2010 &SB

16th International Conference on "Open and Sustainable Building"

Proceedings of the international conference jointly organized by CIB W104 – Open Building Implementation and TECNALIA

Bilbao, Spain
May 17-19, 2010

Edited by: José A. Chica, Peru Elguezabal, Sandra Meno & Aitor Amundarain

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PROCEEDINGS OF THE 16th INTERNATIONAL CONFERENCE OF THE CIB W104 OPEN BUILDING IMPLEMENTATION ON *"OPEN AND SUSTAINABLE BUILDING"*, ORGANISED JOINTLY WITH TECNALIA.

MAY 17-19, 2010 BILBAO (SPAIN)

O&SB 2010

Edited by

- **Dr. José A. Chica,** ***Head of Tecnalia Industrialised Construction.***
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COVER PHOTOGRAPH:

FRONT COVER

Upper image: "KUBIK by Tecnalia ® research facility" by Fernando Fernandez (Tecnalia)

Lower left image: THE SOLIDS, Amsterdam. Architect: Baumschlager and Eberle

Lower right image: NEXT 21, Osaka**.** Architect: Yositika Utida, Shu-Koh-Sha Architecture and Urban Design Studio

BACK COVER

Upper image: Arabianranta, Helsinki. Architect: Esko Kahri Oy

Lower image: Wenswonen, Zaltbommel, NL. Architect: Jan van den Brink

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Preface

These proceedings contain the papers presented at the 16th International Conference of the CIB W104 Open Building Implementation titled “**Open and Sustainable Building”**. Previous conferences have been held around the world in such places as Delft, Helsinki, Washington DC, Tokyo, Taipei, Mexico City, Hong Kong, and Paris. Previous conferences have produced published proceedings. More information can be found at the CIB W104 website www.open-building.org.

This conference took place from the 17^{th} -19^{th} of May, 2010 in Bilbao (Basque Country, Spain) and hosted by Labein TECNALIA. It was held in the The Euskalduna Conference Centre and Concert Hall, at the Technology Park of Bizkaia and at the Research Facility “*KUBIK by Tecnalia*”, Tecnalia´s headquarters in Derio (Basque Country, Spain).

All papers were peer reviewed by international experts in the field of open building. The papers address issues ranging from health care to housing, building technology to design methods, and represent research and practice by experts from Asia, Europe, North America and South America.

In addition to the papers presented at the conference, the winners of the 2^{nd} International Open Building Student Competition are presented, along with the challenge issued to the students. An international jury of architects reviewed more than 60 entries in coming to a list of winners.

The book of proceedings is introduced by a *Challenge to the Open Building Movement*, authored by Dr. Stephen Kendall, Professor of Architecture at Ball State University in the USA, one of the joint coordinators of the CIB W104. It offers a brief history of the CIB W104, its primary focus and principles, and outlines a number of challenges facing the design, construction and long-term management of a sustainable, open building stock.

Fundamental support has been provided by the CIB W104 Open Building Implementation Commission of the CIB, INTERNATIONAL COUNCIL FOR RESEARCH AND INNOVATION IN BUILDING AND CONSTRUCTION. These proceedings contain the latest developments, reviewed by these two organizations.

As members of the National Organising Committee, we wish to express our appreciation to the authors, reviewers, session chairs and programme committee members for all their hard work towards the publication of this book. We are particularly grateful to Prof. Dr. Stephen Kendall, Ball State University, USA., Prof. Dr. Beisi Jia, University of Hong Kong, China., Prof. Dr. Kazunobu Minami, Shibaura Institute of Technology, Japan and Prof. Dr. R.P.Geraedts, Delft University of Technology, The Netherlands.

Our sincere appreciation also goes to the Basque Government, Department of Education, Universities and Research and Department of Housing, Ministry of Science and Innovation and Ministry of Housing and to the sponsors of this conference whose support and financial contributions allowed the costs for participants to be kept to a minimum.

We hope that this book will provide a helpful reference and an incentive to architects, engineers and manufacturers to build more innovative, competitive and sustainable open building in the future.

The information provided in this publication is the sole responsibility of the individual authors, it does neither reflect the opinion of the editors nor of the supporting organisations and they are not responsible for any use that might be made of data appearing in this publication.

Previous conferences of the CIB W104 on Open building

All the information about these events is available at the CIB W104 website, www.open-building.org.

- 15th International Conference “Changing Roles”, Noordwijk, the Netherlands, 2009
- 14th International Conference “Education for Open Architecture”, Muncie, the USA, 2008
- 13th International Conference in conjunction with the CIB World Building Conference 2007 “Construction for Development”, Cape Town, South Africa, 2007
- 12th International Conference “ADAPTABLES 2006”, Eindhoven, The Netherlands, 2006
- 11th International Conference in conjunction with the SB05 Sustainable Building Conference in Tokyo “Action for Sustainability”, Tokyo, Japan, 2005
- 10th International Conference “Open Building and Sustainable Environment”, Paris, France, 2004
- 9th International Conference “Dense Living Urban Structure”, Hong Kong, China PR, 2003
- 8th International Conference “Balancing Resources and Quality in Housing”, Mexico City, Mexico, 2002
- 7th International Conference “Agile Architecture”, Delft, The Netherlands, 2001
- 6th International Conference “Continuous Customization in Housing (OBT2000)”, Tokyo, Japan, 2000.

Previous to this, the commission met in Tokyo, Delft, Helsinki, Taipei, Washington, DC, and Brighton, UK.

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Organization of the O&SB2010

The conference was organized over two and a half days. Professor Stephen Kendall and Alfonso del Águila offered keynote speeches. General Plenary sessions each day were organized to give all attendees access to key papers and presentations, followed by parallel paper sessions, technical tours of Bilbao and visits to “KUBIK by Tecnalia”. A conference dinner on the second day had the special focus of recognizing the winners of the student competition and awarding the prizes.

International Scientific Committee:

- Prof. Dr. Stephen Kendall, Ball State University, USA.
- Prof. Dr. Beisi Jia, University of Hong Kong, China.
- Prof. Dr. Kazunobu Minami, Shibaura Institute of Technology, Japan.
- Prof. Dr. R.P.Geraedts, Delft University of Technology, The Netherlands.

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- Mr. Juan Pérez, *Head of Tecnalia R&D for Innovation in Construction Processes.*
- Prof. Dr. Alfonso del Águila, *Department of Building and Architecture Technology, Polytechnic University of Madrid.*
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Organizations of the O&SB2010

- CIB W104 Open Building Implementation

- Labein TECNALIA

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Following the conference a select number of authors will be invited to revise their papers for peer reviewing and publication in special edition of the indexed publication, Open House International Journal, www.openhouse-int.com.

On behalf of the **O&SB2010** National Organising Committee:

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- Department of Education, Universities and Research (Basque Government).
- Department of Housing, Public Works and Transport (Basque Government).
- Eraikal, *Program for the promotion of the introduction and the improvement in the quality management systems, encourage sustainability and support innovation in those businesses in the residential building sector of the Basque Country.*
- FYM Italcementi Group
- ArcelorMittal
- Department of Housing (Spanish Government).
- The Basque - Navarro Official Association of Architects (COAVN).
- The Biscay Official Association of Industrial Engineers (CIIB).
- Bilbao Town Hall .
- Madrid Polytechnic University (UPM).
- “Informes de la Construcción” Journal
- The Eduardo Torroja Institute for Construction Science
- Master Laboratorio de la Vivienda del Siglo XXI
- “Art and cement”, the construction sector magazine.
- Solar Decathlon.
- The Biscay Official School of Surveyors and Technical Architects.
- Professional Development centre of Technical Architecture (ATZ).
- Innobasque, the Basque Innovation Agency.
- Spri, Basque Development Agency.
- Bizkaia Technology Park

We also want to express our appreciation to the jury of the Student Competition:

- Dietmar Eberle, Prof. of Architecture, ETH Zurich; Director of Baumschlager Eberle.
- Alfonso del Águila, Dr. Prof. of Building and Architecture Technology, Polytechnic University of Madrid (UPM).
- Renee Y Chow, Prof. of Architecture, University of California.
- Andrés Mignucci, Prof. of Architecture, Polytechnic University of Puerto Rico.

- Jaehoon Lee , Prof. of Architecture, Dankook University, Korea.
- John Ng, Ex-Chief Architect of Housing Authority, Hong Kong.
- Ziqing Yue, Chief Architect of HSArchitects, Shenzhen, China.

and to the Coordinators of the Student Competition:

- Professor Jia Beisi, University of Hong Kong, China.
- Professor Stephen Kendall, Ball State University, USA.
- Jose A. Chica, Ph. D. Eng., LABEIN Tecnalia, Spain.

Finally we want to acknowledge the support provided by our colleagues from Tecnalia: Ms. Teresa Valtierra for her support in all the organizational issues, Ms. Heather McGregor and Ms. Itziar Rodriguez for the support to the authors travels arrangements, Ms. Mirenlur Santiago and Ms. Anais Silban for their help regarding the promotion and dissemination and Mr. Miguel Angel Lopez for the design and management of the website: www.Openbuilding-2010.org.

We hope that this book will provide a helpful reference and will be an incentive to architects, teachers, students, researchers, developers, clients and product manufacturers to work vigorously and proactively in pursuit of a more open and sustainable building stock – a building stock with long asset life, energy effective, adaptable and deeply connected to its local culture.

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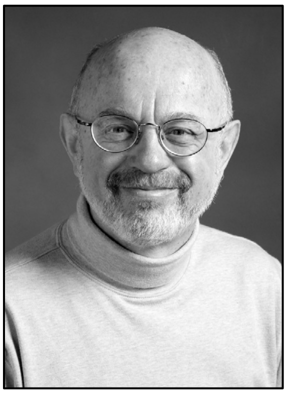
INTRODUCTION BY PROFESSOR STEPHEN KENDALL



"New Challenges for the Open Building Movement"

The Open Building Implementation network (www.open-building.org) was formed in 1996, under the auspices of the CIB (International Council for Research and Innovation in Building and Construction). Members of the CIB W104 come from many countries including the incubators of open building – Japan and the Netherlands – as well as the USA, the UK, Finland, France, Italy, Switzerland, Korea, China, Taiwan, Indonesia, Mexico, Brazil and South Africa.

Its original purpose was twofold. First, we intended to document developments toward open building on the international stage. Second, we would stimulate implementation efforts by disseminating information and by convening international conferences at which government and university researchers, practitioners, product manufacturers and others could exchange information and support local initiatives. These activities focused largely on the technical and methodological aspects of residential open building. There was interchange between colleagues in the less developed countries and developed countries, but the dominant focus was the latter.

During the intervening years, we met at least 15 times, in Delft, Tokyo, Taipei, Washington, DC, Mexico City, Brighton (UK), Helsinki, Paris, Hong Kong, and Muncie, Indiana (USA), on a few occasions with other CIB Commissions, and at several of the triennial CIB World Congresses. The most recent conference in the United States focused on education, and included an international student competition, with winners from Korea, China, Singapore and the USA.

Each conference has produced a published book of proceedings, containing a total now of over 300 peer-reviewed papers. A book titled Residential Open Building was published (Spon, 2000) and later was translated into Japanese. A second book, reporting on many new examples of open building, in the Chinese and English languages, is in preparation. A number of books have been published specifically on the subject and dozens of technical reports have been produced in several languages. Open building is referred to in countless books, scholarly papers, dissertations, and articles in professional journals, and in-depth country reports and studies have emerged in Finland, the Netherlands, the USA and Japan. (http://en.wikipedia.org/wiki/Open_building)

In the last few years, a number of developments in various countries suggest that the commission – and the open building movement more generally - should continue its focus and expand its arena of investigation. Residential open building is no longer a speculative idea of a few pioneer practitioners and theorists. It has or is poised to become mainstream. While disseminating information in professional journals, books and scholarly publications about the technical and methodological dimensions of residential open building continues to make sense, there is reason to pose new questions and reexamine old ones.

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State of the Art

Open Building is the term used to indicate a number of different but related ideas about the making of environment, for instance:

- *The idea of distinct levels of work in the built environment, such as those represented by 'support' or 'base building' or 'core and shell', and 'infill' or 'fit-out' or 'tenant-work'. Urban design and architecture also represent two levels of action.*
- *The idea that users / inhabitants may make design decisions in their sphere of control, as well as professionals;*
- *The idea that, more generally, designing is a process with multiple participants, among whom are different kinds of professionals;*
- *The idea that the interface between technical systems allows the replacement of one system with another performing the same function - as with different fit-out systems capable of being installed in a specific base building;*
- *The idea that built environment is in constant transformation, and that, as a consequence, change must be recognized and understood;*
- *The idea that built environment is the product of an ongoing, never ending design process in which environment transforms part by part. (www.habraken.org)*

We have recognized for some time that shopping centers and office buildings exhibit the characteristics of open building. As far as we know, no theoretical or methodological work preceded their coming of age. Their first appearance and subsequent evolution progressed pragmatically, as a response to new realities, led by real estate developers and business entities. Architects, engineers and contractors learned how to provide the needed services, often producing work of exceptional quality. Product manufacturers and their supply chains began introducing suitable products, fabrication and construction methods. New standards, regulations and financing tools were developed to match the new realities. These developments are international in scope, crossing economic, political, cultural and technical boundaries. The principle is the same: large buildings under the control of one party are built to be fine-grained inside, each occupant controlling its own space.

