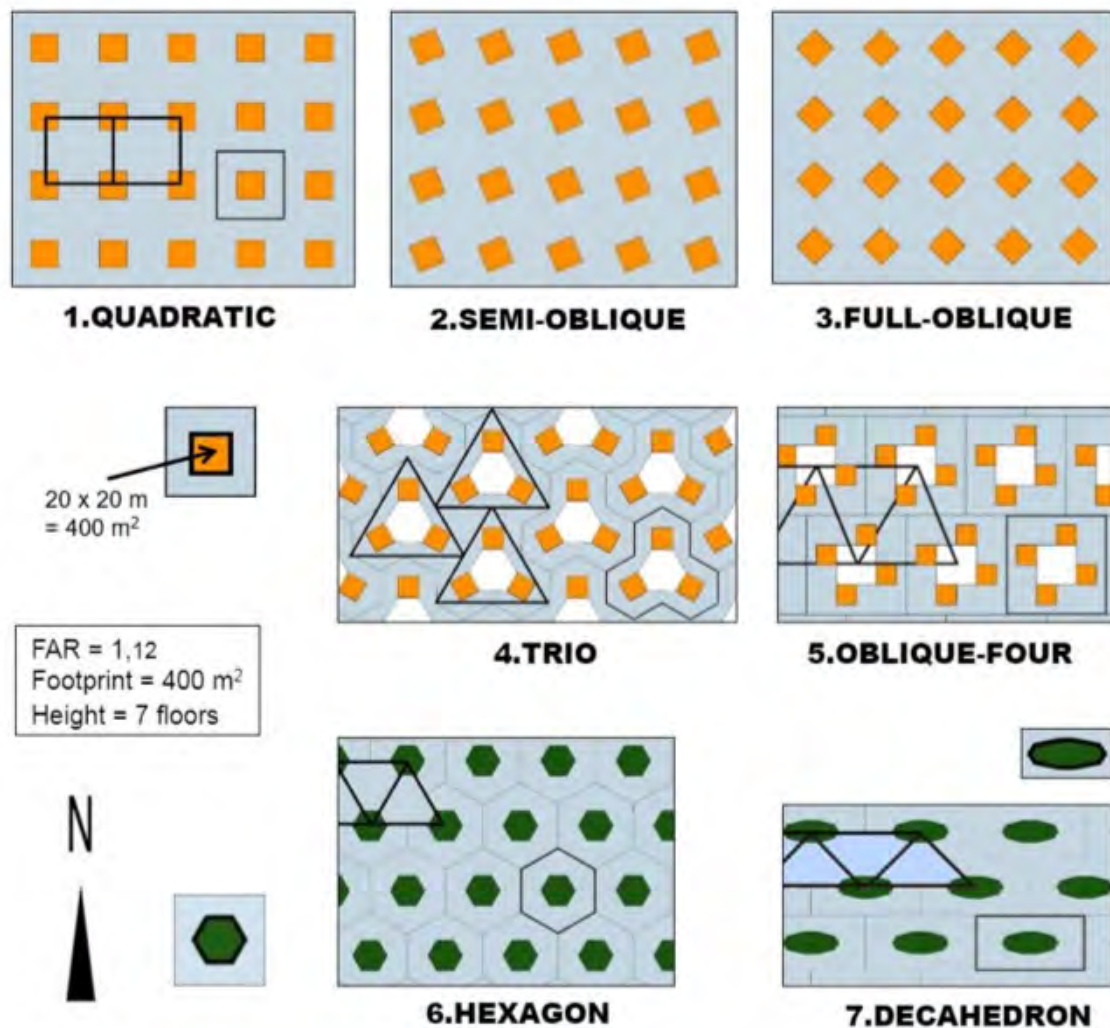


Figure 3 The seven alternatives for groups of tower blocks.

Modern tower blocks are often 20 meters wide with four apartments (one in each corner) which are wider than previous blocks of around 18 meters. This is because of new building regulations for disabled people and economic considerations. The following dimensions have been used in all alternatives (except the footprints in the alternative 6 and 7):

$w$  = width = 20 m

$A_{fl}$  = floor area =  $w \times w = 400 \text{ m}^2$

$A_{bg}$  = building area (built area on the ground, foot print) =  $w \times w = 400 \text{ m}^2$

$n$  = number of floors = 7

$h_{fl}$  = 3 m (height of each floor)

$H$  = 21 m (total height)

$A_{pl}$  = plot area =  $50 \times 50 \text{ m} = 2\,500 \text{ m}^2$

**FAR** = floor area ratio = total floor area/plot area =

$$n \times A_{fi}/A_{pi} = 7 \times 400/2500 = 1,12$$

FAR = FSR (floor space ratio), FSI (floor space index), site ratio and plot ratio.

Even groups of taller buildings (skyscrapers) and smaller ones (villas) demonstrate the same relative advantages for patterns with the same grouping and the same foot print. However, in this study, it was important to investigate the specific conditions for each group of tower blocks.

### 3. The Daylight in the Urban Areas

The daylight conditions in the seven alternatives, see figure 4, have been simulated in three ways:

- Sunlight radiation on façades and on plots, average value, during the 1st of May from sunrise to sunset (kWh/m<sup>2</sup>).
- Vertical Sky Component on the façades (VSC), average of all façades; 50% is the maximum value.
- Sky Component on the plot area (SC), average across the plot; 100% is the maximum value including visual access to the whole hemisphere.

All the simulations have been done with DIVA for Rhino, a well-recognized tool for climate based and static daylighting calculations. The DIVA (Design, Iterate, Validate and Adapt), a plug-in for Rhinoceros software, enables effective calculations of daylight metrics, e.g. daylight factor, using the Radiance/Daysim engine. Climate data for Stockholm was used. By keeping the reflection factor of the block surfaces and the ground close to zero (0,01%) the daylight factor script in DIVA was used to calculate SC and VSC. All simulations have been executed by Postdoctoral Fellow Shabnam Arbab at the NTNU, Trondheim, Norway.

All seven alternatives have good daylight accessibility, e.g. the average VSC, Vertical Sky Components, is over 40% (27% is recognized as good enough and 50% is the maximum). The average SC, Sky Components, on plots is also high, see figure 4. HEXAGON has highest values both on façades (VSC) and on the plot (SC).

All the six alternatives to the QUADRATIC have slightly greater sunlight radiation on the façades due to the less perpendicular positions of the surrounding blocks. Regarding sunlight radiation on the plot areas, only HEXAGON has a higher value compared to the QUADRATIC. It is different to optimize for the buildings compared to optimizing for the plot. The exception, HEXAGON, has more daylight and an even better view depending on its form and a small rotation of the building (30,00) from the original position on the plot.

The differences between average solar radiations on façades in the alternatives are not strong as very high values of top and middle floors dominate calculations of average values. However, deeper consideration of the details of the simulation results confirms that solar radiation on façades at the level of 1st floor (worst places on façades) on all alternatives is significantly higher than in QUADRATIC.

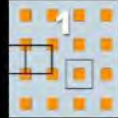


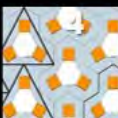

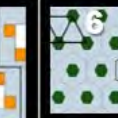
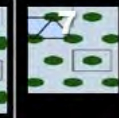
<b>DAY-LIGHT</b>	 <b>1</b>	 <b>2</b>	 <b>3</b>	 <b>4</b>	 <b>5</b>	 <b>6</b>	 <b>7</b>
	<b>QUADRATIC</b>	<b>SEMI-OBLIQUE</b>	<b>FULL-OBLIQUE</b>	<b>TRIO</b>	<b>OBLIQUE-FOUR</b>	<b>HEXA-GON</b>	<b>DECA-HEDRON</b>
<b>SUNLIGHT RADIATION 1<sup>ST</sup> OF MAY : Facades (kWh/m<sup>2</sup>)</b>	<b>2.94</b>	<b>2.96</b>	<b>3.04</b>	<b>3.04</b>	<b>3.00</b>	<b>3.06</b>	<b>2.95</b>
<b>Plots (kWh/m<sup>2</sup>)</b>	<b>3.88</b>	<b>3.86</b>	<b>3.84</b>	<b>3.83</b>	<b>3.81</b>	<b>3.95</b>	<b>3.85</b>
<b>VERTICAL SKY COMPONENT: Facades (%)</b>	<b>43.78</b>	<b>43.82</b>	<b>43.87</b>	<b>44.07</b>	<b>43.53</b>	<b>44.34</b>	<b>43.28</b>
<b>SKY COMPONENT: Plots (%)</b>	<b>76.72</b>	<b>76.61</b>	<b>77.53</b>	<b>75.12</b>	<b>76.61</b>	<b>78.19</b>	<b>76.52</b>

Figure 4 Daylight conditions in the alternatives.

#### 4. The Views in the Urban Areas

People's views in urban settlements consist of their visual experience of the outdoor environment. Qualitative details of the views of beautiful streets with well-designed outdoor furniture and decorative façades are important to that perception. The aspects of people's experiences in views from windows are many; see Matusiak & Klöckner (2015).

However, the crucial aspects to consider in the early stages of urban planning are the geometrical structures which limit both quantitative and qualitative opportunities of the fields of vision. Here we only consider simplified building alternatives.

Wide angle views of long distances give better opportunities for attractive views than short and narrow views even in detailed urban design. Large open spaces and strategically positioned openings between buildings are examples of how settlements can create such views. The measurements for the views described below, 1-4, are part of the criteria for the comparison of alternatives.

The views are multifaceted and include important aspects such as privacy and safety. It is also important to remember that there is a correlation between the assessment of daylight and the view quality as well as indoor privacy. The presence of people in the views is also appreciated in most cases even if exceptions exist such as noisy outdoor events.

Aesthetic values depend greatly on individual preferences which differ from person to person. However, general aspects of the aesthetics are important in urban design and are correlated with complexity, maintenance, age, composition of the view, etc. In a current EU-standard the diverse aspects of views are described as follows:

*"View windows provide contact with the surrounding, information about orientation, weather changes and time over the day. A composition of a view, which includes layers of sky, city or landscape, and ground, could counteract fatiguing monotony and contribute to relief from the feeling of being closed in. All occupants should have the opportunity for the refreshment and relaxation afforded by a change of scene and focus. A natural view is preferred over a view towards man-made environment and a wide and distant view is appreciated more than a narrow and near view. A diverse and dynamic view is more interesting than a monotonous view. View to the nature may have positive influence on people's sense of wellbeing, on job satisfaction, and recovery of surgical patients." see CEN/TC, Annex C, (2018).*

The view described as the length of the sightline in different directions is of primary interest. Some settlements have good possibilities for views and some do not despite the same density measured as floor area ratio. This is of importance especially in the planning of high density settlements.

#### 4.1. Geometry Impact the Privacy

Increasing urbanization including the replacement of low buildings with taller ones and infill with new buildings leads not only to darker indoor and outdoor environments. Privacy will also be reduced.

A good view consists of many attractive elements. In contrast to the visual connection between the parents and their children, the sight of a stranger often reduces privacy. However, privacy is difficult to achieve in dense urban settlements and requires intelligent geometry such as zigzag façades, star block houses and chamfered. The six alternative groupings of tower blocks give more privacy than the QUADRATIC group depending on longer sightlines and less central views to the surrounding tower blocks in the alternatives.

#### 4.2. Two Different Views from the Windows

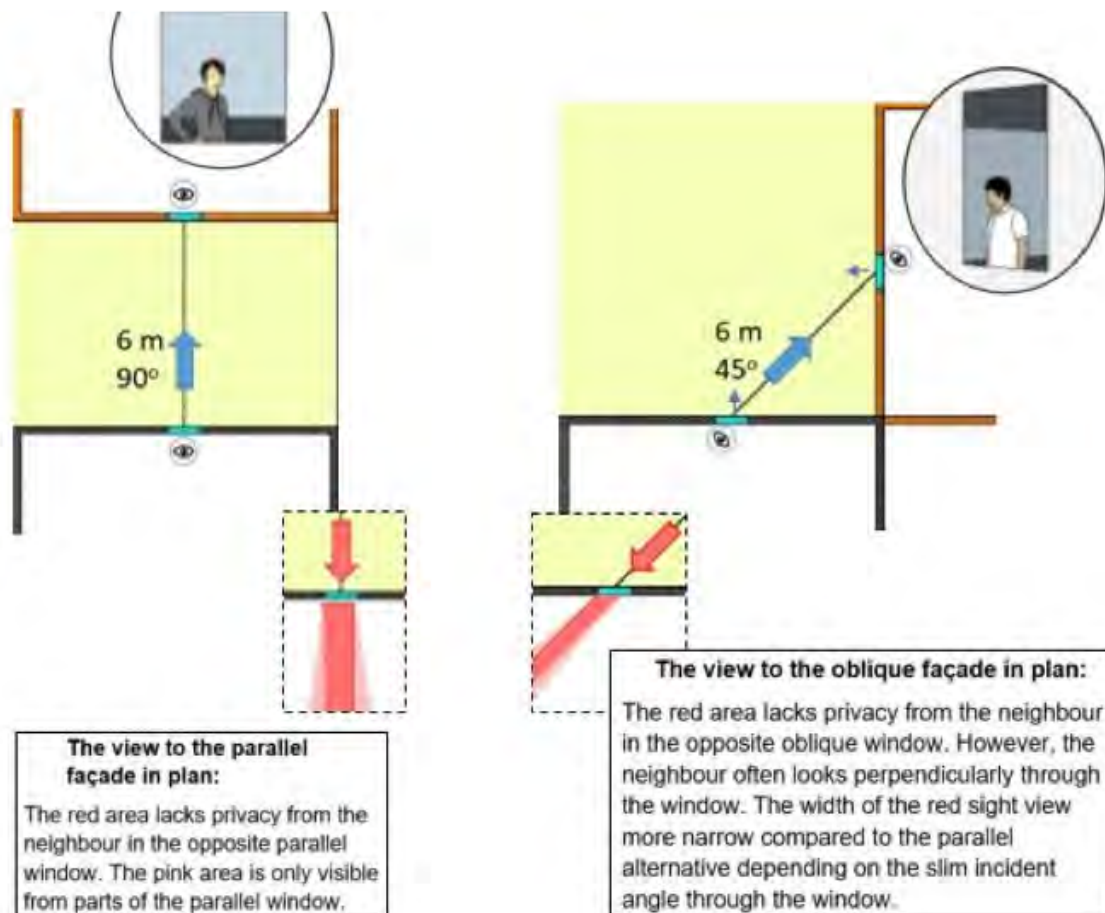


Figure 5 The view to a parallel and an oblique façade.