We now see that many parties – public and private - are asking for residential open building on a regular basis. This is evident in Finland, Poland, Japan, and the Netherlands. In other countries, residential open building – known by many names – is no longer seen as particularly unusual. We see evidence of this in Russia, Switzerland, Germany, China and to a lesser extent in the United States. New examples of housing designed by professionals to be incrementally upgraded in an informal user-controlled process come to light constantly, whether in Chile, Mexico, or South Africa. There is good reason to think that members of the Open Building network have contributed in some ways to this new coming of age of residential open building.

Mainstreaming of open building is apparently a response to the pressures, conflicts and waste caused by continued adherence to rigid functionalism – that is, defining functions and designing buildings to fit. Open building is also a pragmatic answer to a state of technical entanglement in buildings that has resulted from the incremental addition, over a long period of time, of new technical systems and the claim to these new systems by different trades who rarely cooperate. These pressures are forcing all parties to reconsider and realign their procurement and investment practices, their accounting methods, and their regulatory systems. In mass-consumer societies, attitudes toward the control exercised by inhabitants in the making and transformation of environments are changing vis-a-vis the control exercised by the many experts hired by large corporations, governments and communities. The idea that investments should consider long-term asset value is also forcing all parties to learn to make buildings – especially but not limited to multi-occupant buildings - that can adjust as technologies, social patterns, and preferences – both individual and community – evolve.

These changes in attitude and priorities are now taking the force of law. In part this can be explained by the widespread – and parallel - adoption of a sustainability agenda. For example, the Japanese parliament passed new laws in 2008 mandating 200 year housing, accompanying the legislation with enabling tools for use by local building officials who have the responsibility to evaluate and approve building projects. Projects approved under the new law receive a reduced rate of taxation. Other incentives may be added. In Finland, one of the largest real estate companies is regularly developing open building projects for their residential portfolio. In the Netherlands, a number of companies – from product manufacturers to developers to architects – are doing open building, by other names. In Warsaw, Poland, open building is known as the "Warsaw Standard". In San Francisco, residential developers build "bulk" housing, ready to be fitted out individually. Around the world, old office buildings, retained their social and economic value, are being converted to residential occupancy, after being "gutted" to prepare them for new uses and layouts.

We also see that in many countries, under the pressure of a rapidly evolving health care sector, hospitals are moving toward open building. Hospital clients can no longer afford to let short-term functional programs drive facilities procurement methods and investment decisions. They are demanding "change-ready" facilities, assessed by their accommodation capacity over time, rather than by short-term functional performance. But significant regulatory and financing barriers remain. We see this in the United States, Switzerland, Germany, Belgium, the United Kingdom, and the Netherlands. Similar developments are undoubtedly happening elsewhere, but usually without recognition.

These projects - often large and complex, providing space for housing, offices, commercial, health care and other uses - have the systemic properties of large private (or public) infrastructures. They involve many decision-making bodies and users over long time periods and often implicate numerous territorial claims. As such, they present technical, economic, political and cultural questions that go far beyond the dominant architectural discourse that still tends to emphasize the special case, breathless excitement over formal gymnastics, and the self-expression and self-aggrandizement of the designer and client. Generally speaking, these developments toward open building are not taking place for their ideological purity but for pragmatic reasons. In some cases, advocates of these new ways of working write and speak about them, but most simply get to work in daily practice, and meet new realities without much fanfare.

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An important task to continue

Much remains to be done to make open building projects come about with architectural excellence, to improve coordination, and to make long-term adaptation take place without fuss and at high quality. Yet those “in the trenches” have little incentive or time to report on and generalize from their work. A role continues to exist, therefore, for academics interested in detached and careful observation of what happens in the world of practice, with the expectation that new insights and sound generalizations may emerge to serve the built field.

Much remains to be done – on a continuing basis – in reporting on and accounting for developments toward open building. This effort should aggressively encompass not only residential but other ordinary classes of projects such as hospitals, schools, retail/commercial and office buildings and mixed-use properties and sites. The recent interest in new urbanism and other movements seeking thematic coherence of urban tissues will undoubtedly produce a building stock designed to accommodate varying occupancies.

Now that evidence is mounting that open building is not an aberration but a norm, we can expect building economists to develop data on the economic advantages of this way of working and to study the migration of economic activity toward the fit-out level. It should be possible for studies of buildings-in-use to track and evaluate user response to varying cycles of building and equipment change. Building information modeling software will soon enable designers and researchers to keep good records of how buildings change, enabling clients to make better decisions on their next investments. These signs of the evolution of the building stock should be carefully studied and general principles sought.

Some questions that remain for the open building movement

BASE BUILDING ARCHITECTURE

Interior public space and the urban façade are two architectural issues that demand new thought.

John Habraken, Denise Scott Brown and others have written about the importance of interior public space as part of larger patterns of space in urban tissues. Both have used the Nolli Map of Rome to articulate a view of the connectivity of urban design and architecture. Next 21 in Osaka – one of the most significant open building projects to date - was conceived as three dimensional urban design, challenging old assumptions about where the city ends and the building begins, raising new questions about territorial hierarchy.

Form-based codes are showing how rules and themes defining building envelopes that shape public space can supersede traditional functionalist zoning and abstract form making. Property developers are instructing their architects' - each hired to do an individual building - to adhere to thematic agreements in the design of the facades of new buildings in large urban extensions.

These developments are not limited to open building, but nevertheless are defining the skill sets, attitudes, methods and knowledge needed to make high quality base buildings and lively urban tissues that exhibit variety-in-coherence. Open building advocates must take the lead by pointing out these and related developments not as random events but as signs of new understandings of an open architecture.

AN INFILL or FIT-OUT INDUSTRY

A new kind of business entity with a new customer value proposition is needed to meet the demand of variable fit-out in open building projects.

Base buildings do not cost more. This was established by sound economic analysis decades ago for the residential sector, most clearly by work done in the Netherlands. Recently, a developer in Amsterdam built an open building project, accepting an initial up-charge of 5%, but recouped that investment within 2 years. This return on investment is evident in the office building and retail sectors, even though little or no building economics' evaluations have been done to prove empirically what is already a matter of course. Base buildings in the health care sector will soon become the norm, albeit with little in the way of theory or economic analysis to back it up, out of the force of necessity. While there is much to be done in improving the design and construction of sustainable and energy efficient base buildings, we can reasonably say that these developments are already well on their way.

Research conducted in the United States in the early 1980's showed that an increasing percentage of value added in the building sector was moving to investments in equipment and away from construction. Equipment is the classification of products that – in the United States - are depreciated on a short cycle, as opposed to the 30-year depreciation schedule of real property (base buildings). Equipment constitutes the kinds of products governed by standards such as those used by the Underwriters Laboratory in the United States and their counterparts elsewhere. Other countries have probably experienced the same shifting investment phenomenon, although little or no research exists to prove this. From an Open Building perspective, these trends signals the growth potential of an infill industry.

The customarily disjointed and quality-plagued way of filling in the empty spaces in open building projects is no longer excusable. There are exceptions, such as the high cost product bundles manufactured and installed by multi-national companies such as Steelcase, Haworth, Herman Miller and similar systems furniture companies. These companies are now moving outside of their traditional market niche of premier office space and are investing heavily in the health care sector. Other companies have learned how to deliver just-in-time fit-out for branch banks, chain stores, and even branded kindergartens, from central warehouses using local certified installation crews. But these represent a very small percentage of total fit-out investments. Aside from these, current practices produce high costs, scheduling complexity, conflict and limited user-choice.

In the residential open building market, no fully integrated fit-out companies exist. Early business ventures such as Matura in the Netherlands (1990-95) provided important technical and business models that deserve careful analysis. That infill

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system is now being upgraded and is reentering the market as a related kit-of-parts rather than a fully integrated system. NEXT-Infill is finding a market for its integrated infill for the new construction and renovation market in Japan. Developments in Finland will almost certainly evolve into fully integrated logistics and infill delivery. Time will tell if these business ventures will succeed in displacing the conventional, disintegrated fit-out delivery process and if similar developments will take root in other countries.

But in general, a mature infill or fit-out industry has yet to be born. In this arena, open building knowledge is crucial, and here, too we can be useful.

INCREMENTAL HOUSING IN DEVELOPING SOCIETIES

In developing economies, in which the informal sector is a vital part of the housing process, open building principles are evident.

New housing, designed by professionals, is incrementally adjusted, added to, and modified over time by the action of each household. This, too, is not new. New forms of public/private partnerships emerge, old technologies are used in new ways, and informal settlements become stable in ways that can only be understood by long-term observation. Recognition of the role of the user in the creation of environment is alive and well, if too often forgotten as part of the future of architecture. In developing economies, as in developed economies, experts in large bureaucracies and corporations are usually loath to relinquish control. But some learn to make money and protect the public interest by careful repositioning of their ways of working, harnessing the often invisible but complimentary economic engine of individual and local initiative in the housing process.

EDUCATION FOR AN OPEN ARCHITECTURE

From the perspective of open building, a renewal of the education of architects is urgently needed. The schools need to catch up with a profession already taking part in addressing the new realities of an open architecture, and may be able to assist in developing the knowledge, methods and the tools needed for the job.

Open architecture calls for new ways of teaching and perhaps new kinds of courses. The most durable but most problematic fact of life in contemporary architectural education is the assumption that every design project in the studio must begin with a program of functions. If we now see that programs of functions are inherently fleeting, we need a new basis for making architectural design decisions and assessing quality. The concept of capacity – and methods to assess capacity - must find its place in the lexicon and tools of architectural design education.

The studio as conventionally conceived is ill suited to teaching the skills needed to handle form making in support of an open architecture. Yet, the ability to distinguish design skills from programs of use is no stranger to the building systems, building technology and structures courses. There, exercises in technical thinking are most often assigned independent of specific uses or sites. The same is needed in architectural thinking and methods.

Faculty in schools of architecture should be encouraged to rethink the sacred cow of the design studio if open building principles, methods and attitudes are to find their

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place in already crowded university curricula. There is no question that these skills and attitudes are developed in an ad-hoc fashion on-the-job, in offices all over the world. Architecture schools need to catch up and provide sensible leadership in improving the state-of-the-art.

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ACCOUNTING
Taking stock of emerging patterns of control in the making of built environment

Stephen Kendall, PhD

Professor of Architecture
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ACCOUNTANTS

Students of the built environment have to be accountants. We take stock, watch it evolve, and name what we observe, trying to make sound classifications with the goal of finding general principles of its behavior. Practitioners also need to be accountants. But those colleagues in practice – in the business of implementing plans and policies – are also change-agents. What, in my opinion, we need to be accounting for and what we need to focus our change-energies on should become clear in the comments to follow.

(Photo by author)

The fact that the built environment is never finished is declaring the obvious. Yet taking stock of that phenomenon and developing methods to work with this reality isn't easy. Our societal propensity to focus on the short term adds to the difficulty. Our focus on the special buildings - the monuments, the icons, the extra-ordinary - also makes this perspective somewhat foreign.

We must be students of the built field not seen as an immutable construct to which people passively react and behave, nor as a technical phenomenon of bits and pieces, but as an artifact that lives by the action of many parties each taking part in the making of environment.

(photos by author)

For the record, proponents of open building include all kinds of professionals, as well as lay-people, in the making of environment, because the built world is not just the plaything of experts. In fact, we should beware of a tyranny of experts. As you'll hear later, we're particularly interested in reenergizing the sphere of control of the individual – people of all ages and genders and interests – in the environment game, increasingly dominated by big, powerful agents – both public and private.

PRODUCTION MODES

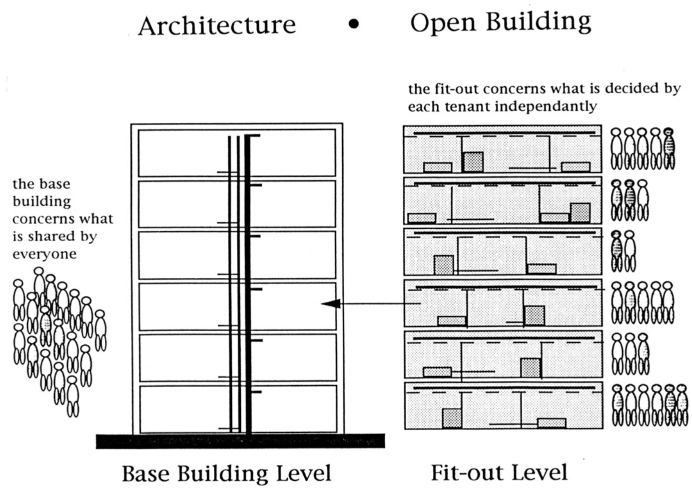
As students of the built field, we also watch closely the way production is organized. We can recognize three modes of production: Industrial production; construction; and prefabrication. Each needs the other, but each is a distinct mode of operation, initiative and risk-taking, and are therefore importantly different.

(photos by author)

These three modes are too often confused. Industrial production occurs by the initiative and at the risk of the producer, while construction occurs at the initiative and risk of the user, as does prefabrication.

REEMERGANCE OF PATTERNS OF CONTROL

As a way to explain what I'm trying to say in concrete terms, I'd like to discuss the reemergence of certain patterns of control in the building industry and to suggest why understanding their origins and their reappearance is important, but why also this is not happening without difficulty.



The patterns I speak of aren't mysterious, but they are often missed when our viewpoint is short-term and focused only on the exceptional building. Therefore, observing the "ordinary" environment is key to recognizing these patterns of control. In attending only to the special and the avant-garde, which of course deserve our attention, we may miss what needs our attention most urgently.

This re-patterning of control is producing an open architecture - increasingly liberated from the straightjacket of short-term functionality. The implications are very important. The quality of the results is mixed – as we would expect - in part because we are not very well focused as educators on the problem of cultivating the excellence of the "ordinary" building stock.

The Next 21 project in Osaka is just one example of courageous efforts to rethink the questions of time and control. We will learn more about it later this morning. It's a whole story in itself, but suffice it to say that NEXT 21 has been, since its completion in 1994, a continuing experiment in open building, in energy systems innovation, dimensional coordination and utilization of autonomous building systems in producing a remarkably "living" building. You may notice that the exterior skin of the building evinces both an overall coherence but also differentiation. Over the years, different architects have designed and redesigned each dwelling unit using a shared repertoire of façade elements, designed as a system by a team who did not design any of the dwellings.

A SHIFT

Why is this shift to an open architecture happening? Are there general patterns to be observed, blurring old functionalist lines? Several new realities are worth mentioning.

First is the urgency of the sustainability agenda, which also means learning how to produce a building (Next 21, Osaka, Japan, photo by Fukao) stock with long-term asset value.

Second is the demand for a “fine-grained” environment, even in the face of large powers building BIG projects. In this respect, Denise Scott-Brown has it right when she declares that form no longer follows but rather evokes or enables function.

Third is the emergence of a new classification of activity – an infill or fit-out industry - to serve these realities, a development generally happening under the radar. I will say more about that later.

For a long time, office buildings and shopping centers have behaved in an “open building” way. Architects design buildings that are erected by a construction company. Later, the spaces inside are filled-in by other design firms, working for different and changing occupants, whose plans are realized by other construction companies specializing in that kind of work.

Other parts of the ordinary fabric such as housing and health care are following suit…and both are running into similar problems that I will characterize as fundamentally problems of accounting and control. Increasingly, buildings are not known by function anymore – except for a moment in time. Is a new consilience taking place.

TWO PRINCIPLES

All four of these functional use types – offices, retail, housing and healthcare - share at least these two principles:

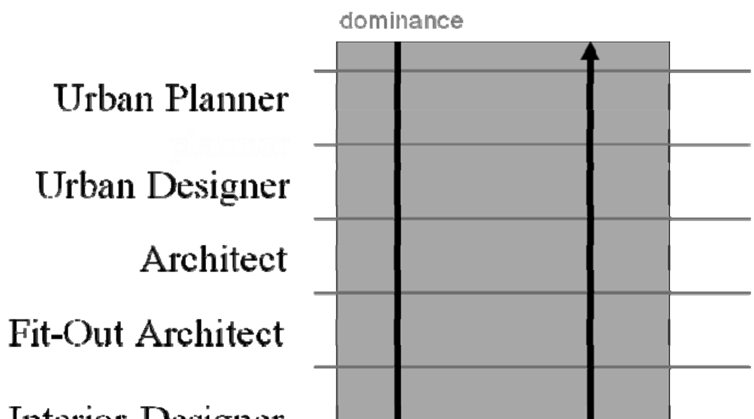
• *They all operate in the framework of levels of intervention*
And
• *They are all the products of distributed control*

Let me explain briefly. As the built field has increased in complexity and as the number of players has increased, the growth of specialized knowledge and disciplines has followed. This continues apace. We have more rather than fewer specializations needing to be coordinated. They inevitably find themselves operating on a certain level in a very straightforward hierarchy. It's not a good or bad hierarchy, but it does structure our work and makes change possible and manageable. Architects have struggled with the issue of specialization and coordination, and our failure to come to grips with it still troubles our schools, if not the profession as such.

Accounting for the interplay of these agents' work reveals the hierarchical order represented in this diagram. Urban planners make urban structuring plans, which, when implemented, set the stage for urban designers to make urban morphology and urban space. New Urbanism comes to mind, with the concept of form-based codes. Over time, the urban tissue is filled in by buildings designed by architectural teams who were not involved in the design of the "rules of the game".

Buildings are fitted out over time by others sometimes called architects and sometimes interior architects, and so on. The higher levels dominate the lower ones, meaning that a change at a higher level ripples downward, while a change at a given level is possible without disturbing the higher level, as when a building is demolished and replaced without forcing the urban pattern as such to adjust.

There may be other levels – in fact levels emerge and disappear in time - but these are obvious ones that help us explain ourselves as professionals and the various roles we play today. This is vividly described in Habraken's seminal book The Structure of the Ordinary, one of the most lucid and important works of theory written in the last 100 years – it is not an ideological treatise, but a book explaining how the built field comes into being and transforms.



(from Habraken)

We need to situate the emergence and disappearance of technical systems in their socio-economic context. That means asking why some ways of working and some systems become conventional, and others fail to take hold, and why some work processes and physical parts are given certain names, classified in certain groups, and are claimed by certain parties such as professions or trades or industry sectors.

NAMING and CLASSIFICATION

The issue is naming, classification and codifying, something that is always embedded in a social group. Everything has a name, but the name continues to exist – or emerges in the first place - when it describes something that matters to particular agents who operate on the building stock. I'm sure you can think of words that once existed to explain the built field but that no longer are in currency, and other words that are now in use but have emerged only recently.

Much more needs to be understood about this, if for no other reason than to understand larger patterns and make sound generalizations which might lead to better forecasting and set the stage for invention that actually gets traction.

Of course, in terms of naming and accounting, there is the very troubled world of architectural language, now overwhelmingly personalized, undercutting the maturation of a knowledge base we can call our own.

Building industry classifications and names have their place in conventional activities in the building sector. In the office market and in shopping center development, we easily recognize "base buildings" and "tenant fit-out", often called "core and shell" and "tenant work" or "commercial interiors."

The US Green Building Council's LEED (Leadership in Energy and Environmental Design) rating system has a name for some of these "levels of intervention" in their various products. Separate divisions within design and construction firms exist to serve this reality, and regulations recognize the distinction. So do financing instruments, and multi-national manufacturers of an expanding array of smart technical products.

These distinctions are conventional in the best sense of the word. They describe something in common of which thousands of variations exist.

(photo by the author)

They point to a reality to be accounted for by scholars and educators – the demand for a fine-grained environment even while accepting large projects for the sake of efficiency, and recognizing the existence of very large players whose interests are served by large territorial interventions.

OPEN BUILDING

This is really the story of open building – the methods and practices applied to the task of balancing the large-scale infrastructure intervention with the “fine-grain” serving the individual inhabitant’s changing preferences.

In an office building, the “individual” may well be a corporation or a business, not a family, claiming territory in an architectural infrastructure that is itself under the control of a higher-level party. Tenant’s ‘parts’ are now designed to be replaced, resold and recycled.

The base building is meant to last longer – to be sustainable – vis-à-vis the fit-out, and the fit-out is meant to be longer lasting than the equipment that occupants bring in to support their activities, preferences and budgets.

The architectural challenges are significant, including a new understanding of interior “public” space as an extension of the 3-dimensional urban design – a subject too few have written or teach about, but which goes on all the time in practice.

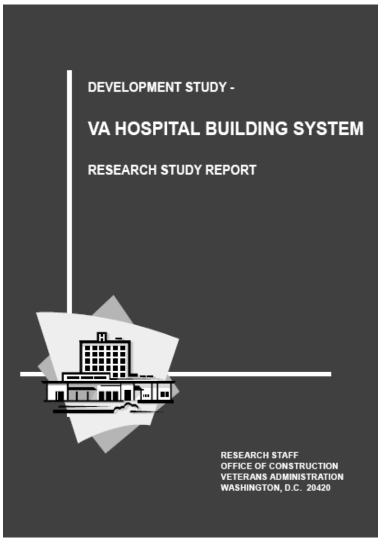
(photos by the author)

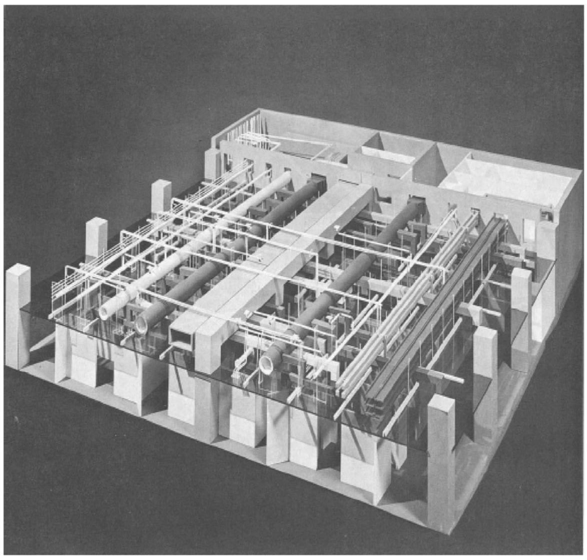
HEALTH CARE

In the health care sector, the issues of cost control, flexibility and time are reemerging with a vengeance. But these facts are recognized differently, and unevenly.

Planning for change was the subject of intense and comprehensive R&D in the United States in the 1970’s and 80’s, leading for example to the VAHBS (Veterans

Administration Hospital Building System). Twelve VA hospitals used the system, but there has been no systematic longitudinal assessment to draw out lessons. The VAHBS came into disfavor, in part because it was too much about a belief in integrated technical systems and not sufficiently focused on the actual political, environmental and organizational realities at each site, each seeking a different solution. Similar developments were occurring in the UK with the Nucleus Hospitals around the same time.





(from the Veterans Administration Hospital Building System handbook)

Speaking of the effect of accounting standards on the health of the building stock, currently in the US Department of Defense and the Veterans Administration there is a budgetary distinction between new construction and renovation/repair. But this accounting does not include “functional” failure as a reason to spend “renovation” funds. Only “failed conditions” (for example failed mechanical systems or other hardware) qualifies for release of “renovation” funds, based on an assessment of the work classification bureaucrats. This is a problem because spatial layout and patient and caregiver flow problems, for example, can emerge before hardware failure, and the accounting rules prohibit allocation of renovation funds to deal with these problems.

In the private sector, accounting methods in large health care systems do not distinguish new construction and renovation/ repair. This gives them more decision flexibility, but on the other hand data is not readily available to distinguish the behavior of their building stock in an “open building” way.

All healthcare owners are now struggling to get “sustainable” and “flexible” facilities. What this really means is that they are trying to figure out how to do open building.

However, the accounting is not yet ready; the terms of reference are confused; the standards of practice, the methods of partitioning tasks and distributing control, the understanding that function cannot drive base building design decisions…all of these are not yet mature.

Clients that have set up their accounting – and their architectural infrastructures – in an open building way can harness evidence from new research findings as it evolves, applied when functional areas design decisions are made. This makes good sense if the base building has been designed to accommodate change and if the architectural infrastructure is worth it.

For pragmatic reasons, clients are expecting their service providers to design buildings that have capacity for variable functions over their lifetime. This too, is what a number of us around the world are paying attention to…and trying to account for.

The idea in this diagram of distinguishing “differential obsolescence” is therefore taking on greater importance. This is essentially a business view, with several investment horizons.