### 4.3. Obstructions in Views from the Windows

With the assumed measures of the window in the simulations it is possible to see 138° using different viewing positions. On both sides along the façade, up to 21°, there are absolute obstructions.



Figure 6 Three different viewing positions have different possibilities for width of view.

### 4.4. Viewing Conditions for the Alternatives

The following four ways describe the views in urban alternatives. All views are from one window in the building (calculated as an average of different positions along the façade):

1	<b>D<sub>average-138</sub></b>	Average distance to the surrounding buildings within 138° excluding 42° of the 180° of the sight which are obstructed by the frame of the window, see figure 6.
	<b>D<sub>average-54</sub></b>	Average distance to the surrounding buildings within 54° (m) – angle width for a central field view, (from CEN/TC 169).
2	<b>D<sub>perpendicular</sub></b>	Perpendicular distance to a building (m) - measured along the perpendicular sight line to the window. Broad views out consist of that sightline.
3	<b>D<sub>max</sub></b>	Maximal distance to a building within 138° (m). A long maximal distance is good for the view and for daylight distribution.
	<b>C,centrality</b>	Centrality angle for the maximal distance (°). The best is the perpendicular view from the window, 90° and worst is 21° which is the lower limit depending of the obstructing beam of the window.
4	<b>D<sub>min</sub></b>	Minimal distance to a building within 138° (m). For good privacy the distance should be further than 20 meters according to practical guidelines.
	<b>P,periphery</b>	The peripheral angle is the deviation in the minimal distance from the perpendicular normal (°). Oblique distances with very peripheral angles preserve privacy better and are limited to 69° depending on the obstructing frame of the window.



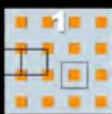



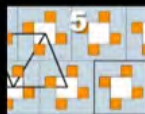


<b>VIEW</b>							
D <sub>istances:</sub> (m)	<b>QUADRATIC</b>	<b>SEMI-OBLIQUE</b>	<b>FULL-OBLIQUE</b>	<b>TRIO</b>	<b>OBLIQUE-FOUR</b>	<b>HEXAGON</b>	<b>DECAHEDRON</b>
D <sub>average</sub> 138°	78,5	103,9	80,4	80,3	95,0	91,2	-
54°	75,7	88,5	87,6	96,8	90,2	119,7	-
D <sub>perpendicular</sub>	30,0	90,8	50,7	73,0	90,0	71,5	93,3
D <sub>max</sub>	166,3	299,6	192,8	172,6	610,7	228,0	274,2
C, Centrality 21-90° =Perpendicularity	51,5°	27,9°	54,4°	72,0°	33,7°	68,0°	83,2°
D <sub>min</sub>	30,0	27,7	29,6	32,5	22,6	32,4	27,5
P, Periphery 0-69° =Obliqueness	0°	19,2°	58,8°	45,9°	26,6°	39,5°	11,5°

Figure 7 View values in the alternatives.

The views are calculated and analysed for the QUADRATIC group and the six alternatives, see figure 7. Summing up the view analysis:

- In alternative groups of tower blocks, the sightlines can be up to 3-7 times longer than the QUADRATIC and the interior privacy can be improved and secured.
- The QUADRATIC group has the worst possibilities for views with a perpendicular view of only 30 meters compared to distances 50,7 to 93,3 meters for the alternatives.
- In all the distance parameters the results point in the same way except for some minimum distances which are up to 7,4 meters lower than the quadratic value, 30 meters. Those exceptions consist of more peripheral sightlines than the perpendicular view for the QUADRATIC so the difference in perception of privacy is not so big.
- The maximal distances are longer in all the alternatives to the QUADRATIC group - up to 610,7 meters compared to 166,3 meters.
- Each alternative has its own specific profile of view conditions. Depending on those differences in the alternatives, local needs and local conditions can often be satisfied.
- The secret to the advantages of the alternative groups is the different geometries of the oblique and triangular groups as well as the different configuration of the ground area of the blocks.

## 5. Conclusions

All seven models have good daylight conditions with average Vertical Sky Components on façades well above 40%. The average Sky Components on plots are also high in all alternatives, over 75%. HEXAGON scores highest values, both on façades and on the plot. The alternatives to the QUADRATIC have higher sunlight radiation, which is the result of less perpendicular positions of the surrounding blocks in the alternatives. This is especially significant at first floor level. The alternatives to the QUADRATIC group of tower blocks have up to 3-7 times longer sightlines. The special geometries give advantages to the alternative oblique, triangular and scattered groups as well as the different shapes of the ground area of the blocks.

The QUADRATIC group is the most used pattern for tower blocks in town planning. Unfortunately it also has the worst possibilities for offering views with a perpendicular view of 30 meters compared to distances 50,7 to 93,3 meters for the other alternatives. Local conditions as well as technical requirements must – as always – influence layouts. However, the alternative tower

blocks can still produce tangible consequences thanks to considerations of daylight and view. After some practical applications we will know better how big these impacts can be.

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# ASSESSING THE LIGHTING PERFORMANCE OF AN INNOVATIVE CORE SUNLIGHTING SYSTEM

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## Summary

This paper presents an efficient daylighting technology to improve the lighting conditions in deep interior spaces of multi-story buildings without the penalties of increased solar heat gains. A passive horizontal solar light pipe is proposed to efficiently redirect sunlight to distances between 5m to 10m from the building façade. Photometric measurements throughout a year show that the system can consistently provide more than 300 lx during 9 hours (9:00 to 18:00) under clear and partly cloudy skies, and during 4 hours under overcast sky conditions (exterior global horizontal illuminance, EXGH, over 18-20 klx). In addition, the illuminance values, over 1,000 lx are achieved consistently between 10:30 and 16:30 under clear sky conditions. At the back of the space (7.6m under the light pipe), the Useful Daylight Illuminance autonomous (UDI-a, 300-3,000 lx), UDI autonomous for aging eyes (UDI-a AE, 600-3,000 lx) and UDI-a Bright Daylight (BD, 1,000-3,000 lx) ranged between 60-88%, 44-64%, and 28-45% respectively. The light pipe introduces consistently illuminance levels ranging between 300 lx to 2,500 lx throughout the year, saving energy during peak load electricity demand, and providing the daily bright light doses necessary to regulate and entrain building occupant's circadian rhythms.

This passive solar system proves to be an energy efficient sustainable technology that utilizes direct solar energy, and provides high illuminance levels of full-spectrum light without the negative effects of glare and solar heat gains that are found in buildings with large expanses of glass.

Keywords: Daylighting; Sustainability; Energy-efficiency; Solar light pipes; Circadian Light

## 1. Introduction

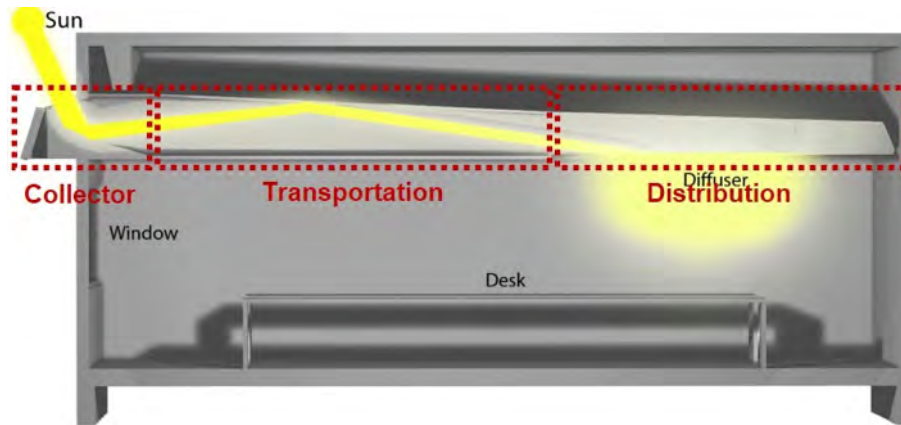
It has been demonstrated that the use of daylighting in commercial office buildings is an effective strategy to offset electrical lighting, reduce cooling, and heating loads; as well as to increase human comfort and productivity (Heschong and Mahone, 2003). This paper intends to demonstrate that this passive horizontal light pipe provides adequate light levels in building cores without introducing additional solar heat gains.

We live and work in buildings that are often isolated from natural light and where electric light is often around 200 lx and seldom exceeds 400-500 lx (Foster 2011). In recent years light pipes have been explored because of their potential to introduce daylight further into the building core. One of the first developments of a passive horizontal light pipe suitable for deep plan office buildings was developed by LBNL (Beltrán et al, 1994, Beltrán et al, 1997). The characteristics of the light pipe presented in this paper are based on the preliminary design concepts developed by the author at LBNL. Other researchers adapted the passive horizontal light pipe to locations at low latitudes (3°N, 14°N) (Chirarattananon et al, 2000, Garcia and Edmonds, 2003), where the light pipes were oriented to face the sun towards the East or West limiting the light pipes' daylight performance. An anidolic (non-imaging) ceiling was developed to collect light rays from the sky and redirect the emitted light in a 6m room. This system is suitable for locations with predominantly overcast skies (Courret et al, 1998). Recent developments include active light guiding systems that integrate electric lighting, as backup lighting, along with heliostats and tracking mirrors to redirect sunlight (Rosemann et al, 2007, Mossman et al, 2018).

## 2. Description

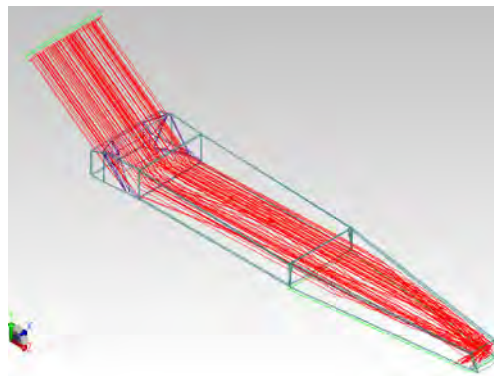
The light pipe system is designed to be placed within the ceiling plenum or can be exposed hanging from the underside of a floor slab above. The light pipe collector extends 0.25m from the building facade plane, so that it could be used with flush and articulated facades. This system can be used in new buildings, and in existing buildings. The current light pipe was designed to be used in combination with a lower, sidelight window, and was tested in a room 6m wide by 9.1m deep. It provides supplementary illumination at distances between 4.6m and 10m.

Our proposed light pipe system was designed to introduce daylight passively in any floor of deep-plan multistory buildings. The light pipe uses a small inlet glazing area, 0.3m by 1.6m, to efficiently redirect sunlight at distances up to 10m from the window wall (Figure 1). The window wall ratio (WWR) and window floor ratio (WFR) of the light pipe are 4% and 1.6%, while the sidelight window has a WWR of 41% and a WFR of 16%. The glass area of the light pipe is less than one tenth of the sidelight window. The challenge of the design stems from the large variation in solar position and daylight availability throughout the day and year. Several reflectors are used to collimate incoming sunlight to minimize inter-reflections within the transport section of the light pipe, and to maximize the efficiency of the system (Beltrán et al, 1997). The current light pipe design has been redesigned to improve performance and adapted to our current location. The pipe is coated with a 99.3% specular reflective film. The distribution element at the back end of the light pipe consists of a 4.6m long diffusing radial film located at the ceiling plane with an 87% visible transmittance ( $T_{vis}$ ) and an area of 4.2m<sup>2</sup>.



*Figure 1 Light pipe longitudinal section.*

The light pipe design was optimized by computer-assisted ray-tracing calculations that determined the optimum geometry of the various light-redirecting optical elements (Beltrán and Uppadhyaya, 2008). Hourly sun rays were traced to verify that rays are directed along the light pipe shaft (Figure 2). Efforts were focused on determining the optimum aperture size, reflectors size and shape, taking advantage of the optical properties of the films, and accommodating the sun path viewed by the window for a specific orientation and building latitude.



*Figure 2 Ray-tracing analysis of optimized light pipe for June 21, 12:00.*

### **3. Methodology**

#### **3.1. Experimental Set-up**

The experimental facility consists of a 360° rotating room that represents a section of a deep open plan office space of 3.0m high, 6m wide and 9.1m long (Figure 3). The facility is located in College Station at Texas A&M University Riverside campus (latitude 30.6°N) in an open area with no obstructions around it. This paper presents the photometric measurements of the light pipe facing south. The space includes two sidelight windows of 2.74m wide by 1.52m high (4.16m<sup>2</sup> each) with Tvis of 51%. The WWR of the sidelight windows is 45% and WFR of 7.5%. The windows have external moveable blinds with a reflectance of 0.8. The interior surface reflectances are 0.81 for the ceiling, 0.88 for the walls, and 0.15 for the floor. The light pipe glass area is 5.5% of the sidelight windows.