(Courtesy Canton Bern Office of Properties and Buildings)

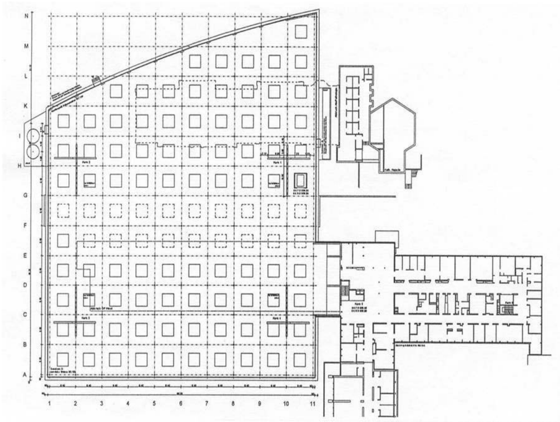
The renewed commitment to research – based decisions in healthcare architecture found in Evidence Based Design is laudable. EBD may help address problems of function and human behavior, but it is not yet able to help on issues of capacity. Yet capacity must now replace functionalism as a primary concept in the accounting, because of the imperatives of procuring and maintaining an open and sustainable building stock.

INO

The INO project at the Inselspital Hospital in Bern, Switzerland, is a useful model. It’s a very large addition to an existing health care campus, including surgery, ER, pharmacy, etc (but not beds). The client – the Canton Bern Office of Properties and Buildings - made the decision to change the procurement method it had been using for decades, a procurement method which was no longer viable.

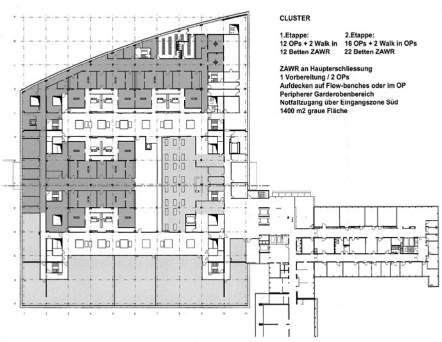
A competition was organized to select a base building or primary system design team, without giving them a detailed program. When the building was under construction, another competition was held to select a fit-out or secondary system design team with healthcare expertise, and detailed programming was done. This firm had to accept the base building as it was, but the base building – being an open building – could accommodate a wide array of fit-out decisions. Then, a third competition resulted in the selection of a company to provide the movable equipment, furnishings and so on.

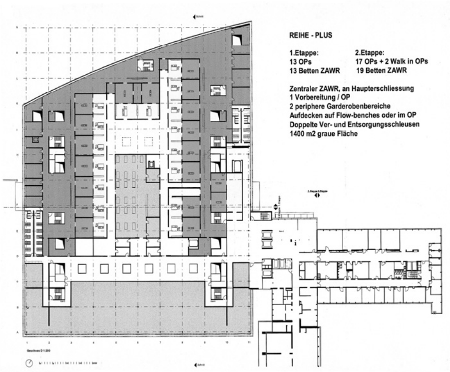





(photos by the author)

Before the building's primary system was even finished, the firm designing the secondary system needed to change the surgery suite layout because a new doctor had been hired who liked another layout. The primary system proved its capacity to the satisfaction of the client.

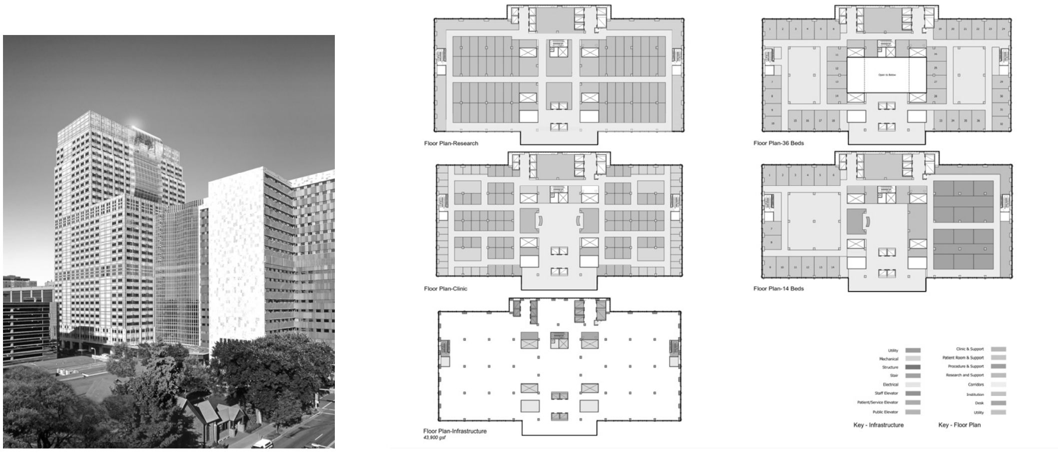




(courtesy of the Canton Bern Office of Properties and Buildings)

The project is nearing completion, after a difficult process caused by the need to change many habits and practices. It was and is controversial. But the success has led the Canton Bern (the client) to implement this process in its procurement of all public buildings in their portfolio including schools, hospitals, university buildings, prisons and elderly housing.

Now, after a decade or more of boom times in the US which are clearly coming to an end, during which clients had little incentive to consider long-term consequences of present actions, leading healthcare clients are gradually coming to grips with these realities I’ve been discussing, once again.



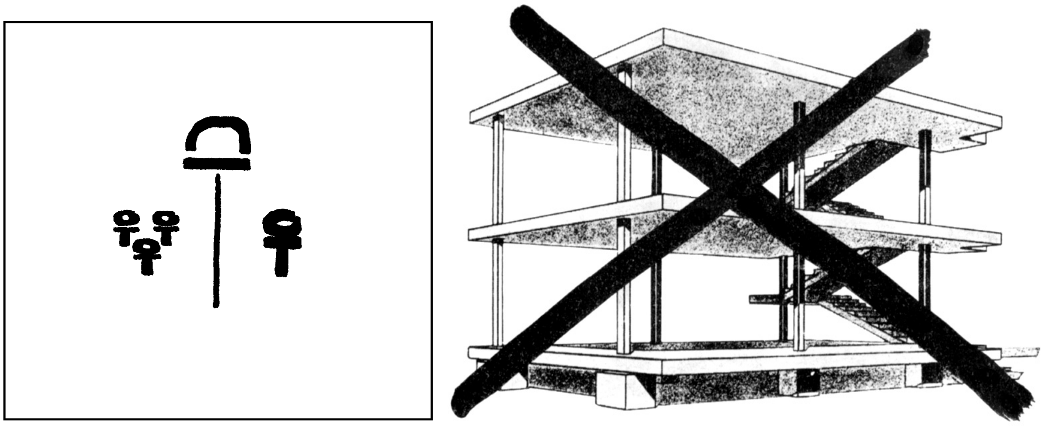
(Courtesy of Ellerbe Becket, Architects)

But they do so against many ingrained methods and attitudes spread across the spectrum of players.

And the architecture schools are no help, still turning out students imbued with the old functionalist paradigm of program first, then integrated building design follows.

RESIDENTIAL OPEN BUILDING

When it comes to the residential real estate sector, the diagrams made by John Habraken in the 1960’s are still compelling.



(from Habraken, The ABC’s of Housing)

Before WWI or thereabouts, accounting for housing production didn’t matter. Housing was a more-or-less organic, local process. The “natural relationship” was alive and well, more or less, in which individual households took part in the process and were instrumental in the process working. After the great upheavals of the early 20th century, this natural relationship collapsed.

Large corporations and central governments, staffed by experts, moved in, largely eliminating the natural relationship in the name of efficiency. Mass housing resulted (but not much in the US, for interesting and important reasons).

The experts (the Taylorists, the functionalists, the pseudo-scientific rationalists) gained power. This happened, if differently and from different ideological directions, in both centrally controlled and market economies. In the latter, it was in the interest of large corporations to marginalize the individual based on a narrow view of efficiency and scientific management. In centrally controlled economies, the same thing happened except that the argument was that the public sector had to be efficient.

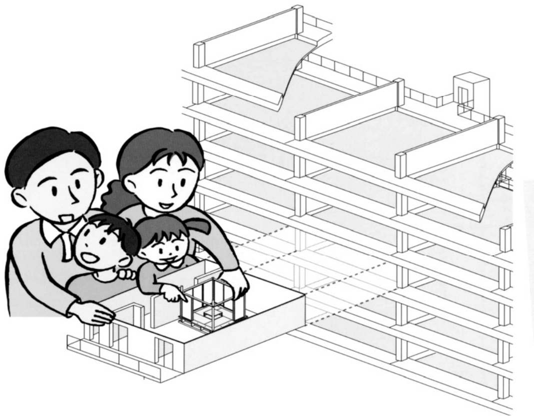
But the functionalist, corporatist/central control paradigm soon had cracks. Functionalism - initially a way for experts to mediate between built form and people - came to be a straightjacket when the time dimension came to be important. Rigidity and conflict was not far behind, or, in the wealthy societies, false and superfluous excesses were delivered to as a kind of unnatural variety.

Gradually, in very different contexts and for very different reasons and motivations, an alternative accounting has started to bloom – residential open building. I reported on this in a book now 10 years old by that name. It seems now that variety can be efficient. This is what a number of us around the world have been paying attention to…trying to account for.

We now see that where the individual had been lost from the accounting sheets, the individual is beginning to reappear as “the consumer” and not just in single-family houses, long the bastion of individuality and self-expression of clients and architects alike. We see such ideas as “mass customization” being explored in the building sector. The balance of power begins to be redressed but the resistance is strong. The old question “who decides about what” becomes active again, with all kinds of administrative, technical and methodological implications crossing all kinds of disciplines.

Consumption by itself has begun to have a hollow ring. The question is now sometimes seen (although rarely formulated this way) to be NOT about efficiency, or consumer-oriented services, but about the distribution of power in the making of environment.

No one wants the uniformity of increasingly large projects, now technically and financially viable on a massive scale. The natural instinct for the fine-grained reemerges as an important force. Architects and developers begin to pay attention. Now it is evident in banal ways in the false facades of shopping centers wanting to look like old town centers; and in the false variety of townhome developments “expressing individuality” while under tight, top-down development controls. But there are more positive signs, such as the principles (if not always the results) of new urbanism. And the many examples of residential open building around the world point the way.



(Courtesy HUDC Japan)

RESIDENTIAL OPEN BUILDING EXAMPLES

Many hundreds of residential open building projects have been reported and more are discussed each year at international conferences of the CIB W104 commission on open building implementation.

Here is a residential open building in Seattle built by a developer for the condominium (sale) market. It won an award from the American Institute of Architects.

It was built “empty” and later filled in to suit the preferences of individual inhabitants. It continues to experience “fine-grain” adaptation, with no special techniques involved.

(photo by the author)

This one is in Moscow. I visited it with the architect and is one of hundreds built at high quality there in recent years. The architect made a design of a building showing all floor plans. After it was granted a building permit, the architect deleted the dwelling floor plans and gave the empty building to the construction company. Later, each family hired its own designer and contractor to fit-out its house.

(Photo by the author)

Below (left) is a project in Helsinki. It won the Finnish Steel Industry Innovation Award. Its success has led to a number of other projects by major developers. An internet-based method was devised to help buyers make their choices from a menu of possibilities.

(photos by the author)

Above (right) is just one of hundreds of residential open building projects in Japan. In Japan, the term SKELETON / INFILL is popular now. This project exemplifies the understanding that the skeleton is the social part, while the infill is the individual part – called Two-Step Housing.

Below is a case in the Netherlands. This one is in Amsterdam, the initiative of the group of middle-class families living in the neighborhood of Westerpark near the center. They jointly hired the architect to design the base building. Then each designed their own dwelling with the assistance of various designers.

(photo by author)

The following project is in Zevenaar, designed for an “active elderly through continuing care” population. It’s owned by a non-profit association and follows “organic” architectural principles of anthroposophy as well as open building for the individual apartments, each a bit different in layout and equipment suited to each occupant, and planned to be changed when new occupants move in over the years.

(photo by author)

The project below, now under construction in Amsterdam, designed by the well-known European firm Baumschlager and Eberle, is called the Solids. Professor Eberle will be giving a talk on Wednesday as part of this conference. Its developer owns thousands of dwelling units and is convinced that the best investments are those that are adaptable, energy effective and lovable. Those are his words. Inhabitants are largely free to plan their interior space but are not allowed to change the façade of their space.

(photo courtesy of Baumschlager and Eberle)

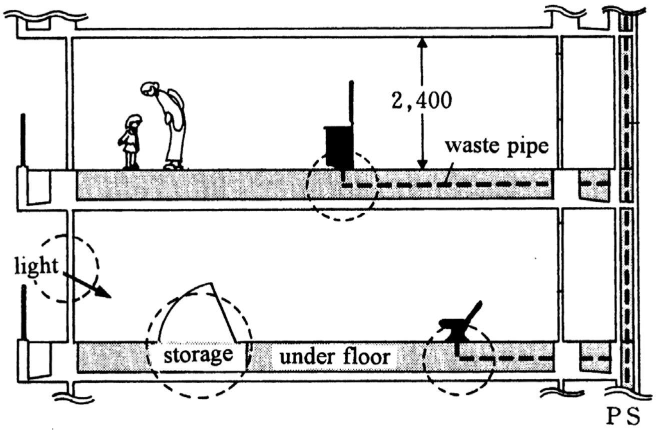
Space is leased in the building through a bidding process, and inhabitants can use their space for an office, a house, a business or a day care, and each inhabitant owns it's fit-out.
I would add that one of the long-term outcomes of an open building approach, detached as it is from short-sighted functionalism is that the efficiency experts can no longer use their old excuses for legislating what are often age ghettos or income ghettos. Social dynamics are a fact of life, and these dynamics should find their counterpart in the way we organize cities and construct buildings. Open-ended is part of that story.

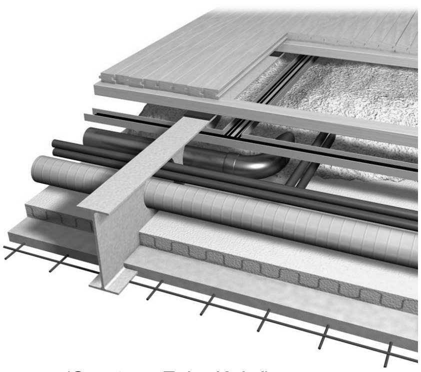
TECHNICAL ISSUES: Base Building Construction Methods

This is a good point to shift to some of the technical issues. First, what are alternative ways to build residential supports or base buildings? I will show some new products, as well as design concepts using traditional materials assembled in new ways.

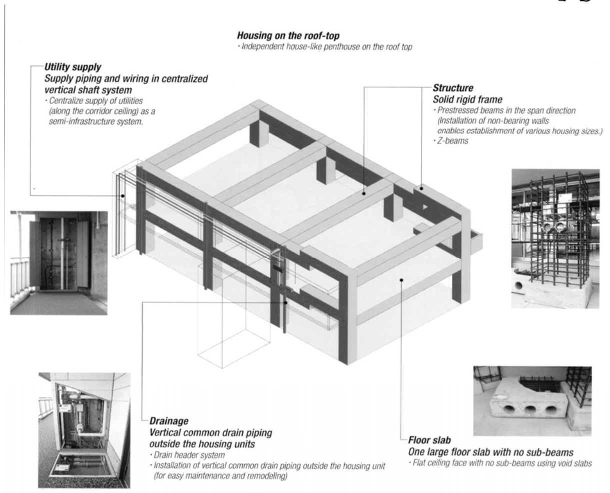
(Courtesy FlexCasco)

(courtesy HUDC / Japan)





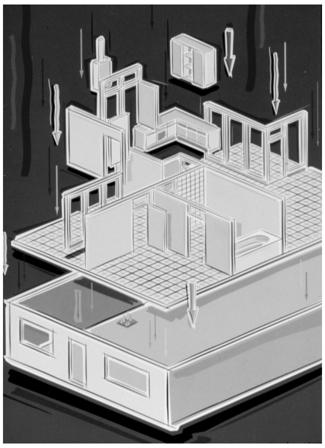
(Courtesy Esko Kahri)

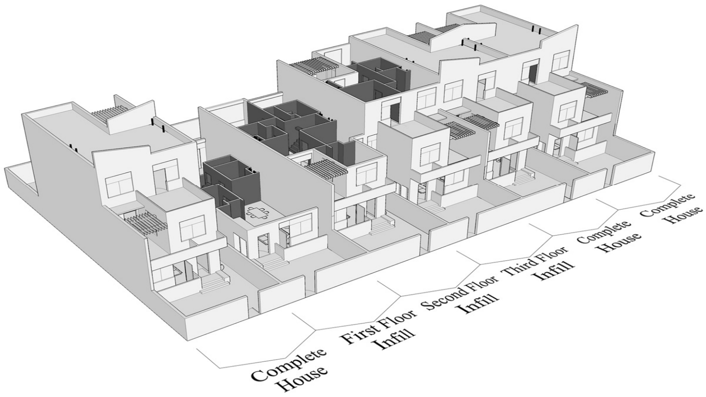


(Courtesy KSI / Japan)

NEXT STEP: AN INFILL OR FIT-OUT INDUSTRY

This brings me back to the gradual emergence of an infill or fit-out industry. My understanding is that this is happening in the real world, around the world, but without much attention paid to it. The implications to construction technology, logistics, data management, skills training and architecture are too significant to justify further ignorance of these realities.





(Courtesy Infill Systems BV)

I've been tracking these issues for some time, with a focus presently on the products needed for a fit-out company to deliver high quality, just-in-time and on-budget services.

I've asked how a divided construction cost accounting spread sheet might look in which some costs are allocated to the base building and some to the fit-out – of multi-family residential projects. Of course, this is normal in office buildings and shopping centers.

I'm particularly interested just now in the MEP product bundle, including cable and piping management. Some of the products here are in use in Europe and some of their manufacturers are actively involved in getting code and regulatory approvals in the US.

SUMMARY

In this continuous process that exhibits both stability and change, both coherence and variety, some of us have become interested in the emergence of a fit-out industry in the service of the fine-grained in large projects. I believe such an industry is already nascent, and is coming into being as part of the long road toward a sustainable, open, fine-grained building stock.

The general principles of such an industry and the companies that will deliver customized, just-in-time residential fit-out include these:

• Industrial mass - production of general and small parts, each with competitive substitutes providing the same performance;
• Parts are designed for assembly/disassembly/reuse/recycle
• Logistics from fabrication shop to dwelling unit site
• Multi-skilled work cells for installation work on-site
• Streamlined building approval and inspection
• Good IT systems, from user interface to installation team
• User manual for occupants

The world moves on, new realities present themselves, and my antennae tell me that open building, by whatever name, is alive and well and that an infill or fit-out industry, a necessary next step, is just around the corner.

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THE ADAPTATION OF BUILDING INDUSTRIALIZATION IN A WORLD SUBJECTED TO MULTIPLE CHANGES

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THE “PREHISTORY” OF MODERN TIMES

Testing with several kinds of prefabricated concrete and different types of metallic copies began in the mid-19th century , both in the form of panels and small 3D units.

Inventors, engineers and builders such as Godwin, Coignet, Edison, Moppin and Perret, representatives of as many experiencies in the development of the firsts prefabricated concretes, mainly for building.

Nevertheless, two legendary names in the prestige of the application of prefabrication and industrialization techniques appear in the “roaring twenties and thirties”. They are the architect Le Corbusier and the engineer Jean Prouvé, although none of them possessed the academic qualifications, in fact Le Corbusier is known as a French architect although he wasn’t an architect, nor French (he was Swiss)… and his real name was not Le Corbusier.

But no one can deny his figure as one of the most important architects of the 20th century, to whom those of us hoping during all our lifes for the Industrialization of Construction should be immensely grateful.

Those two figures gave an unequaled prestige and quality to the prefabrication applied to building, which was broken with the big misfortune of the II World War and subsequent consequences.

The shortage of housing that took place in Europe as a consequence of this tragedy, with a vast destruction of the building heritage and millions of human lives, entailed the search for solutions with three premises: a fast carrying out; saving of economic resources and a maximum reduction of labour.

It was not by chance that the solution was found in the systems of big prefabricated concrete panels, but there was a latent technological preparation. They were used both in Occidental Europe and the Europe corresponding to the Soviet orbit.

The development of the plans of the millions of housings made in the forties, fifties and sixties was left in the hands of engineers, economists and solicitors. This meant: EFFECTIVENESS, ECONOMY AND SPEED, but WHERE WERE THE AESTHETICS?

There was a “hunger” for housing, but as soon as that primary need was relieved, the quality, technical as well as architectural and environmental, was questioned. It was the second half of the sixties.

The big prefabricated panels were blamed for that massification, excusing traditional construction (for instance in our country the “massification” was brick by brick), when the culprits were promotion systems that, for lack of economic resources or social experimentations of a political kind, had not considered those problems.

The system was mistaken with its wrong use, as seen since the nineties with the production of housing complexes of great quality.

In the end of the sixties took place the first clear vision of how to understand the Industrialization in Building. The so-called “MODELS METHOD” and “ELEMENTS METHOD” were established internationally and for the first time, for industrializing complete buildings or their parts, a classification that has prevailed up to now but differentiation less and less defined.

THE EARLY STAGES OF OPEN INDUSTRIALIZATION

In view of the widespread criticism to the “Models Method” represented fundamentally by the systems of big prefabricated concrete panels, two effects took place:

- A NEGATIVE ONE: Since then the expression PREFABRICATION IN BUILDING can not be used, since prefabricated construction was totally discredited. It can be used in Civil construction, where there are no qualms about talking about a prefabricated bridge or a prefabricated dam, etc.

- A POSITIVE ONE: It gave rise to the Club of Rome’s considerations on the housing quality.

Thus were established the following PRINCIPLES:

1.- A higher aesthetic value in housing and urban complexes;

2.- A lesser visible weight of technique in those,

3.- A higher social sense, avoiding massification, with flat building of a reduced number of floors, open spaces, sports and green zones, etc.

4.- Contact gap between user and interior concrete, not considered very “friendly” to human beings (it’s hard, doesn’t transpire, is not comfortable). Ever since gypsum claddings have become practically obligatory.

All of this caused that the architect appears again in the house design with the use of innovative constructive systems and a growing dialogue with engineers and consultants.

It's worth noting that during the previous stage the architect had remained “mute” (In the Congress of the International Union of Architects -IUA- of 1967 the motto was “the architect is like the white horse: expensive and out of fashion”).

And also, the value enhancement of Open Industrialization begins to be considered as a way to carry out the Club of Rome principles more successfully than what could be done with Closed Systems

This way, at the end of the “seventies” and beginning of the “eighties”, and “Open” Industrialization or “Compatible components” Industrialization started to be suggested, with hopeful initiatives that opened new horizons (such as the very important French initiatives “ACC” and “PIP”).

The meeting of the “SPRINT” Programme in Stuttgart in 1992 is worth highlighting, where the already budding European Union supported the modernization of Building through Open Industrialization.

THE CURRENT SPANISH SITUATION OF THE INDUSTRIALIZATION OF CONSTRUCTION

In a preliminary analysis of the state of the art in housing industrialization, we can state that the construction industry in Europe represents more than 9,7% of its GDP, housing taking almost 27% of its total volume.

This one is in turn very slow for change and innovation and quite incapable to introduce and assimilate new technologies.

In all of Europe, to a greater or lesser degree, the Building Sector is dragging a handicap of technological obsolescence, totally out of place in a society of the 21st century.

In Spain sometimes “handmade” techniques are said to be used, but it's impossible because there are no “artisans”, since most of the labour has no specialization, coming directly from the agricultural sector, even though the crops fields are in Ecuador or Maghreb.

It's also said that “we build like in Roman times”, to which could be answered that we wished as much.

It's a totally disorganized Sector in every aspect: labour; its productivity; high rate of industrial accidents; lack of mechanization; habitual failure to fulfil financial planning and schedules; lack of participation of female labour; descending quality; hampering innovation.

In Spain there's some industrialization in housing building based principally on prefabricated concrete panel systems, whose distant origins were in the seventies, but with important modification and technological innovations that make them totally different, both from a conceptual point of view and a technological one.

Also, there's some development of prefabricated and industrialized constructive elements, such as GRC and architectural concrete façades, slabs with “tables”, highly mechanized formworks for in-situ concretes, an important sector of prefabrication of structural systems and slabs, gradual use of prefabricated laminated gypsum partitioning, without forgetting 3d “modular” construction, in which Spain has a great potential.

There aren't, in any case, agreements of dimensional or compatibility coordination.

OPEN INDUSTRIALIZATION AS A PATH OF TECHNOLOGICAL INNOVATION TO MODERNIZE BUILDING

The huge worldwide economic development from the end of the 20th century and the beginning of the 21st caused a strong enthusiasm for investments, which had repercussion on Europe in the hope to get away of the technological backwardness of Building through, specially, Open Industrialization or industrialized constructive components. A good exponent of this has been the European project ManuBuild, which is going to be continued, it would seem, in ManuBuild II, if the end of the economic recession is confirmed.

The advantages of the Open and Adaptable Industrialization are grouped in general advantages and advantages linked to industry and labour.

The first ones are about: technological advantages; interior and exterior flexibilities; higher quality control, as well as financing and of schedules; social (for instance, the role of the incorporation of women to work and management processes and, on the other hand, the involvement of the user during the decision-making stages) and, lastly, to make possible a sector more sustainable during all the “cycle of life”.

In the second group can be listed: a better work control; a production adapted to the works needs, in what's known as “just in time”; a higher financing and schedule control and what isn't less important the productivity of the labour, more specialized, more stable, with a higher performance and steady salary costs.