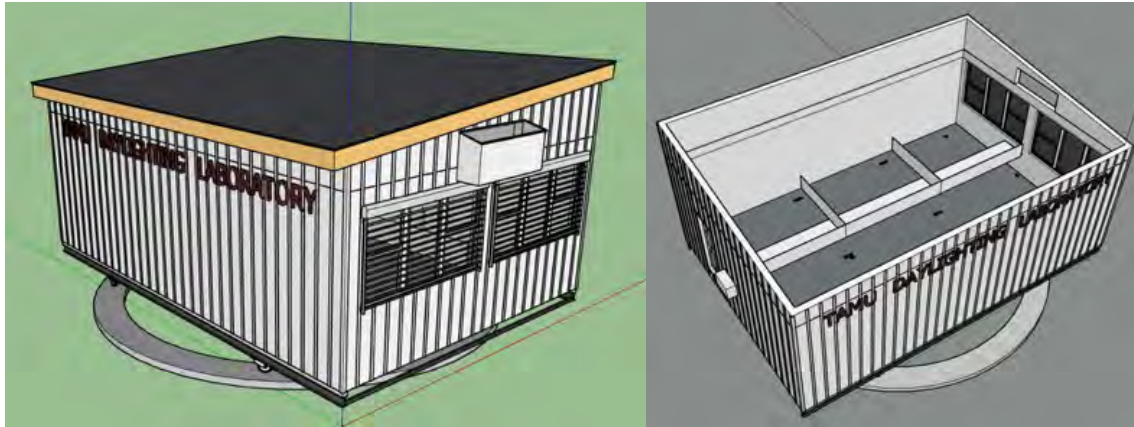


Figure 3 Experimental facility, exterior and interior views.

### 3.2. Measurements

Photometric interior illuminance measurements were taken at twenty five reference points at workplane height, 0.76m. Twenty five cosine- and color-corrected LI-COR photometric sensors (LI-210SA) were placed over the workplane at equal distances, 1.5m to 7.6m from the window wall, at centerline (Figure 4). Outside the test room, two sensors were placed on the roof and façade to take global horizontal illuminance (GH) and global vertical illuminance (GV). Data was collected every 30 seconds for an entire year. The analysis of illuminance levels are based on 10 hours, 8:00 to 18:00 true local time (TLT), which is typical office building schedule.

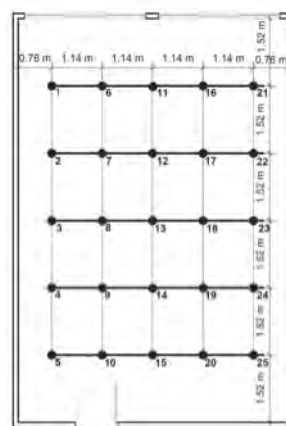


Figure 4 Location of the 25 photometric workplane sensors (#14 and #15 are located at 6m and 7.6m from the window wall).

High Dynamic Range (HDR) images were created using the programs Photosphere to assess visual qualities in the testing room. HDR images were created from eleven bracketed exposures to cover from 1-20,000 cd/m<sup>2</sup>. A Nikon Coolpix 5400 camera and a FC-E9 Nikon fisheye lens were used to capture a wide view of the space as well as the external conditions. False-color images were created from the HDR images to visualize the spatial luminance distribution, and measure the luminance variability across the space.

### 3.3. Performance metrics

Daylight autonomy (DA) and Useful Daylight Illuminance (UDI) are two metrics to assess the annual occurrence of illuminance across the workplane maintained by daylight alone and that

are within a range considered “sufficient” and “useful” by occupants. Four thresholds were used to report the daylight levels achieved at the rear of the room (7.6m) modified from the UDI paradigm of Nabil and Mardaljevic (2015): (1) UDI autonomous, UDI-a (300-3,000 lx); (2) UDI supplementary, UDI-s (100-300 lx); (3) UDI autonomous for aging eye, UDI-a AE (600-3,000 lx); and (4) UDI autonomous and bright daylight, UDI-a BD (1,000-3,000 lx);

## 4. Results and Discussion

### 4.1. Workplane illuminance

The light pipe and sidelight window provide natural light evenly distributed over the workplane and throughout the space. The space shows an overall uniform daylight distribution (Figure 5), the sidelight window illuminates the front of the room and the light pipe illuminates the back. Illuminance values at 4.5m to 8.5m from the window wall are higher than at 3.6m. The high illuminance levels introduced by the light pipe at the back of the space demonstrates the efficiency of the light pipe design, which with an opening of 1/18th of the sidelight window area provides 5-6 times higher illuminance levels than those provided by the sidelight window at the back of the space. Figure 5 compares the illuminance distribution throughout the space with and without the light pipe on April 23 at around solar noon. It is noticeable how daylight is uniformly distributed throughout the space. It is also worth mentioning that a single light pipe is able to introduce adequate illuminance levels across a 6m wide space. Long-term illuminance measurements confirmed that the light pipe provides similar lighting levels at the back of the room as in areas adjacent to the windows (Figure 5); for example, at 1.5m from the window, light levels reach over 2,500 lx while at the back of the space (beyond 6m) light levels reach over 2,000 lx. Daylight delivered by the light pipe at the back of the space provides high illuminance levels of full-spectrum daylight in interior office cubicles or basement throughout the day.

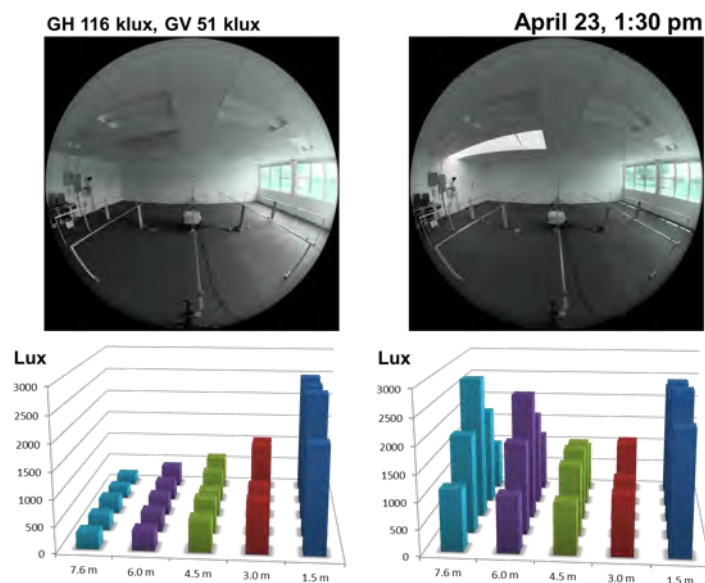


Figure 5 Daylight distribution in the room without (left) and with (right) the light pipe.

Figure 6 depicts the illuminance levels at the back of the room (6m-7.6m, Sensors #14 and #15) under different sky conditions throughout a week around the solstices and equinoxes. On clear and partly cloudy days, the light pipe provides between 300 to 2,500 lx for about nine hours at the back of the space (7.6m) throughout the year. Under partly cloudy sky conditions the light pipe introduces higher illuminance values at the back of the space than under clear skies, as observed during the vernal and autumnal equinox weeks in Figure 6. The highest illuminance values (over

1,000 lx) are achieved consistently between 10:30 and 16:30 under clear sky conditions. Under overcast sky conditions the light pipe introduces at the back of the space more than 300 lx when EXGH was over 18-20 klx. When the EXGH falls below 18 klx, electric lighting will be used to supplement the 150-200 lx needed throughout the space, front and back.

Figure 7 depicts plots of the EXHG and workplane illuminance at 7.6m (Sensor #15) from the window wall during one week around the solstices and equinoxes. It is noticeable the large amount of hours when illuminance levels are above the threshold of 300 and 600 lx. The highest illuminance levels (>2,500 lx) are achieved when EXHG is above 70-75 klx.

Table 1 presents a summary of the UDI values of Sensor #15 at the back of the testing room (see Figure 4). The light pipe helps to achieve UDI-a ranges (300-3,000 lx) from 60% to 88% (average UDI 80%) during the weeks around the solstices and equinoxes. The high annual UDI-a means that a building with the light pipe can be illuminated by daylight alone most hours of a typical 10-hour working schedule year-round (including weekends), and may need to use supplementary electric lighting for less than one hour per day throughout the year mostly between 8:00-9:00 and 17:00-18:00 during the winter months and under overcast conditions. The annual UDI-a BD (1,000-3,000 lx) at the back of the space during solstices and equinoxes ranges from 28% to 45% (average 39.5%). The fact that the light pipe system introduces more than 1,000 lx of full spectrum light for about three to four hours most days of the year is extremely beneficial for building occupants, especially to those that cannot be outdoors, e.g. nursing homes, hospitals, etc. The illuminance levels introduced by the light pipe (>600 lux, with annual average UDI-a AE of 58%) exceed current recommendations for reading and writing in spaces where at least half of the occupants are over 65 years old (DiLaura, Houser, Mistrick, & Steffy, 2012). This is particularly important due to an increased aging population (65 years or older) with needs for higher illuminance levels due to the fact that less light reaches the retina of an aging eye than it does in a younger eye.

In recent field studies, researchers have demonstrated the benefits of bright light in building occupant's well-being. Subjects exposed to bright light showed reduced sleepiness, shortened reaction times on psychomotor vigilance task, increased alertness and vitality (Iskra-Golec & Smith, 2008; Smolders, de Kort & Cluitmans, 2012; Phipps-Nelson, Redman, Dijk & Rajaratman, 2003). The benefits of having bright light in building cores become extremely important for occupants that spend most of their time indoors.

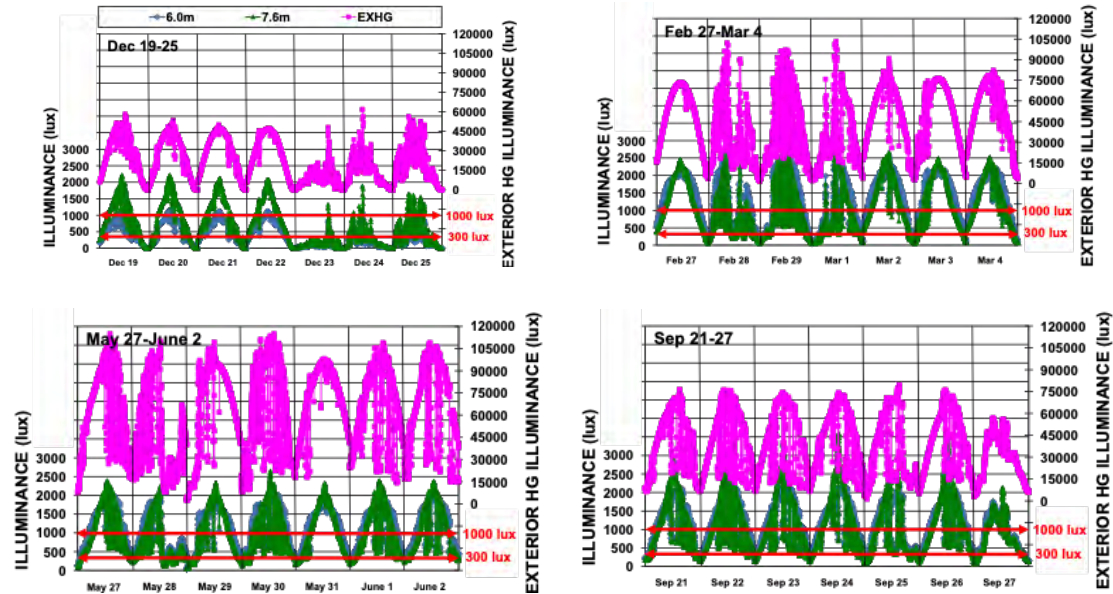


Figure 6 Illuminance at rear workplane sensor #15, solstices and equinoxes.