Maybe the most important social demand would be to answer in housing to the changing structure of people's grouping, so different to what existed not more than a decade ago.

Many variation possibilities in the composition of interior spaces are required for it to adapt to the necessities through time to one or more certain user(s) or the variation of people in its use.

That is, mobile partitioning is needed, responding to the necessary habitability and security requirements, and with a more affordable price than what exists in the Market!

This entails problems with connections, practicable materials, displacement slides systems, etc.

But the need for EXTERIOR FLEXIBILITY is also started to be required, assimilated to the possibility of changes in the façade composition. Mainly for the adaptation to innovations in bioenergetic enclosures.

And how can we answer to innovative themes in CRISIS SITUATIONS?

The present crisis opens many fronts that give us cause for asking ourselves if it is an economic crisis, a competitivity crisis or a productivity crisis.

And also, if it's going to last long in Construction.

We have to take into account that the Construction Sector has a lot of inertia and that, just as it has taken a lot of time in almost stopping in Spain, we should consider also a period of 3-5 years to set off after getting out of the economic crisis.

But we have to understand “the crisis” in its true concept, that is not only negative, but also a far-reaching moment where we have to do some self-examination and see which are our weak points, to correct them or choose a different path, like the famous book says “they have eaten your lifelong cheese” because they've learnt to adapt to circumstances better than you. This means that we have to take advantage of the crisis by innovating our productive processes, modernizing, at last!, building construction.

THE INNOVATIVE TECHNOLOGICAL ANSWER IN VIEW OF ALL THOSE CHALLENGES.

To face all those demanding aspects we are going to offer a series of interventions that we have treated, in its majority, in the UPM acknowledged Research Group “INNOVATIVE AND SUSTAINABLE BUILDING TECHNIQUES” (“TÉCNICAS INNNOVADORAS y SOSTENIBLES DE LA EDIFICACIÓN”, “TISE”).

Themes of interior and exterior FLEXIBILITIES in residential buildings have been based on studies on HABRAKEN’s theory of “supports” and of the “removable unit”, in the 60s, very similar to the Japanese and Korean studies of “structure” and “infill”.

The themes of MODULAR and DIMENSIONAL COORDINATIONS have been studied with a comparative analysis of practically every international regulation.

The search for ANCHOR BOLTS for structural unions and for CONNECTION systems for “infill” elements is being researched so as to find UNIVERSAL and ALL-PURPOSE solutions;

There’s also work being done in the area of REHABILITATION BY INDUSTRIALIZED MEANS for its application on several hundred thousands houses obsolete from a technical-requirement point of view. About this subject we have presented a paper in the International Congress “SUSTAINABLE BUILDING AND REHABILITATION” April 29 2010.

The following research works, carried out or in development, are stated as examples of necessary tasks to give an answer to the social, economic and technical demands that and Open, Adaptable and Sustainable Industrialization needs to respond to.

1.- INDUSTRIALIZATION AND SUSTAINABILITY, where the work of checking the sustainability of complete work units is being boosted, that is, for instance, an industrialized façade completely finished, compared to its traditional equivalent, since it’s interesting to know to which degree industrialization is beneficial.

2.- Another of the tasks proposed has been the FLEXIBILITY, that is, the user participates in the interior layout of the house, which can be adapted easily and affordably to the evolution of their space needs. This would make easier the access to the house via renting, breaking the tradition, damaging to the user, that links “accessing the house” to “buying the house”, which introduces rigidities that can’t be assumed by a society with an economy in crisis and a conception of familiar grouping-disaggregation that reaches levels unseen until now.

A mobile partitioning system is being researched to this end, which complies with the security and acoustic conditioning, to name the most important, in addition to a reasonable price.

As in all our tasks, contacting with firms in the sector to carry out the research jointly is essential, the aim being to develop a prototype that can become a patent.

3.- The very important theme of CONNECTIONS is also taken into account, considered as a key instrument for the coupling and diversity of unions that facilitates the use of industrialized constructive components from different manufacturers in the same building, based on an industrialization adaptable to the different requirements, be it architectural, environmental, of interior and exterior flexibility of the houses.

With this we enter the complex world of the FORMATION AND RESOLUTION OF JOINTS, anchorage systems, fixed and mobile connections.

The discovery of a universal anchorage system which could work both for the main structure and the union of different pieces, making easier the flexibility, would be a milestone in research. It's understandable that this type of work can't be done alone by a university research group, it needs to go hand in hand with leading firms in the sector, with which there's a collaboration.

4.- THE CONCEPT OF OPEN INDUSTRIALIZATION IN DEPTH. In this sense we are betting on an open industrialization through manufacturing components and constructive systems that are assembled in the work site by fast and easy procedures, preferably “dry” (screws, clips, welding, etc.) to achieve a radical change in the actual procedures in building, modernizing them, going from a “construction in situ” to an “open industrialization” of the sector.

Not only the advantages of the industry are applied to the constructive process, but also the integration of all the agents that take part in the construction sector.

We can't either forget the role played by the Administration, that in these moments has to give incentives to a tight collaboration UNIVERSITY+FIRM, basis of the productive development needed as one of the factors to overcome the crisis.

-To everything aforementioned we have to add the development of the BIM methodology (BUILDING INFORMATION MODELLING) which allows the different researchers to work simultaneously from different points, even far away.

At the same time it allows the carrying out of the sustainability COMPARATIVE EXPERIMENTAL STUDIES with no need to materialize the models or tests of the different work units functionally independents.

Our Group “TISE” has take part up to 2009 in the “Optimization of Housing Production. Industrialization, Efficiency and Sustainability.” Singular and Strategic Project (Proyecto Singular y Estratégico de “Optimización de la Producción de Viviendas. Industrialización, Eficiencia y Sostenibilidad. INVISO”), whose aim is the modernization of the building sector through open industrialization with the participation of all the agents involved: manufacturers, research institutions, public promoters, as well as universities.

The main ACHIVEMENTS OF SUBPROJECT 5 OF THE “INVISO” PROJECT have been:

1.- A “DATABASE” of all the industrialized elements and constructive systems existing in Spain, through the making of a “card” in which are detailed a complete technical, graphic and lacation description of each of them, and even a first approximation to the fulfilling of the basic principles of sustainability.

2.- Through the computarization of these cards, organized in families, we could obtain “INTELLIGENT CATALOGUES” that would mean an easy access to the different users, useful for the design, manufacturing, “virtual stocks” (that would mean a “zero” capital immobilization) and the expansion of the innovative products market.

3.- Thanks to the analysis made on the entire world's regulation on “modular coordination” (about 200 standards) the drafting of some DIMENSIONAL COORDINATION AGREEMENTS has taken place, for which the common sense has been a priority so as to achieve an easy starting up of an industrialization by assembling components coming from different manufacturers.

4.- Also, some joints and connections or couplings BASIC COMPATIBILITY AGREEMENTS PRINCIPLES are being studied, which will make possible, with the dimensional ones, the modernization of construction through the use of an adaptable industrialization.

5.- Another fundamental aspect taken into account is to wonder if the SUSTAINABILITY PRINCIPLES, indisputables nowadays, would be better fulfilled by building with industrialized and innovative methods instead of the “traditional” methods used presently. The knowledge acquired could bring enough light to make possible the bet for industrialization in building.

As seen the challenges set out by a Society in constant CHANGE NEEDS to be resolved with fast and flexible SOLUTIONS IN BUILDINGS , that only a modernized Sector can supply, with an innovation based on the KNOWLEDGES of the 21st century, considering that the best way is the innovation through AN INDUSTRIALIZATION IN BUILDING OPEN, FLEXIBLE AND ADAPTABLE.

We have, then, to take advantage of the crisis by innovating the productive procedures, modernizing, at last!, buildings construction.

The firms of the sector have to innovate their manufacture system and their “in situ” assembly systems so they can provide us with building with enough flexibility that respect, during their whole life cycle, all the sustainability principles, including here aesthetical, architectural and environmental values.

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KUBIK: OPEN BUILDING APPROACH FOR THE CONSTRUCTION OF AN UNIQUE EXPERIMENTAL FACILITY AIMED TO IMPROVE ENERGY EFFICIENCY IN BUILDINGS

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ABSTRACT

KUBIK is aimed to the development of new concepts, products and services to improve the energy efficiency of buildings.
The main characteristic of KUBIK is the capability to built realistic scenarios to analyse the energy efficiency obtained from the holistic interaction of the constructive solution for the envelope, the intelligent management of the climatisation and lighting systems and the supply from renewable energy sources.
The R&D infrastructure consists of a building able to provide up to 500 m2 distributed in an underground floor, a ground floor and up to two storeys; the main dimensions are 10,00 m. width x 10,00 m. length x 10,00 meter high (plus and underground floor 3,00 m. depth). The supply of energy is based on the combination of conventional and renewable energy (geothermic, solar and wind). In addition, the building is equipped with a monitoring and control system which provides the necessary information for the R&D activities.
KUBIK´s main structure provides an experimental, adaptable and reconfigurable infrastructure to create the indoor environments to analyse and to allow the assembly of the constructive solutions for the envelope, floors and partitions which performance must to be assessed under realistic conditions.

Keywords: Industrialised product development, Reconfigurable, Disassembly, Energy efficiency, R&D infrastructure

INTRODUCTION

The design of KUBIK is based on an industrialised approach to achieve a flexible and adaptable experimental facility, an open building-system, to evaluate and optimise new construction components and solutions, systems and services for the improvement of building energy efficiency.

The Open Building concept is not new and the main principles have been established by Habraken (Habraken, 1998):

- Distinct Levels of intervention in the built environment, such as those represented by 'support' and 'infill', or by urban design and architecture.
- Users / inhabitants may make design decisions as well.
- Designing is a process with multiple participants also including different kinds of professionals.
- The interface between technical systems allows the replacement of one system with another performing the same function.
- The built environment is in constant transformation and change.
- The built environment is the product of an ongoing, never ending, design process in which environment transforms part by part.

However, there is still a need to disseminate and to train the stakeholders of the construction sector to fully understand and to implement the Open building concept in our buildings and built environment (Open House International, 2006), (Kendall, 2008).

On other hand, one key innovation regarding the implementation of the Open Building concept is the industrialisation of it. The industrialisation of the open building concept has been dealt at concept level and the state of the art introduced by the CIB (International Council for Research and Innovation in Building and Construction) (Sarja, 1998). And, more recently, has been a hot topic for R&D in Europe (Manubuild, 2009).

To finalise this introduction of the issues that have influenced the design of the research facility, KUBIK, it is compulsory to address the current environmental concern that affects the building industry, mainly driven by the energy performance of the built environment and the new European Energy Performance Directive in force (EPBD, 2008) and the R&D initiative lead by the European construction sector to meet this challenge, the Energy Efficient building Joint Technology Initiative (E2B JTI, 2010).

As summary, KUBIK provides the needed support to improve the energy performance at building level, as requested by the EPBD, and in a comprehensive way, the envelop, the demand and energy generation, and based on industrialised construction systems.

KUBIK AIMS AND DESCRIPTION

The *“openness”* of KUBIK

Although it is necessary to acknowledge that does exist a previous similar facility by the Fraunhofer Institute of Building Physics in Germany (VERU, 2005), whose team has collaborated with Tecnalia in KUBIK, KUBIK offers new characteristics that make it a distinctive and unique world-class experimental R&D infrastructure designed for the evaluation and optimization of new construction components and solutions, systems and services for the improvement of building energy efficiency under real conditions.

The main distinctive feature of KUBIK is its capacity to create realistic scenarios, its *"openness"*, to perform experimental research with regard the building energy efficiency resulting from the interaction of the constructive solutions, the intelligent management of air-conditioning and lighting systems and the non-renewable and renewable combinations of energy supplies. And, in addition, is focused in the development of industrialised components for the implementation of the open building concept, see Fig. 1.

Figure 1. Current envelope in KUBIK

The infrastructure encloses a maximum of 500 m^2 distributed over a basement, a ground floor and a further two floor levels*;* the main dimensions are 10,00 m. width x 10,00 m. length x 10,00 meter high (plus and underground floor 3,00 m. depth). The supply of energy is based on the combination of conventional and renewable energies (geothermic, solar and wind power). Finally, the building is equipped with a monitoring and control system that provides the necessary information for the development of R&D. The building is totally demountable and allows reconfiguration of the scenarios at construction level, by exchanging the components of the envelope, the roof, the floors and the partitions.