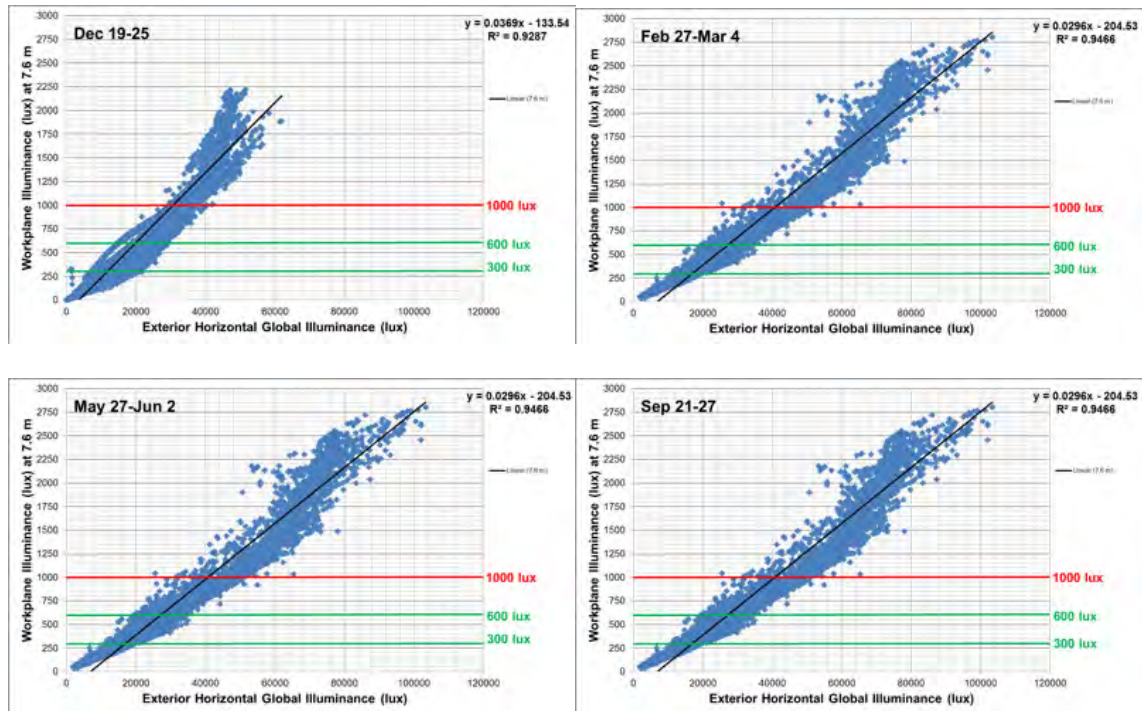


Figure 7 Workplane illuminance (#15) vs. EXGH solstices and equinoxes, 8:00-18:00.

## 4.2. Luminous flux distribution

Figure 8 depicts a time lapse of the daylight distribution in the room on May 3. Luminance levels across the space are uniformly distributed throughout the space, as can be observed over the floor and ceiling between 9:00 and 17:00. Around noon (12:00-15:00) hours when the sun is perpendicular to the façade wall, the back wall luminance is significantly greater than on the side walls, indicating that the luminous flux would have been distributed much deeper than the physical limits of the testing room (9.1m).

Table 1 Summary of UDI around the weeks of solstices and equinoxes (8:00-18:00)

Illuminance at rear workplane sensor	Useful Daylight Illuminance (UDI)	Dec 6-12	Feb 27-Mar 4	Jun 21-27	Sep 27-Oct 3
	Number of overcast days	3	1	1	1
< 100 lx	UDI 'fell-short' (or UDI-f)	19%	3%	0%	0%
100-300 lx	UDI supplementary (or UDI-s)	21%	13%	12%	13%
300-3,000 lx	UDI autonomous (or UDI-a)	60%	84%	88%	87%
600-3000 lx	UDI 'for elderly' (or UDI-ae)	44%	64%	61%	62%
1,000-3,000 lx	UDI 'bright light' (or UDI-a BD)	28%	45%	42%	43%



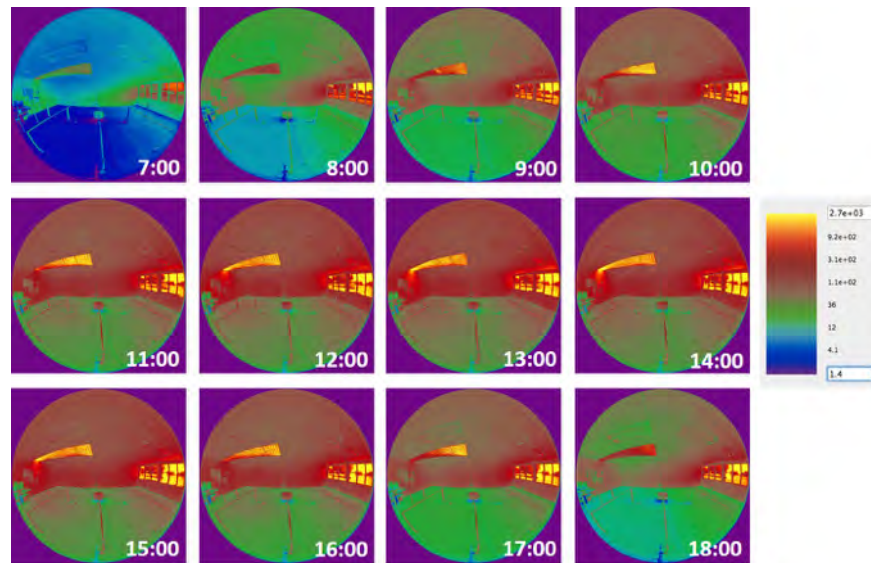


Figure 8 Time lapse of high dynamic range luminance maps (cd/m<sup>2</sup>) distribution, clear sky conditions, May 3. DGP 0.21, DGI 14

## 5. Conclusions

The passive solar horizontal solar light pipe presented in this paper is an effective system that can provide healthy full-spectrum lighting in South-facing deep floor plan spaces for more than 9 hours under clear and partly cloudy sky conditions. The light pipe introduces consistently throughout the year illuminance levels between 300-2,500 lx at 9m from the window wall. Exposing building occupants to bright light (>1,000 lx) can help them regulate the timing of their circadian rhythms, which also has a direct effect on sleep patterns, alertness and performance (Foster, 2011). The light pipe is a building component designed to meet not only visual needs, but to increase the circadian light exposures in deep-floor plan buildings.

The lighting levels provided by the light pipe at the back of the space are similar to the ones provided by the sidelight window at the front of the space, even though the light pipe's glass area is only 5.5% of the sidelight window area. The cooling loads generated by the light pipe glazing will be insignificant compared to the ones generated by the sidelight window, and to the cooling loads generated by the electric lighting it offsets. In addition, the light levels distributed uniformly throughout the space creates a visually comfortable space for occupants of deep floor plan buildings.

The light pipe is a sustainable technology that can change the way buildings will be designed in the future. It may not be necessary to have large expanses of glass to introduce more daylight to the core of buildings and deal with the effects of increased cooling loads. Several building types (e.g. offices, schools, nursing homes, hospitals, housing for the elderly and visual impaired people) can benefit from this technology, which utilizes direct solar energy with no operational costs, provides high illuminance levels of full-spectrum light, and regulates occupants' circadian rhythms.

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# VERTICAL LIGHT PIPE POTENTIALITY FOR BUILDINGS IN SURABAYA, INDONESIA

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## Summary

In Surabaya, Indonesia, retail shops and offices are popular trend building typologies. Those buildings usually have a thick plan to maximize their land area usage. This affects daylight contribution in the deeper space of the buildings. Since Surabaya is located at  $-7.25^{\circ}$  S Latitude and  $112.75^{\circ}$  E Longitude and sky conditions in Surabaya are predominantly in intermediate sky condition (Rahim & Mulyadi, 2000). Those conditions support the use of light pipes where the sun is at around zenith most of the time. The potential of daylight strategy under the circumstance is to bring daylight from the top.

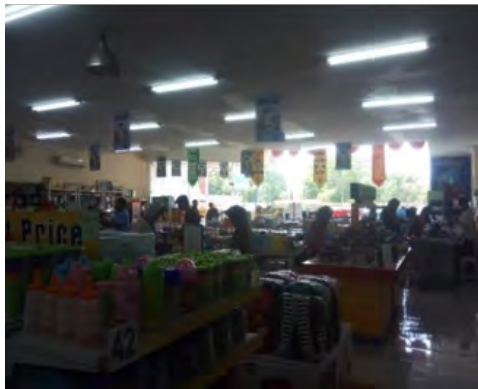
This study demonstrate the potential of using vertical light pipe in Surabaya as one strategy to obtain daylight for deep space building. This research was conducted by model simulation through DIALux 4.13. A room of  $16 \times 16 \times 3$  m is created in DIALux using virtual model. Wide space of the room was created to avoid any reflectance effect from wall which falling to the calculation surfaces. The height was set at three meters as this is common in Indonesian buildings. Furthermore, the light tube was set in the middle of the virtual model which has various tube diameters from 0.6 m, 0.8 m and 1 m. Several factors was set to get the actual result such as location of Surabaya, sky conditions, and was calculated on four critical dates. The result proclaimed that vertical light pipe is proper to extend daylight availability since the light pipe provides illumination starting from approximately 40 lux – 250 lux. The final part of this study suggests a method for predicting illuminance by length and diameter of the tube.

Keywords: lighting, low energy, light tube, daylighting guideline

## 1. Introduction

In the last decades, the developing construction had increasing in developing countries. This causes an increase in the city's energy consumption. Indonesia, as the country which is still developing infrastructure, has built many buildings and its cities continue to expand. Energy consumption is mainly caused by cooling, lighting, lift and escalators, and others (The Department of Climate Change and Energy Efficiency, 2012). Lighting was determined as the second largest energy consumption in buildings. Moreover, Indonesia has huge potential to expand daylight availability since the sun will shine during 12 hours per day for the whole year. Indonesia is located in Southeast Asia, and lies between the Pacific and Indian Ocean and between the continents of Asia and Australia. Geographically, Indonesia lies between 6 N – 11 S latitudes and 95 E – 141 E longitudes.

Surabaya was chosen as the setting for this study since Surabaya is a metropolitan city and the second largest city in Indonesia. It is located at 7 S latitude and 112 E longitude. Several buildings in Surabaya has a wider plan and this as an impact on daylight penetration with not enough daylight entering the building to illuminate all areas. Consequently, artificial lightings is used during daytime. As shown in figures 1-2, Retail and department stores that have wide plans need to turn on lighting during daytime when Surabaya has the potential to optimize daylighting as the sun travel around zenith during the whole year as shown in figure 3. A vertical light pipe guideline is created from a simulation model which analyzed the illuminance result of light pipes. Vertical light pipe is described as daylight entering from the protruding glasses into the duct wall, reflected in every side of duct wall, exiting from other end of tube and lightening up the room (Wu & Ma, 2005). Through vertical light pipe, internal daylight penetration can be maximized to decrease building energy consumption. During the equinox, the sunlight reflected into the pipe is merely one reflectance. Thus, sun illuminance will not reduce much from input to the output luminaire. However during the solstice, the highest reflection number in June is up to six times, and in December has reflection number only four times. Solar altitude between June and December is different where June is at 59 o and December at 73o (University of Oregon, 2012).



*Figure 1 Wider plan of retail store*



*Figure 2 Luminaires configuration in department store*

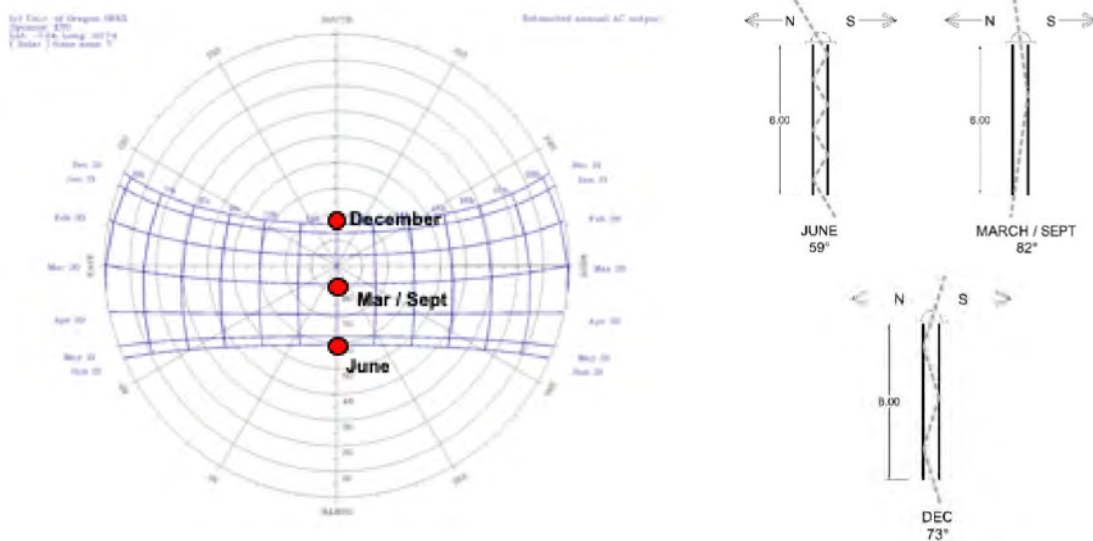


Figure 3 Correlation of Surabaya's sun path towards light pipe reflected

To achieve appropriate lighting in buildings, Indonesia has developed the National Standard of Indonesia as a reference. The level of awareness from design practitioners should be enhanced in considering these documents. The National Standard of Indonesia provides the guidelines for lighting design as in SNI no. 03-6197-2000 of the Energy Conservation in Lighting System (Badan Standarisasi Nasional, 2000). There are also a number of other documents relate to lighting configurations to support SNI documents, for instance from CIBSE and IES (CIE Standard, 2002). SNI set several minimum illumination standards for specific tasks as the recommendation for determining lighting design. The illumination started from the lowest at 60-100 lux for garages, terraces and corridors. For common task areas, for instance offices, schools, shopping complexes, the lux level is approximately 100 – 500 lux. Other specific tasks such as industrial work started from 1000 – 2000 lux. If the standard has been set, this provides the requirement which an architect should consider while designing especially for daylighting.

However, a previous study about implication of SNI document in Surabaya, Indonesia (Pratama & Chaiyakul, 2018) found that mostly architects and design practitioners didn't consider the lighting issues mentioned in the SNI document. It causes that hard to achieve SNI standards. Thus, in this study proposes an option to solve the difficult assessing SNI when using vertical light pipe guideline.

## 2. Method

The aim of the simulation is to determine the average illuminance of each light pipe considered. A simulation in DIALux 4.13 program (DIALux, 2011) has been conducted with several controlled aspects (described in Figure. 4). Those steps to conduct the simulation are:

1. The vertical tube has created in the DIALux with 3 different diameters Ø 0.6 m tube, Ø 0.8 m tube, and Ø 1.0 m tube with length 1 – 6 meter in 1 meter interval in each tube.
2. A 16 m x 16 m x 3 m simulation room was created with the tube placed at the center of the room. To avoid any obstruction illuminance from walls, the room was created larger than usual.
3. Reflectance value was set as ceiling : wall : floor = 70 : 10 : 20.
4. Sky option simulation was set to intermediate sky as this is the sky condition most common in Indonesia.
5. Time simulation was set at 12.00 as the most potential sunlight in a day.
6. Material glass reflectance was set to the highest option of DIALux at 0.90.

7. All these data arrangements were simulated for equinox and solstice periods which are on March 21st, June 21st, September 23rd, and December 22nd.
8. Work plane was set at 0.75 m above the floor, area of work plane 5 x 5 m since from rule of thumb of light that light source has spread angle of 45°. Area of work plane derived from straight line of the 45° angle that was intended from architectural drawing.

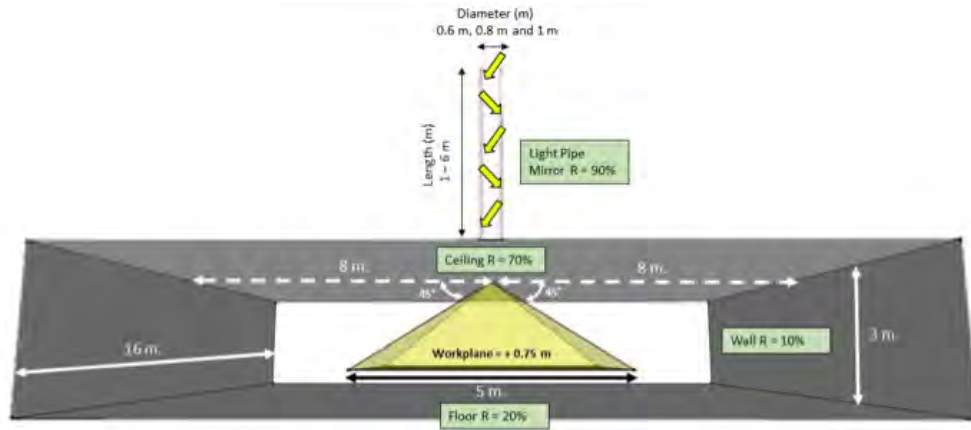
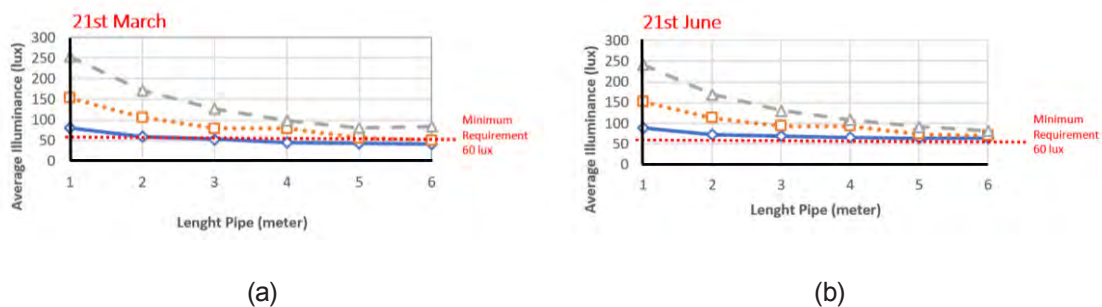


Figure 4 Virtual room simulation on DIALux

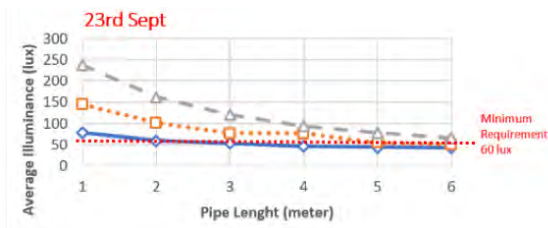
### 3. Discussion and results

From intermediate sky result, it showed that the three various diameter pipes and six various pipe lengths provide an illuminance level range of 40 lux up to 250 lux. Interestingly, differences in the illuminance level provide by from the pipe is affected by the diameter. If the diameter is narrower, the rising illuminance value for the different lengths so not significantly increase. But if the diameter is larger, each enlarged length will provide much difference in value. As illustrated in Figures 5 (a-d), it was found that a 0.6 m diameter pipe provides illuminance starting from 40 – 90 lux. This meet the SNI minimum requirement of 60 lux illuminance for terraces and garages, which mean that several pipes can be used for completing terrace and garage tasks. However to reach 60 lux, it suggested to use at least Ø 0.6 m or higher diameter and 3 meter pipe length or shorter length.

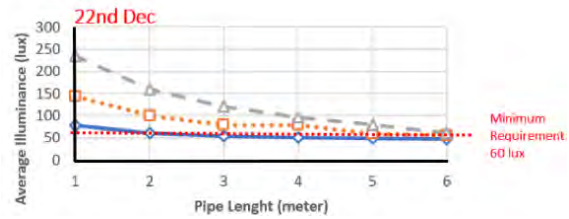
Figures 5(a-d) show the result from the topic above as graph of illuminance level on 4 critical days







(c)



(d)

Figures 5(a-d) Average Illuminance on the work plane at 12.00 during intermediate sky

On the other hand, vertical light pipes can be used also to light up corridors that has requirement of 100 lux by using at least an Ø 0.8 m pipe or a 3 m length. In case of common tasks referred to SNI document which requires levels between 150 – 300 lux, Ø 0.6 m and Ø 0.8 m pipes were unable to provide proper illuminance. Ø 1.0 m of pipe and 3 meter length can be possible used for common task.

Secondly, the study focused on differences of illuminance level on equinox and solstice days. Generally, the result from each critical day are quite close enough with each other because during intermediate sky, direct sun was covered by 30 – 70 % cloud (Boyce & Raynham, 2009) which means the sun might not directly shine into the pipe. The illuminance values of selected dates are slightly different under the intermediate sky. Even though, the number of reflections in June is more than the other month. This may be the effect of the light from other sky and cloud under this sky.

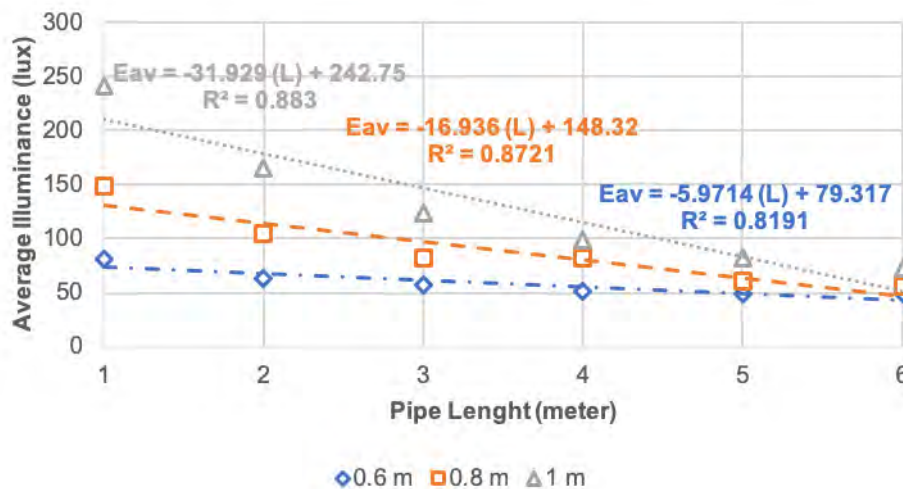


Figure 6 Average illuminance of pipe the whole year in the equation

Factor of light pipe configuration are shown in Figure 6. It is shown that as shorter as the pipe length will effect to illuminance deviation. In the 1 meter pipe length, Ø 0.6 m pipe has approximately 50 lux deviation to Ø 0.8 m pipe. Furthermore, Ø 0.8 m pipe has approximately 80 lux deviation to Ø 1 m pipe. Three equations were derived from date for three pipe diameters as shown in Table 1.

Table 1 Average illuminance in the equation

No.	Pipe Diameter (m)	Model	R2
1.	0.6	$E_{av} = -5.9714\ln(L) + 78.489$	0.8191
2.	0.8	$E_{av} = -16.936\ln(L) + 148.32$	0.8721
3.	1.0	$E_{av} = -31.929\ln(L) + 242.75$	0.883

#### 4. Conclusions

Daylight availability is important to decrease building energy consumption (Asian Institute of Technology, 1998). Besides, it is better than artificial light for human sight requirements. This study aims to obtain one solution for architects who want to design buildings using optimized daylight availability. Moreover, there are a number of vertical light pipe products on sale in the market place (Chatron-Ltd, 2010). Thus, the architect can be predict the dimensions of the appropriate vertical light pipe before considering to the actual product.

To conclude that, light pipe can be applied for daylighting strategy to pass task requirement determined by the SNI document (Badan Standarisasi Nasional, 2000) since light pipe provides proper light itself. Even though the lux levels provided are not enough to pass the requirement, vertical light pipes can be adjusted by increasing the number of pipes, enlarging the diameter, or decreasing pipe length. There are two points that must be noted. Firstly, the illuminance level can be greatly increased by enlarging the pipe diameter. However, this may have impact on the building structure. Secondly, vertical light pipe may not be practical for multistorey buildings that has storey level of more than 6 meter due as the levels of illuminance will drop rapidly.

#### Acknowledgement

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# ENERGY EFFICIENCY OF A HIGH-RISE OFFICE BUILDING IN THE MEDITERRANEAN CLIMATE WITH THE USE OF DIFFERENT ENVELOPE SCENARIOS

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## Summary

This paper investigates different strategies towards advancing the energy efficiency of a high-rise office building by focusing on the building envelope. More specifically, the focus is on the thermal properties of the building envelope and the effect of altitude on energy performance. The studies are focused on Tel Aviv, Israel, a city with a vibrant high-rise building activity. Studying this typology in this Mediterranean climate will be of relevance for other cities with similar climate (e.g. in Middle East, S. Europe, N. Africa) that undergo similar processes of high-rise development. The study is based on thermal simulations of an office reference model at different heights: 8m (ground level), 82m, 168m, 254m, and 340m. Alternative façade scenarios were implemented for gradually upgrading the building envelope and studying its relationship with the changing microclimate with altitude (wind speed increase and dry bulb temperature drop) between ground and top level. The envelope scenarios range from clear single glazing, to LowE double-glazing, triple glazing, the addition of external shading devices, and a double skin façade (DSF). The popularity of DSFs has grown over the last decades, due to their potential of improving a building's energy performance, when compared to a single-glazing curtain wall. The high levels of solar radiation common in latitudes and climates like the one in discussion, result in high cooling loads, especially in relation to the design of glass façades. As a result, studies on the energy performance of DSFs in comparison to a single-glazing envelope become very important for improving energy efficiency. Moreover, published research on DSFs is currently mainly on cold and moderate climates. Energy consumption between ground-to-top floors alters with the changing microclimate in relation to height: heating increases, while cooling drops. Moreover, for an office building in Tel Aviv the energy loads for cooling are much higher compared with those for heating. Results show that single clear glazing performs the worst, while using LowE double glazing in scenario B reduces energy consumption for cooling by 25% from scenario A. The addition of external shading devices in scenario C reduces cooling loads by a further 50% from scenario B. In scenario D triple LowE glazing performs by 1% worse in cooling loads from the double glazing option, however, comparing scenario E of triple glazing with external shading with scenario C of double glazing with external shading, scenario E has 20% higher cooling loads. The comparison between scenario F of the DSFs with scenario C shows that scenario C performs 8% better in cooling loads. However, the shading devices shade a large portion of the facades, while in the DSF option transparency and visibility are maintained, as well as improving the energy performance of the building. The results prompt for further studies on the energy efficiency of DSF in warm climates.

**Keywords:** Energy efficiency, EnergyPlus, building envelope, high-rise office building, Mediterranean climate

## 1. Introduction

Urban development sustainability is defined as the process of integration and co-evolution of economic, social, physical and environmental subsystems. The carrying capacity of a city is another aspect of sustainability within the city (Wei et al., 2016). The aim of sustainable development is to enhance population wellbeing without compromising development possibilities. In terms of city infrastructure and building technology, these need to display technological progress and environmental design principles in order to successfully sustain the growing population.

Population growth, intense urbanization, and expanding industrialization have promoted the typology of the skyscraper as an important solution for the future of high-density urban centers around the world. This is achieved by increasing city-space vertically, as opposed to a continuous expansion outwards that devours natural and agricultural landscapes/resources. However, the skyscraper has to also comply with current strict regulations on building energy efficiency. As a result, the skyscraper as a positive addition within the urban fabric calls for further research and experimentation.