The *"openness"* of KUBIK has been implemented in all the sub-systems of the building:

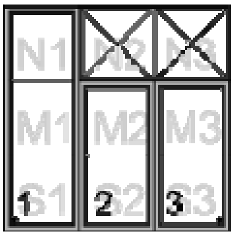
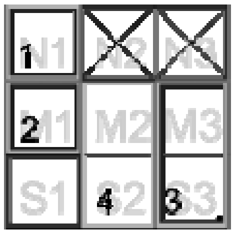
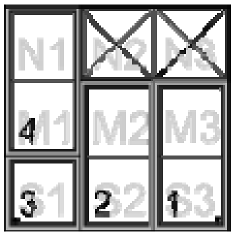
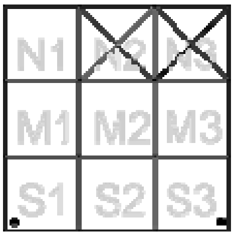
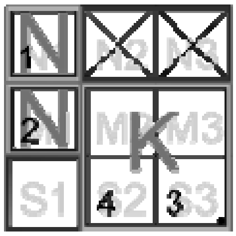
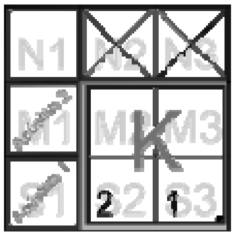
- the structure,
- the envelope,
- the partitions, actually, only dry construction systems are used,
- the services, energy and IT related, and
- the equipment, mainly climatisation and energy intelligent management

The "openness" of all these sub-system will be shown in the following sections of this paper

Experimental capabilities of KUBIK

KUBIK enables the evaluation of energy performance, acoustic performance and air tightness evaluation of the scenarios built, see Fig. 2, taking into account the holistic interaction of the constructive solution for the envelope, the intelligent management of the climatisation and lighting systems and the supply from non-renewable and renewable energy sources.

The main aim of KUBIK is to provide a better understanding of the performance at room or at building level, acknowledging the traditional laboratories as the better for the characterisation at component level according international agreed standards.

Scenarios	Ground Floor	First Floor	Second Floor
Available simultaneously, independent climatisation zones			
Current layout off scenarios			

Captions:

N1, 2, 3: Northern roms M1, 2, 3: Middle rooms S1, 2, 3: Souther rooms

Acústica 1, 2: Rooms equipped for acoustic research.

R insulated
VIP insulated
Ventilated thermal zone
Unventilated Thermal zone

Figure 2. Plan views showing the available layouts with independent climatisation systems

KUBIK has an advanced monitoring system, equipped with over 400 sensors that records conditions inside and outside the experimental facility, climatic conditions. Researchers and customers have access via the Internet to measurements being taken in the scenarios where the performance of the products and systems under development are evaluated. In addition, the monitoring system is integrated into an Intelligent Energy Management System which optimises the energy consumption of the building. The experimentally-obtained results enable diagnoses and proposals for potential product improvements to be made.

It is important to note the contribution of KUBIK for the activities related to the new product development for buildings. Currently, the technical development of a product begins with the numerical analysis and simulation of the product, carried out in a virtual scenario. The product is then tested in a laboratory in accordance with standardised procedures, and is finally launched on the market.

KUBIK offers and intermediate step that allows to evaluate the products performance in realistic conditions. This speeds up the product development and reduces the risk of malfunction of highly innovative products or products without previous experiences on the market place.

The aim of this experimental facility is to offer a flexible infrastructure able to build realistic scenarios with different building components and systems, for that is compulsory to make possible the assembly and disassembly of them. This permits not only in service performance assessment but also help to develop and to evaluate assembly and erection procedures.

STRUCTURAL SYSTEM, SUPPORT STRUCTURE

Foundation and underground floor

The foundation, an underground slab and walls, and hereby the resulting underground floor are really the unique *"not-open"* sub-system of the building. The foundation is made of on-site reinforce concrete but with the innovation of the substitution of the stone aggregates by slag from electric arc furnace for steel manufacturing.

Although *"not-open"*, the slab foundation provides the needed flexibility, "*openness"*, to allow any lay-out of the steel structure columns. In addition, the underground floor is in concept a *"plug"* where the building takes the energy supplies, renewable and non-renewable, to run the scenarios as well as the data connectivity for the IT systems and intelligent management, see Fig.

Figure 3. Left, underground floor with geothermal installation and energy supply and IT connections. Right, steel columns anchored to the foundation slab with bolted (demountable) base plates.

Steel structure and precast concrete floors

The steel structure is made of standardised sections for the columns and fabricated sections for the beams; this special section allows the integration of the floor system and the building services.

The joints of steel structure are bolted and the bracing system includes "X" bracings in the floor to allow the use of demountable precast concrete slabs. The structure, columns, beams and floors allows its de-construction floor by floor level, see Fig 4.

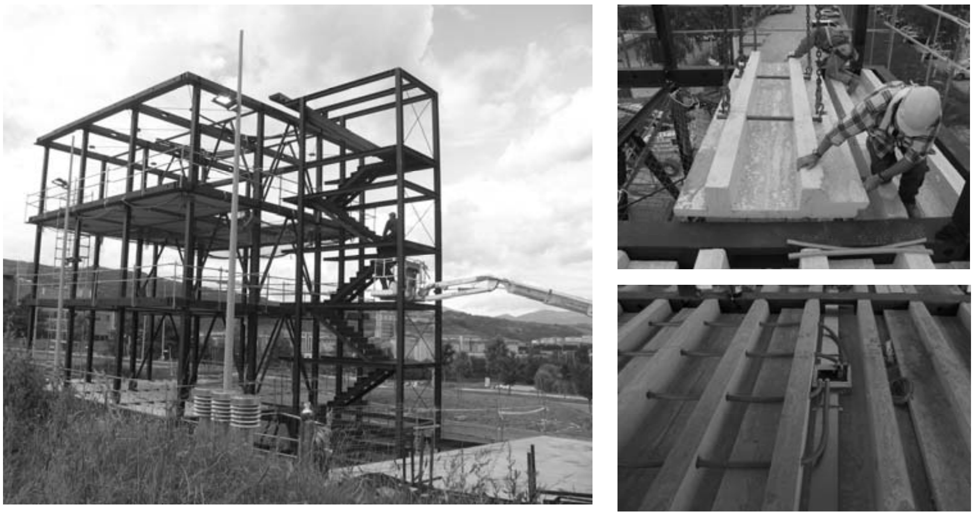


Figure 4. Demountable, floor by floor, steel structure and precast concrete slab. The steel beams and precast slabs allow building services integration.

As it is shown in the Figure 4, the service installations are integrated in the floor slabs, so they are accessible for repair and upgrading. Thanks to a complete demountable timber finishing, the accessibility is accomplished from the all the space being served by those installations, the room or combination of rooms for the analysed scenario.

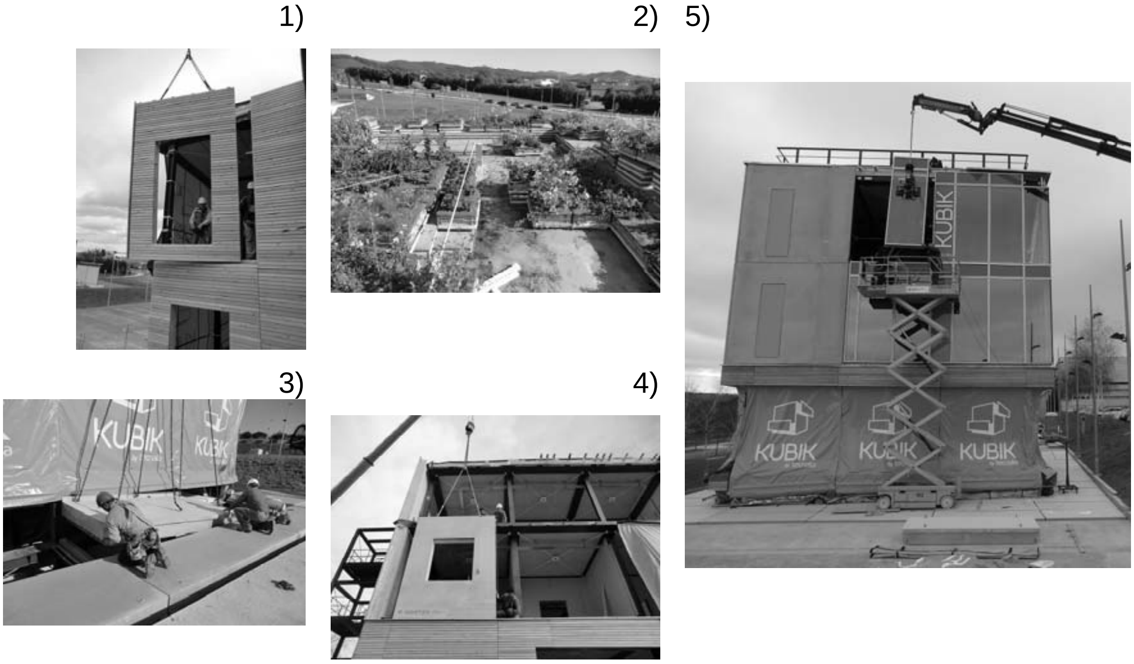
ENVELOPE AND PARTITIONS, INFILL COMPONENTS

The special focus on the R&D activities on the improvement of the energy performance of buildings makes necessary the development of optimised solutions for the envelope taking a special attention, in the case of prefabricated or industrialised components, to the joints and connections to avoid thermal bridges, lost of continuity of the insulation of the envelope…

Currently, in KUBIK there are several solutions under study, see Fig. 5. This variety of solutions for envelopes allows analysing the real compatibility between components made of different materials, with different fabrication tolerances and different erection and joining technologies.

In fact, the keystone for a real open building implementation might be the possibility of having industrialised components available in the market with several *"joining or interface standardised options"* that could make possible the use of components from a variety of manufacturers, materials…And, in addition, the joints are really important to deal in detail how to assess the thermal and acoustic performance of the building but on other hand, they must allow the easy disassembly.

The roof and the façade of KUBIK are made of prefabricated and demountable components. So we refer them as infill systems because they can change when the rest of the infill or fit-out changes, e.g. the scenario (room surface, occupancy, partition walls and the envelope components), following the example of the NEXT 21 project. On other hand, the façade might acts as a support system to include several types of windows, glassing systems, finishing…



1) Modular wooden sandwich panels

2) Modular green roof

3) Precast roof for the underground floor.

4) Precast concrete sandwich panel

5) Modular curtain wall for PV integration

Figure 5. Industrialised systems for facades, building roof and underground floor roof currently under study in KUBIK.

Regarding the internal partitions, light steel frames and timber frames it have been used to arrange the different rooms in each floor to create the "volume control" of each scenario in terms of energy and acoustic performance.

HEATING, VENTILATING AND AIR CONDITIONING SYSTEM (HVAC SYSTEM)

The primary function of the HVAC installation of KUBIK is to provide the energy necessary to keep the different measurement rooms, scenarios, of the infrastructure under controlled indoor conditions (temperature and humidity), as well as measuring the energy delivered to each measurement room to obtain the results to carry out the research regarding the components and/or systems under analysis.

Since the building has been conceived to enable the possibility of modifying the envelope and its floor layout, the HVAC system has been designed to support this feature:

- ability to satisfy thermal loads which may vary (especially for the cooling regime) within a wide range (25 -50 kW), and
- maximizing the ability of the distribution and the diffusion systems to adapt to variable floor layout.

Each of the 3 floors of the building can be divided into a maximum of 6 thermal zones, and if necessary, those zones can provide independent temperature setpoints and measured energy supply, see Fig. 6.

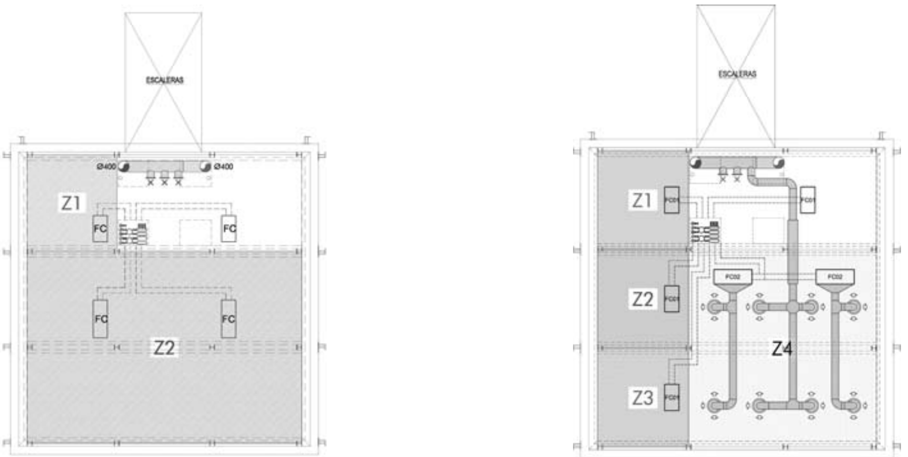


Figure 6. Left, thermal zones on the ground floor and, right, thermal zones on first and second floors (according current layout of KUBIK).