Today, there is a global movement of 'green' high-rise buildings that utilize sustainable technologies on a whole new scale, and possibly celebrate a green certification award, e.g. LEED certification. Nevertheless, the towers are still linked to high-energy demand, environmental and social imbalances (Girardet, 2006). An example is 'The Bank of America' in New York, completed in 2010. The tower received 'Core and Shell' LEED Platinum certification, which is the highest level of LEED certification, and was awarded the 2010 'Best Tall Building Award - Americas' by the Council of Tall Buildings and Urban Habitat. However, in 2013 a New York City public report on the building operations revealed that in 2012 the tower's site energy use was higher than any comparably sized office building in Manhattan (Donnolo, Galatro and Janes, 2014). This leads to the conclusion that there is a potential gap between green certification and operational energy, and that a highly-certified building can still be consuming high amounts of energy and producing high amounts of greenhouse gasses.

The above is a general observation of 20th century's architecture where the availability of cheap energy, and use of HVAC systems, had a profound impact on the design and operation of buildings. Curtain wall facades replaced heavyweight-building envelopes, creating the glass-box style of architecture. However, the building envelope is important to the regulation of a building's thermal behavior relative to the climate and microclimate around it (Trefil, 2003). Its special physical properties, i.e., the thermal resistance and heat capacity of the materials used, must interact appropriately with the ambient climatic conditions to reach healthy, comfortable indoors (Givoni, 1969).

The desired transparency of the building envelope and lightness of the structure initiated in the mid-twentieth century resulted in high-energy demands in buildings, both for cooling and heating. Large-scale buildings, like skyscrapers, have even higher energy demands on the urban fabric. This paper, which is part of a wider research on skyscraper energy efficiency (Saroglou et al., 2017; Saroglou, Meir and Theodosiou, 2017), considers this building typology as an urban phenomenon closely related to contemporary and future city living, and investigates design strategies towards improving energy efficiency with a focus of the building envelope.

## 2. Methodology

The present study is based on thermal simulations of an office high-rise reference model up to 400m high located in Tel Aviv, Israel. The greater Tel Aviv metropolitan area is already growing upwards and is expected to have a significant number of new skyscrapers in the near future, while the city's Municipality Planning and Construction Committee issued the 2025 city master plan that supports new sky-rise development. At the moment there are 21 skyscrapers over 150m, 29 between 120-150m, 35 between 100-120m, and 18 under construction. The average height of these high-rise buildings is 150m, already much higher than the existing skyline. The study of Tel



Aviv high-rise building typology will be relevant for other cities with a similar climate (e.g. in Middle East, S. Europe, N. Africa) that undergo comparable processes of high-rise development (Meir et al., 2012). This paper focuses on an office high-rise, not least because of the high internal heat gains and the increased windows ratio of this building typology, in comparison to a residential option, and their effect on cooling needs in this Mediterranean climate.

Simulations are performed for different single-skin envelope scenarios and a double skin façade (DSF). The single-skin curtain walls are simulated with and without external shading devices, and comparisons are made between the different scenarios and the DSF option. The incorporation of DSF in buildings has increased rapidly over the last decades, as an option of energy conservation and sustainable development, while retaining flexibility and transparency in architecture. DSF studies around the world have shown that the double layer façade envelope can significantly improve the thermal performance of the structure, by mitigating the impact of the exterior environmental conditions on the interior of the building (Chan et al., 2009; Joe et al., 2013). However, contrary to the number of DSF studies, there are still no official specifications on the simulation of DSFs and their energy savings (Joe et al., 2014; Ahmed et al., 2015). In this research paper, the DSF is simulated as a naturally ventilated DSF, and its energy efficiency is compared in relation to height with the other envelope scenarios.

## 2.1. Building Simulation Data

Simulations are conducted at heights of 8m (ground level), 82m, 168m, 254m, and 340m (CTBUH, 2015). EnergyPlus 8.8 was used as the energy simulation engine that can model wind acceleration with height according to ASHRAE (2009), and air temperature drop by elevation. The proposed location for the tower is within an urban environment, yet no other structures were included in its proximity during the simulations presented here. Energy consumption is calculated in relation to indoor thermal comfort standards (Givoni, 1981), with the temperature range according to the Predicted Mean Vote (PMV) model by Fanger at 20°C during winter, and at 26°C during summer (Fanger, 1970). Envelope characteristics (U-values of walls and window-to-floor ratio - WFR) are designed in accordance with Israel's Green Building Standards, SI 5282 (SII, 2011). Internal heat gains are calculated for 10m<sup>2</sup> of office space per person. Table 1 shows the envelope characteristics used in the simulations. In regards to the WFR, the model was designed with the minimum values stated in the standards, noted in bold. Comparisons towards energy efficiency are made between six different curtain wall envelope scenarios, and energy consumption is compared, in relation to height for the climatic conditions of Tel Aviv. The material properties of the glazing are shown in Table 2.

The scenarios are as follows:

- **Scenario A:** Clear Single-Glazing
- **Scenario B:** LowE Double-Glazing
- **Scenario C:** LowE Double-Glazing and Shading
- **Scenario D:** LowE Triple-Glazing
- **Scenario E:** LowE Triple-Glazing and Shading
- **Scenario F:** Double Skin Façade DSF (single\_double LowE)

**Table 1 Thermal properties of building envelope and WFR according to Green Building Standards, SI 5282: Energy Rating of Buildings.**

Mass Wall GBS (SOUTH) U-value 1.02 [W/m <sup>2</sup> °K]	Mass Wall GBS (N/ E / W) U-value 0.54 [W/m <sup>2</sup> °K]	Window Sgl Clr 6mm U-value 5.778 [W/m <sup>2</sup> °K]	Window double Low-E Spec Selection 6mm/13mm Air U-value 1.626 [W/m <sup>2</sup> °K]	Window triple Low-E Film 6mm/13mm Air U-value 1.22 [W/m <sup>2</sup> °K]
19mm gypsum board	19mm gypsum board	Clear 6mm	LowE Spec Sel TINT 6mm	Clear 6mm
Extruded polystyrene - 15mm	Extruded polystyrene - 40mm		Air 13mm	Air 13mm
				LowE Film 6mm
300mm heavyweight concrete	300mm heavyweight concrete		Clear 6mm	Air 13mm
				Clear 6mm
F07 15mm stucco	F07 15mm stucco	SHGC: 0.819 V.T.: 0.881	SHGC: 0.421 V.T.: 0.682	SHGC: 0.361 V.T.: 0.535

Note: windows G3 and / or G4 Low-E Glazing (W/m<sup>2</sup>°K) specifications: G3: U<sub>glass</sub>=1.8 / U<sub>frame</sub>=3.5 / SHGC=0.6 / Daylight trans.=0.6; G4: U<sub>glass</sub>=1.8 / U<sub>frame</sub>=3.5 / SHGC=0.5 / Daylight trans.=0.5

**Table 2 Thermal properties of mass wall and glazing in accordance with Israel's Green Building Standards GBS. Note: Visual Transmittance (V.T.)**

Window-to-floor ratio (WFR) %	Windows thermal properties per orientation	U-value of Walls (W/m <sup>2</sup> K)
S= <b>23</b> -35, N= <b>23</b> -27 E= <b>23</b> -32, W= <b>18</b> -27	N / E = G3 S / W = G3 or G4	N / E = 0.6 S= 1.2 W = 0.6

## 2.2. Design of Reference Models

The typical floor layout is an open plan layout, positioned on a north-south axis with elevations on all secondary orientations: SE, SW, NE and NW (Figure 1 left). The design of the office reference model took into consideration the requirement for natural day-lighting in SI 5282 Energy Rating of Buildings of 5 meters depth of windows to usable floor space, and measures just 460m<sup>2</sup> per floor. The hatched area indicates circulation area within the offices, while the central rectangle marked with diagonals as X is the core of the building. Real life office buildings have a usable floor area 3-4 times bigger and incorporate into the design ceiling reflectors, light wells, central atriums etc. Such multi-layered designs were not part of the simulations conducted at the moment.

The optimum design of the shading devices was configured with the Ecotect 'Shading Design Wizard'. Shading devices were positioned on the south, east and west elevations (Figure 1 right top). The south elevation uses a horizontal shade with vertical fins every 1m. For the east and west elevations a 45° angle shading blocks 50% of the window, due to the low angle sun on these orientations. The shading devices were designed for optimum energy efficiency and did not take into consideration issues like 'view out' and natural light.

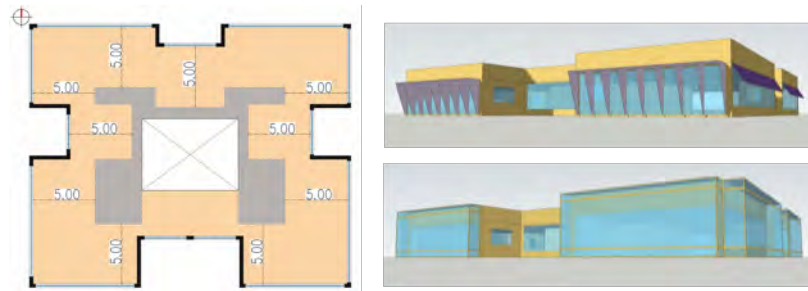


Figure 1 Left: office typical floor plan layout with the requirement set in SI 5282 Energy Rating of Buildings for 5 meters depth of windows to usable floor space. Right top: shading devices on south and west elevations. Right bottom: view of typical floor plan's façades with DSFs on all orientations

In regards to the DSF design scenario, in total there are eight DSFs on every floor level: SE-E, SE-S, SW-S, SW-W, NE-E, NE-N, NW-N, NW-W. The height of the DSF corresponds to the height of each floor level that is 3.9m (Figure 1 right bottom). This design of the DSF, as opposed to a multi-story DSF, allows for similar temperature gradients within the cavity, while each story has more or less the same temperature (Hensen, Bartak and Kal, 2002). In addition, this type of DSF behaves better in relation to acoustical, fire and ventilation issues (Poirazis, 2004). The simulated DSF is a naturally ventilated corridor façade with inlet (bottom) and outlet (top) openings for each DSF, at each floor level. During the cold season (November 1 - March 31) the DSF is airtight, while during the hot season (April 1 – October 31), the inlet and outlet openings are open (outdoor air curtain type DSF). The composition of the DSF under study is: LowE double-glazing (interior layer), an air cavity of 1m deep in the middle, and single glazing (exterior layer). The 1m-cavity is considered a good choice in hot climates due to the increasing air volume that allows for significant pre-cooling of the air during summer (Balocco, 2002; Hamza, 2008; Papadaki, Papantoniou and Kolokotsa, 2014).

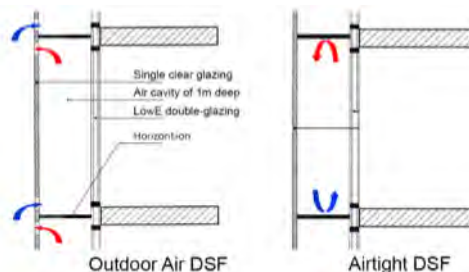


Figure 2 DSF spatial configurations for hot season (outdoor air DSF) and cold season (airtight DSF)

### 3. Simulation Results

Table 3 presents the cumulative changes in energy efficiency between the six different envelope scenarios of the office reference model from ground level to top floor. The improvements in the building envelope are as follows:

Scenario A: Energy consumption of reinforced concrete (RC) structure with clear glazing (6mm), infiltration 0.9ACH. This scenario reflects the design of high-rise buildings in the beginning of 20th century and is included for comparison purposes with the following scenarios.

Scenario B: Replacement of windows with low-emissivity, spectrally selective, tinted double-glazing (LoE Spec Sel Tint 6mm/ 13mm air / clear glass 6mm), infiltration 0.6ACH. The reduction in ACH from 0.9 to 0.6 is based on an assumption that changing window systems from clear-

glass, to LowE double-glazing, including improved sealants and frames, will reduce infiltration (El-darwish and Gomaa, 2017). High cooling loads decreased by approximately 25% for all subsequent heights, while heating decreased by approximately 90%, however very low to begin with (e.g. 1.79kWh/m<sup>2</sup>/year > 0.24 kWh/m<sup>2</sup>/year).

Scenario C: Incorporation of shading devices (Figure 1 right top) on the south, east and west elevation. Cooling energy decreased considerably by a further 50% (e.g. 99.5 kWh/m<sup>2</sup>/year > 49.3 kWh/m<sup>2</sup>/year), while heating increased by almost 4 times, however is still quite low (e.g. 0.24 kWh/m<sup>2</sup>/year > 0.9 kWh/m<sup>2</sup>/year).

Scenario D: Replacement of windows with low-emissivity, spectrally selective, tinted triple-glazing (clear glass 6mm / 13mm air / LoE Film 6mm/ 13mm air / clear glass 6mm). This scenario is like scenario B, but instead of double LowE glazing it uses triple LowE glazing. Comparing scenario B with scenario D we see that cooling loads start by being identical for the ground floor, while with height cooling loads for scenario D perform worst by approximately 1% (e.g. @82m high 87.5 kWh/m<sup>2</sup>/year < 88.3 kWh/m<sup>2</sup>/year). Heating loads in scenario D are lower by 80-90%, but still very low (e.g. 0.9 kWh/m<sup>2</sup>/year > 0.15 kWh/m<sup>2</sup>/year).

Scenario E: Incorporation of external shading devices in scenario D with triple glazing. Cooling loads decreased by approximately 40% from scenario D, however comparing scenario C of double-glazing with external shading devices with scenario E of triple glazing with external shading devices, we see that the cooling loads of scenario E are by 20% higher (e.g. 49.3 kWh/m<sup>2</sup>/year < 60.8 kWh/m<sup>2</sup>/year).

Scenario F: Incorporation of eight DSFs for all orientations: SE-E, SE-S, SW-S, SW-W, NE-E, NE-N, NW-N, NW-W. Comparing scenario C, with scenario E, and scenario F, we see that scenario B of double-glazing and external shading performs the best with the lowest cooling loads by 20% from scenario E, and 8% from scenario F at ground level. However, when studying more closely scenario B with scenario F, we see that the differences in cooling diminish with height, where for example at 340m become almost identical (e.g. 35.8 kWh/m<sup>2</sup>/year < 36 kWh/m<sup>2</sup>/year). In regards to heating loads, scenario F performs better by approximately 70%. However, while heating loads are substantially lower in comparison with the cooling loads at lower levels, at 340m high heating loads for scenario B are 3.06 kWh/m<sup>2</sup>/year, and for scenario F 1.37 kWh/m<sup>2</sup>/year.

*Table 3 Heating (H) and cooling (C) loads of six envelope scenarios: Single Clear and no shading, DoubleLowE and no shading (n.Sh), DoubleLowE and shading (Sh.), and DSF (single\_doubleLowE). U values of wall and windows ratio according to Israel's GBS*

Meters high /kWh/m <sup>2</sup> /year		8m	82m	168m	254m	340
<b>Scenario A</b> Sgl. Cl. Gl. n.Sh.	H	1.79	2.82	3.86	5.03	6.47
	C	133.6	116.3	108.3	101.3	94.3
<b>Scenario B</b> Dbl. LowE n.Sh.	H	0.24	0.3	0.4	0.6	0.8
	C	99.5	87.5	82.3	77.6	73.1
<b>Scenario C</b> Dbl. LowE Sh.	H	0.9	1.38	1.9	2.52	3.06
	C	49.3	43.8	39.7	36.1	35.8
<b>Scenario D</b> Trp. LowE n.Sh	H	0.15	0.2	0.3	0.4	0.6
	C	99.5	88.3	83.4	78.9	74.6
<b>Scenario E</b> Trp. LowE Sh.	H	0.37	0.6	0.8	1.13	1.34
	C	60.8	56.2	52.1	48.3	48.0
<b>Scenario F</b> DSF	H	0.2	0.4	0.7	1.03	1.37
	C	53.2	46.5	41.6	38.3	36.0

For all the scenarios studied above, cooling energy decreased considerably from ground floor to top. In scenario A 30%, in scenario B 26%, in scenario C 27%, in scenario D 25%, in scenario E 21%, and in scenario F 32%. Comparing scenario B of double LowE glazing with scenario D triple LowE glazing, we see that the differences are not great, but scenario B performs slightly better in regards to cooling loads. However, with the addition of external shading their differences escalate in regards to cooling loads. Heating loads for scenario C are about 2.5 times higher from scenario E, but still considerably lower than cooling for an office building in the Mediterranean climate of Tel Aviv, making the double LowE glazing with external shading a more favorable scenario from the triple glazing with external shading one. Scenario F of DSFs is more closely compared with scenario C of double LowE glazing with external shading. The average cooling loads for scenario C is 40.9 kWh/m<sup>2</sup>/year, while for scenario F is 43.12 kWh/m<sup>2</sup>/year. On the other hand, the average heating for scenario C is 1.95W/m<sup>2</sup>K and for scenario F is 0.74W/m<sup>2</sup>K. While the differences in energy loads between the two scenarios are not great, the possibilities of implementing external shading on a high-rise building envelope are much lower in comparison with the option of a double skin façade.

#### 4. Conclusions

This paper discussed the changes in energy loads for heating and cooling between different envelope scenarios of an office high-rise building reference model located in Tel Aviv. Comparisons were made in relation to heating vs. cooling loads between five subsequent heights: 8m (ground level), 82m, 168m, 254m, and 340m. The significant differences in heating vs. cooling are due to the high internal heat gains of the office use, in combination with the climatic conditions of Tel Aviv.

In consideration of the increased windows ratio especially noticeable in office buildings today, the study focused on increasing the energy efficiency of a glass curtain wall construction. The improvements of the building envelope, e.g. thermal properties of glazing and addition of external shading devices, resulted in considerable reductions in cooling loads. It was noticeable that the double LowE with external shading option performed considerably better from the triple LowE with external shading option, with 20% less cooling loads in the Mediterranean climate of Tel Aviv.

In the DSF scenario, cooling energy loads were by 8% higher from the envelope option with double LowE glazing and external shading, however, given the popularity of DSFs, further studies on their energy efficiency is required. This is especially valid in hot climates, where the combination of high solar gains and a glass-building envelope affect greatly cooling loads. Furthermore, regarding skyscraper energy efficiency, actual monitoring of climatic conditions over and around tall buildings in a real urban environment with all its wind and temperatures complexities, becomes vital in order to verify the accuracy of the simulations.

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# IMPACT OF WINDOW EFFECTIVE OPENING AREA ON THERMAL AND ENERGY PERFORMANCE OF MIXED-MODE OFFICE BUILDINGS

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## Summary

Published data from the Brazilian energy sector attracts attention to the excessive energy consumption of buildings. Office buildings have a high energy demand, especially due to the use of air-conditioning systems to keep adequate indoor thermal conditions. The mixed-mode system is a prominent strategy to reduce energy consumption in office buildings. This strategy consists in combining the natural ventilation and the air-conditioning systems in the most effective manner. The window frame design plays an important role to ensure an efficient natural ventilation system in mixed-mode buildings, since its size and type interfere directly on the airflow rate and, consequently, on the thermal and energy performance of the room. This paper investigates the impacts of the solar orientation and the size of window effective opening area on thermal and energy performance of mixed-mode office buildings. Envelope design information was raised for a sample of mixed-mode office buildings located in the city of Sao Paulo, Brazil. Through statistical analysis of the collected data average values of design parameters were identified, in order to set a reference model with the most recurrent design characteristics from the sample. This reference model was then used to perform energy simulations using EnergyPlus software. A range of window effective opening area values was adopted to establish the analysed scenarios, representing different window types (top hung, sliding, louvres and horizontal pivot).

Results obtained through building energy simulations were analysed in terms of cooling degree hours (°Ch), air changes per hour (ACH) and annual thermal loads (W/m<sup>2</sup>.yr) and were presented through graphs containing comparative analyses. The best results were achieved with larger values of window opening effective area, and the top hung window type presented the lowest levels of air change rates, despite being the most recurrent type of windows installed in mixed-mode office buildings of the city of Sao Paulo, Brazil. The choice of the natural ventilation strategy interferes in the number of air changes, with the exception of very a very low window opening effective area (top hung window), which is the most frequently used window type in Sao Paulo's mixed-mode office buildings, from the field study sample.

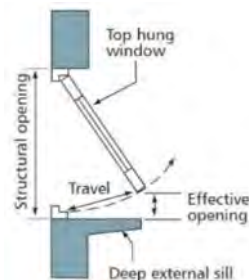
**Keywords:** Thermal and energy performance; Mixed-mode ventilation; EnergyPlus; Office building; Window effective opening area.

## 1. Introduction

Energy consumption has shown a considerable growth in recent years (Chenari et al., 2016). The buildings sector shows a great contribution, in particular office buildings, which usually provide thermal comfort through air-conditioning systems, representing around 50% of its total energy consumption, in Brazilian commercial buildings (Eletrobrás, 2009).

The mixed-mode system is a prominent strategy to reduce energy consumption in office buildings. This strategy consists in combining the natural ventilation and the air-conditioning systems in the most effective manner (CIBSE, 2000). It is largely used in Brazil, through the combination of operable openings and individual air-conditioning systems, such as split units or Window Room Air Conditioners (WRAC), present in 76% of Brazilian commercial facilities (Eletrobrás, 2009). A mixed-mode building allows spaces to be naturally ventilated during periods when it is feasible or desirable, and air-conditioning is used for supplementary cooling when natural ventilation is not sufficient or useful (Brager, 2006). Therefore, associated with envelope design optimization, the mixed-mode system helps reaching ideal indoor environmental conditions in respect to thermal comfort and thermal performance, while reducing energy consumption and operation costs with the air-conditioning system (Brager and Baker, 2008).

In mixed-mode buildings, the indoor airflow rate is directly related to the system's effectiveness, and it depends on a number of envelope characteristics, such as the size and location of openings (CIBSE, 2005). Different window types show different ventilation efficiencies, which could be correlated to the window effective opening area. According to CIBSE (2005), the window effective opening area for ventilation corresponds the cross-sectional free area of the window frame available to airflow. Figure 1 illustrates the difference between window structural opening (which corresponds to the size of the window frame interspace) and effective opening, for a top hung window.



*Figure 1 Structural opening, effective opening and travel distance for a top hung window (CIBSE, 2005)*

A systematic mapping of the literature shows a lack of studies about the influence of window effective opening area on the thermal and energy performance of mixed-mode office buildings. Among 58 reference papers about mixed-mode ventilation in office buildings, studies about variation in window-opening were found in only two researches. The first one is from Wang and Chen (2013), which present a semi-empirical model to investigate the impacts of the size of window effective opening area, climate, insulation, and thermal mass on the cooling energy savings of mixed-mode office buildings, located in three US climates. The results showed that the thermal mass and insulation have a large impact on energy savings, while the three window opening modes (fully open; half open; and one-quarter open) presented a relatively small impact, since the ventilation rate was sufficient to save electricity for cooling even by using the smaller window opening. The second one, from Bayoumi (2017), used computer simulation to investigate the relationship between the window-opening and energy savings in hot-humid and hot-arid climates, considering variations of WWR (33%, 50% and 66%) and of window effective opening area (10%, 50% and 100%). The results revealed that the windows could be opened more frequently in the arid climate, in comparison to the hot-humid climate, considering the number

of hours per month in which the outside temperature was below or equal to 25°C. However, the impact of window opening on the energy savings was greater for the humid climate, due to the better use of natural ventilation through large openings during the hours of operation. The author states that the effective opening area and the window-to-wall ratio (WWR) are crucial in determining the cooling load of an environment and, thus, its energy demand.

## 2. Method

The scientific method is classified as modeling, which consists on a simplified representation of reality to allow a better understanding of the environment being studied (Dresch et al., 2015) and it was conducted through computer simulations using EnergyPlus version 8.9. The method was structured in five stages, as explained in the following items.

### 2.1. Field survey: a sample of mixed-mode office buildings

A database containing architectural design information of 153 mixed-mode office buildings built over a twenty-year period (between 1995 and 2016) in the city of Sao Paulo, Brazil, was raised by Neves et al. (2017). 30% of this sample was selected to be part of a field survey, in which envelope and natural ventilation parameters were raised, such as façade color; coating; number of floors; floor shape (rectangle, L shape, T shape, etc.); floor area; solar orientation of the building and of the glazed facade(s); room shape and dimensions; sill height; windows characteristics (type, location, dimensions, glazing type, operable panes, effective opening area); solar shading devices characteristics; natural ventilation strategy; type and location of air-conditioning system. The collected data was statistically analyzed (Pereira and Neves, 2018) in order to identify the most recurrent design characteristics from the sample, which were used as a reference to set the base case models used in the building energy simulations.

### 2.2. Base case model definition

The database analysis led to the definition of three base case models, used as a reference to develop the current analysis. Each model represents a mixed-mode office room, with variations on the natural ventilation strategy: single sided ventilation, cross ventilation through adjacent facades and cross ventilation through opposite facades (Figure 2).

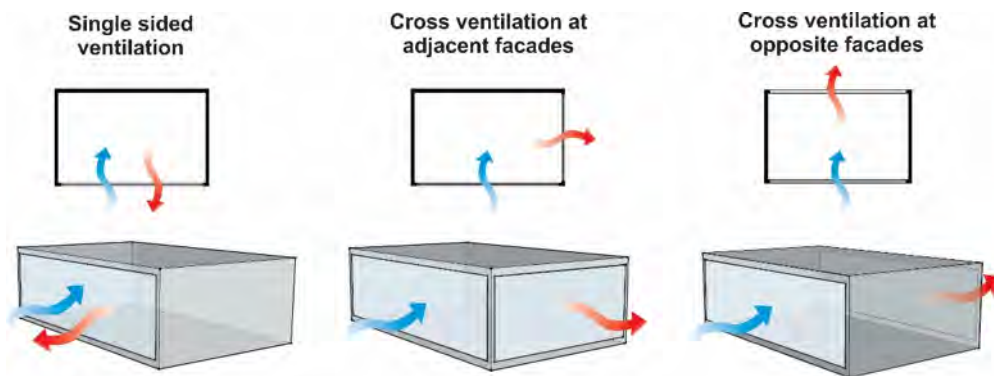


Figure 2 Base case models

The base case models' envelope characteristics were defined according to the most recurrent results obtained from the field survey statistical analysis and are the same for the three models, with the exception to the window-to-wall ratio, which was considered to be the database's maximum value, in order to allow a wider range of variation of the window effective opening area, which is the focus of this study. Since the model was considered to be an office room located at an intermediate floor, the floor, the ceiling and the interior walls were considered adiabatic



surfaces, that is, there is no heat transfer between them and the outdoor environment. Indoor thermal loads (occupancy, artificial lights and equipment) were set based on Brazilian standards and regulations. Table 1 shows the base models characteristics.

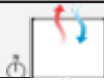


*Table 1 Base case model characteristics*




Parameters	Values	Reference
Floor height	13.25 m (6th floor)	Database average value
Office room area	39.2 m <sup>2</sup>	Database average value
Ceiling height	2.50 m	Database average value
Exterior shading device	0 (no shading devices)	Database most recurrent case
Window-to-wall ratio	81%	Database maximum value
Wall absorptance of solar radiation	0.61	Database average value
Glazing thermal transmittance	5.8 W/m <sup>2</sup> .K (single glazing)	Database most recurrent case
Solar heat gain coefficient	0.62 (tinted glass)	Database most recurrent case
Visible transmittance	0.75 (tinted glass)	Database most recurrent case
Slab thermal transmittance	4.43 W/ (m <sup>2</sup> .K) (15 cm concrete slab)	ABNT, 2005
Wall thermal transmittance	2.38 W/ (m <sup>2</sup> .K) (mortar 2.5 cm + concrete block 19 cm + mortar 2.5 cm)	ABNT, 2005
Wall thermal capacity	258.6 kJ/ (m <sup>2</sup> .K) (mortar 2.5 cm + concrete block 19 cm + mortar 2.5 cm)	ABNT, 2005
Occupancy schedule	10h/day (weekdays)	INMETRO, 2018
Internal loads - occupancy	65 W/m <sup>2</sup>	ASHRAE 55, 2013
Internal loads - lights	9.7 W/m <sup>2</sup>	INMETRO, 2018
Internal loads - equipment	10.7 W/m <sup>2</sup>	ABNT, 2008

### 2.3. Parametric analysis

Two parameters were chosen as variable parameters, to perform the analysis: the window opening effective area and the solar orientation. The variations of window effective opening area were determined according to the minimum and maximum possible opening values, representing different window frame types of the building industry (Lamberts et al., 2014). Therefore, the variations occurred from 10% to 100%, considering a 10% interval between each scenario. The solar orientation was also determined as a variable parameter, since it is directly related to the window position (i.e., the wind direction) and to the heat gains through the envelope. The variations were set as follows (considering the facade(s) with windows) (Table 2):

*Table 2 Solar orientation scenarios*

Ventilation strategy		Solar orientation
Scenario 1	Single sided ventilation 	North
	Cross ventilation at adjacent facades 	North and west
	Cross ventilation at opposite facades 	North and south

	Ventilation strategy		Solar orientation
	Single sided ventilation		South
Scenario 2	Cross ventilation at adjacent facades		South and east
	Cross ventilation at opposite facades		East and west

## 2.4. Building energy simulation

To perform the building energy simulations, a Typical Meteorological Year (TMY) weather file of the city of Sao Paulo, Brazil, was used, available in an EnergyPlus weather file (epw) format (LABEEE, 2017). The cooling system was modeled as an ideal air conditioning system, considering an outdoor airflow rate of 27m<sup>3</sup>/h.person, as required by the National Health Surveillance Agency (ANVISA, 2002). The natural ventilation was modeled through the AirflowNetwork model, which performs calculations of pressure, air flow, temperature, humidity and heat exchanges (EnergyPlus, 2016). The surface average calculation built-in option for high-rise buildings was adopted as input data for the wind pressure coefficients, which is valid only for rectangular buildings. The discharge coefficient was set as 0.6, as recommended by Jones et al. (2016).

Since the AirflowNetwork model has a limitation for the window opening control, an EnergyPlus runtime language (ERL) code was written through the Energy Management System (EMS), in order to provide a binary control (opened or closed) for window opening. The EMS was also used to settle the mixed-mode operation according to the adaptive thermal comfort model of ASHRAE 55 (2013), which is recommended for naturally ventilated environments and is considered the most adequate model for mixed-mode systems (Deuble and De Dear, 2012). The adaptive thermal comfort model defines a comfort zone based on the indoor operative temperature, which varies according to the outdoor air average temperature. The program implemented to control the opening of windows and the operation of air conditioning was based on the following conditions:

- The air-conditioning system turns on and windows are closed when the zone is occupied and the zone sensor indicates that the operative temperature is outside the comfort limits.
- The air-conditioning system turns off and windows are opened when the zone is occupied and the zone sensor indicates that the operative temperature is within the comfort limits, and the outdoor temperature is below the zone operative temperature.
- The air-conditioning system turns off and windows are closed if the zone is unoccupied.

## 2.5. Results analysis

Results were analyzed through the following outputs: cooling degree hours (°Ch), air changes per hour (ACH) and annual thermal loads (W/m<sup>2</sup>.yr). The analyses of cooling degree hours and annual thermal loads outputs were performed considering the full range of window effective opening area variations (10% to 100%), in order to compare each scenario. The analysis of air change rate was narrowed to the four most recurrent types of window frame from the field survey (Table 3). Since the effective opening area of the top hung and the louvres window types may vary, its values were set as the mean value from the field survey (Pereira and Neves, 2018).

Table 3 Window types and their window effective opening area

Window type	Top hung	Sliding	Louvres (45°)	Horizontal pivot
Window effective opening area	20%	40%	70%	90%

### 3. Results and discussion

The cooling degree hours and the annual thermal loads analyses showed significant differences between both solar orientations, for all base case models (Figures 3 to 6). The model with single sided ventilation presented the largest difference, since the amount of heat gains through the envelope between north and south facades present a major gap. Raising the window effective opening area had, though, a positive impact over all the scenarios, since it resulted in lower values of cooling degree hours and thermal loads. For both solar orientations tested (scenarios 1 and 2), the cross ventilation at opposite facades is the best option if the window opening effective area is high (louvres or horizontal pivot window frame types, for example). If the effective area is low, the cross ventilation at adjacent or opposite facades can only be beneficial if windows are facing facades with lower thermal gains (east or south).

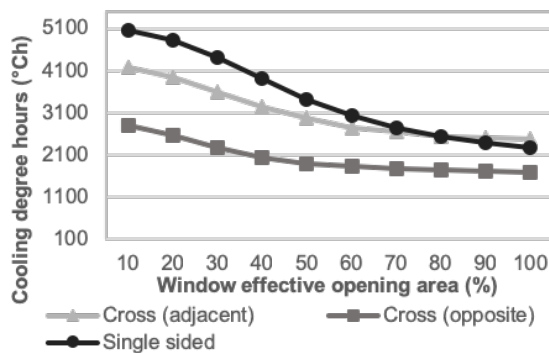


Figure 3 Cooling degree hours (Scenario 1)

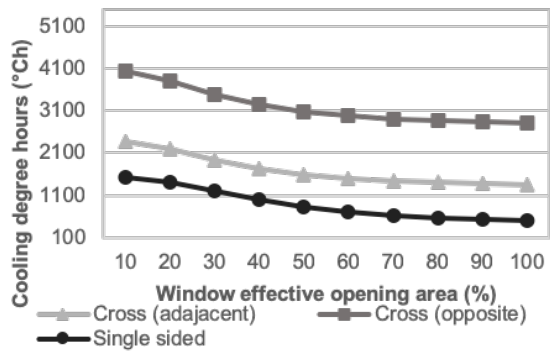


Figure 4 Cooling degree hours (Scenario 2)

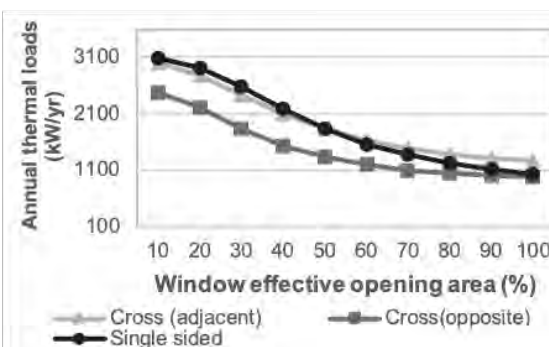


Figure 5 Thermal loads (Scenario 1)

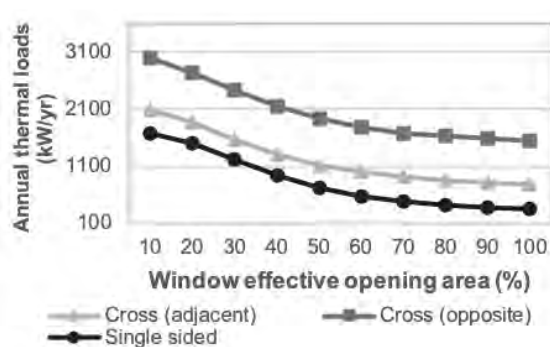


Figure 6 Thermal loads (Scenario 2)

Figure 7 presents the air change rate variation of four types of window frame, for the three base case models, considering the solar orientations of Scenario 1 (worst solar orientation). The cross ventilation at opposite facades showed better results for the sliding, louvres and horizontal pivot window type options. The top hung window type did not present good air change rates for any natural ventilation strategy, showing the inadequacy of a very low window opening effective area. This was, though, the most recurrent window type in the field survey results, representing 84% of the cases (Pereira and Neves, 2018).

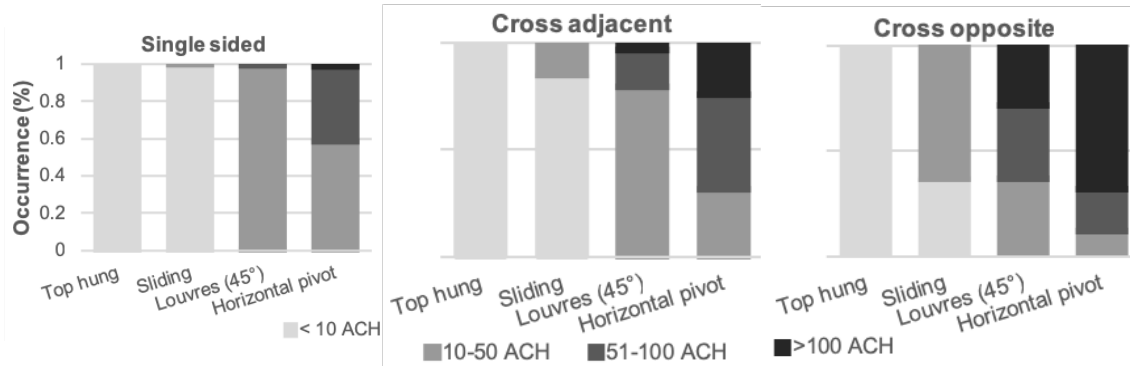


Figure 7 Air change rate variation of four types of window frame

Figure 8 presents the air change rate variation according to the wind speed, for the four types of window frame, considering the solar orientations of Scenario 1 (worst solar orientation). The wind speed data is from the meteorological station, monitored in an open space at 10 m height from the ground. It can be observed that the wind speed did not significantly affect the airflow inside the room for the scenarios with lower values of window opening effective area (top hung and sliding options). In addition, the natural ventilation strategy (single sided, cross ventilation at adjacent or opposite facades) did not have a significant impact over the results for wind speeds lower than 2 m/s. For higher values of window opening effective area (louvres and horizontal pivot options), the airflow increased proportionally to the wind speed, for the three natural ventilation strategies.

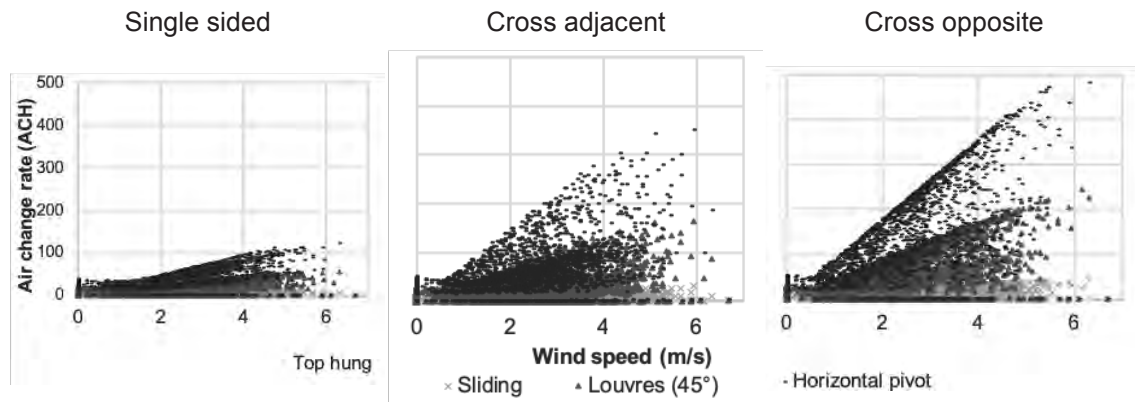


Figure 8 Air change rate variation of four types of window frame

#### 4. Conclusion

This study evaluated the impact of window effective opening area on thermal and energy performance of a mixed-mode office building, for two solar orientation scenarios and three types of natural ventilation strategy: single sided ventilation, cross ventilation at adjacent facades, and cross ventilation at opposite facades. The best results were achieved with larger values of window opening effective area, and the top hung window type presented the lowest levels of air change rates, despite being the most recurrent type of windows installed in mixed-mode office buildings of the city of Sao Paulo, Brazil. The choice of the natural ventilation strategy interferes in the number of air changes, with the exception of very a very low window opening effective area (top hung window), which is the most frequently used window type in Sao Paulo's mixed-mode office buildings, from the field study sample. The best natural ventilation strategy was the cross ventilation at opposite facades, but no buildings from the field study presented this design solution. In addition, the solar orientation had great influence on heat gains through the envelope,

showing that, for an adequate solar orientation (south), it could be the best option in terms of lowering the number of cooling degree hours.

The main contribution of this work consists in determining the impacts of window frame types, in respect to their window opening effective area, focused in the Design of Experiments (DOE), i. e., valid and defensible solutions, since it is based on design solutions from a sample of real buildings.

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