In addition, the entire HVAC installation have been designed so that its expansion through the integration of additional elements will be possible without the need to modify none of the main sub-systems of the facility (generation, distribution, measurement and diffusion), beyond the minimum required adjustments.

For research purposes, KUBIK sums up to the conventional generation systems and air conditioning elements:

- Distributed electricity generation from renewable sources (photovoltaic and wind).
- A ground source heat pump, coupled to a heat exchanger with the surrounding ground (superficial) for water.
- A Canadian well, formed by a heat exchanger with the surrounding ground (superficial) to provide outdoor air for ventilation when the difference of outside air and ground temperatures is adequate.

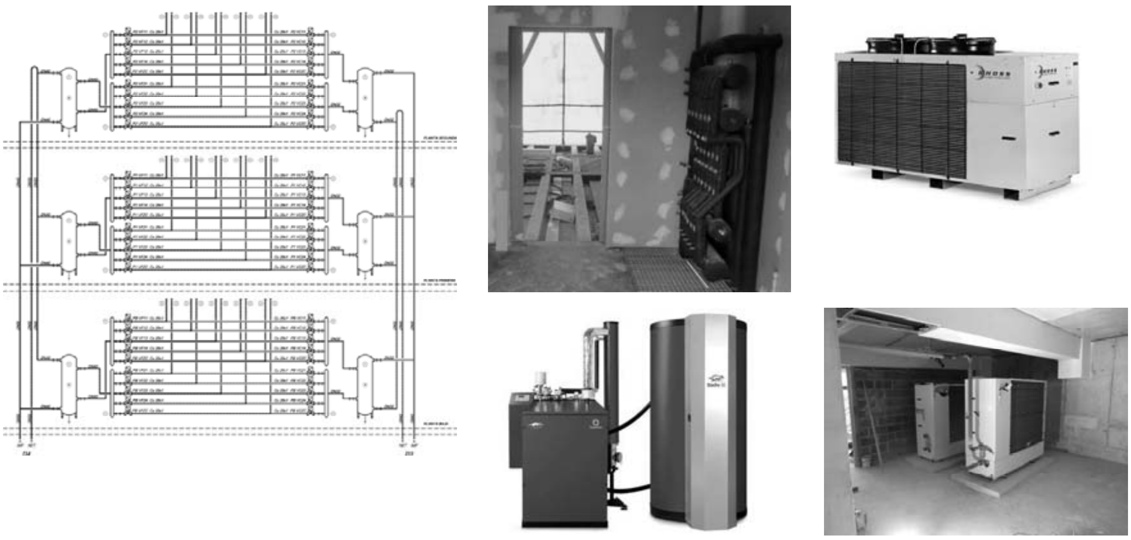
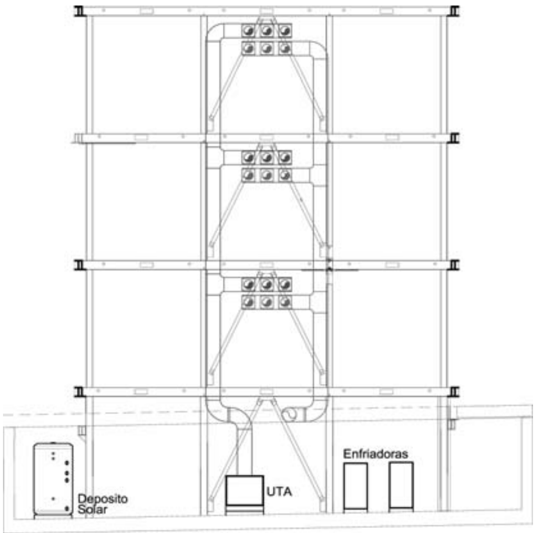


Figure 7. Hydronic systems for the HVAC installation. Left, scheme; right, distribution pipes and equipments related to thermal energy: natural gas micro CHP (12.5 kW of thermal power and 5.5 kW of electrical power), storage tank, condensing boiler and 2 air-condensed chillers 22 kW each.

The HVAC installation of air conditioning of KUBIK consists of an hydronic system, see Fig. 7, and a Variable Air Volume system (VAV), see Fig. 8. Both systems, will have independent distribution, measurement and diffusion subsystems. And for thermal energy generation, both systems will be fed by a common generation sub-system based on natural gas.



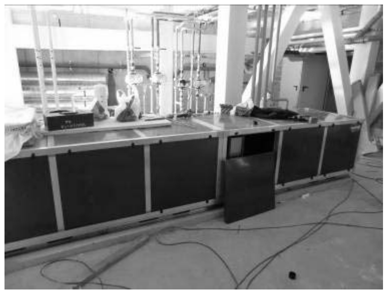


Figure 8. Variable Air Volumen System (VAV) for the HVAC installation. Left, scheme; right, variable flow air handling unit (maximum flow of 2,500 m3 / h).

The air handling unit has been dimensioned to carry out the ventilation of the whole building or alternatively to reproduce on a single floor, the conditions of a building conditioned by a variable air volume system. It is possible to supply ventilation air up to 3 independent thermal zones per floor. The location of diffusers is optimized to maximize the capacity of the air system to accommodate changes in the thermal zoning of the different floors.

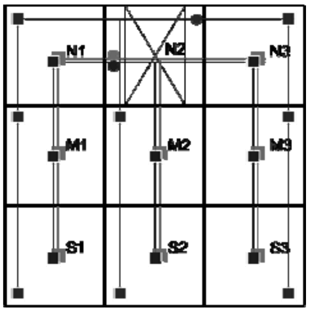
Summarizing, the HVAC system is in the Support or Base Building and the diffusers and other services such us electrical power, water… are placed integrated in the floor and ceiling of each room so we can consider that from this point the parts become infill elements...

MONITORING AND MANAGEMENT SYSTEM

At the end, all the flexibility required to KUBIK aims to provide a R&D infrastructure able to perform diverse scenarios and to capture the necessary information to carry out the analysis and assessments.

The infrastructure has up to seven individual measurement rooms; one control room and one service room per each of the three floors, see Fig. 9. It provides the possibility to combine some individual rooms into a unique measurement room if it is required by the experiment it and also allows to have all the three floors as a unique building, for example an specific office, school, etc….. This flexibility is possible thanks to the structural design and to the services design: each individual measurement room has the climatisation, power and data network that needs to build an scenario.

The Figure 9 shows the nine rooms of each floor with the electrical and data network: the individual measurement rooms are: N1, M1, M2, M3, S1, S2 and S3; the control room is N3 and the service room is N2. Figure 6 shows too an example of a possible layout of one floor: three individual measurement rooms (N1, M1 y S1) and one combined measurement room (a combination of M2, M3, S2, and S3) and their respective HVAC system.



Captions:

Blue boxes: sensor at floor level

Pink boxes: sensor at ceiling level

Brown boxes: power electricity

Figure 9: Equipment by each individual measurement rooms. A floor integrated sensor box is showed in Fig.4.

The monitoring and management system is integrated in an intelligent energy system (IES) which optimizes the energy consumption of the building satisfying each measurement room needs. IES manages the HVAC system (heat and electricity demand and production equipments), the lighting system and the supply from renewable energy equipments, see Fig. 10.

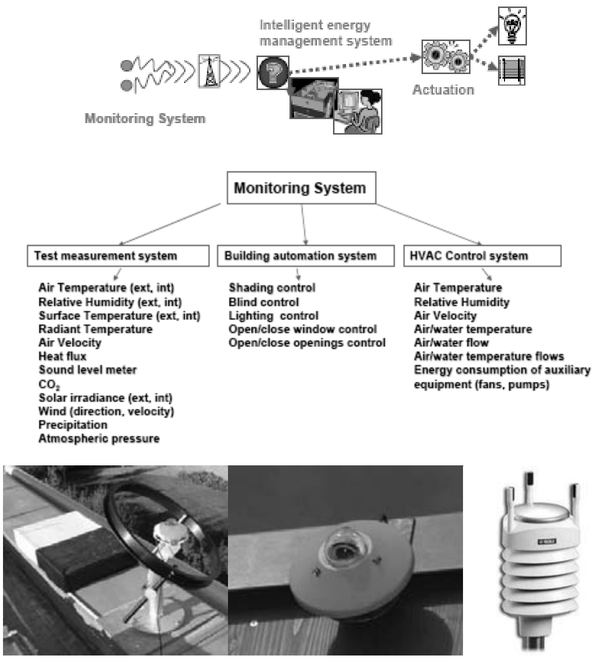


Figure 10. Monitoring and management system integrated in an intelligent energy system. Some sensors are shown below the schemes, form left to right: Diffuse solar radiation, solar radiation and weather conditions.

The monitoring system is in charge of data gathering and management tasks and to provide comprehensive information necessary for the analysis along. It collects data from the: measurement system; building automation system, HVAC control system and external meteorological conditions.

The monitoring system is equipped with over 400 sensors that records conditions inside and outside, weather conditions, the experimental facility. Researchers have access via the Internet to measurements being taken. The test measurement system includes the following sensors: indoor air temperature, surface temperature, radiant temperature, humidity, air velocity, heat flux, solar irradiance, luminance, CO2 concentration, sound level meter ….

The building automation system includes sensors for: shading control, blind control, lighting control, open/close window control, open/close openings control,... The HVAC control system includes the following sensors: air temperature, relative humidity, air velocity, air/water temperature, air/water flow, air/water temperature flows, energy consumption of auxiliary equipment (fans, pumps). The external meteorological conditions are defined by: air temperature, humidity, solar irradiance, wind direction, wind velocity, precipitation and atmospheric pressure.

The experimentally-obtained results enable diagnoses and proposals for potential product/concept design improvements to be made and the thermal/energy performance.

The chosen measuring and management system is based on a PLC platform with Windows Embedded technology allows simultaneous scenarios analysis as well as with different requirements, boundary conditions.... The PLC layer of the control system is in charge of gathering data from the sensors and writing commands into the remote actuators, not only this but the PLC layer processes update the central database with the sensor and actuator values.

On the other hand, the Windows layer hosts the developments done in order to analyse different energy efficiency policies, e.g. will be dedicated to energy efficiency developments from a holistic approach, this means taking into account not only the potential energy demand reduction but considering, too, the storage and generation capabilities deployed in the KUBIK.

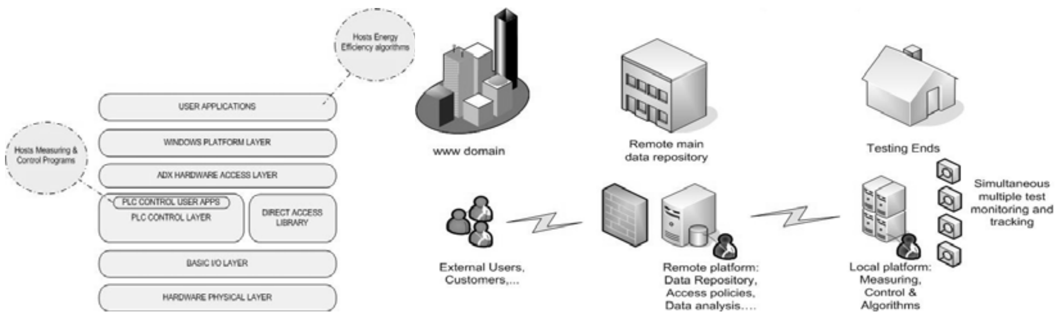


Figure 11. Left, architecture of the monitoring and management system and, right, concept for the measuring and management system.

The technology used to build the energy efficiency algorithms is based on expert systems development platforms as Jess (Java Expert System Shell) and Hybrid Finite State Machines (Hybrid FSM). Both technologies are in the domain of the intelligent agent development field. The background for both technologies is that they are based on the skills to simulate complex scenarios and not only simple state transitions. Those skills are used to model scenarios in which user behaviour and preferences, outdoor and indoor conditions, altogether, are factors in order to take a decision.

CONCLUSIONS

KUBIK provides the needed support to improve the energy performance at building level, as requested by the EPBD, and in a comprehensive way, the envelope, the demand and energy generation, and based on industrialised construction systems.

The aim of this experimental facility is to offer a flexible infrastructure able to build realistic scenarios with different building components and systems, for that is compulsory to make possible the assembly and disassembly of them. This permits not only in service performance assessment but also help to develop and to evaluate assembly and erection procedures. In addition the service installations are integrated in the floor slabs, so they are accessible for repair and upgrading.

The roof and the façade of KUBIK are made of prefabricated and demountable components and can be considered as infill systems because they can change when the rest of the infill or fit-out changes, e.g. the scenario (room surface, occupancy, partition walls and the envelope components). Even though the façade might acts as a support system to include several types of windows, glassing systems, finishing…

With regard the services, the HVAC system has a clearly identified part on the support or base building, and the diffusers and other services plugging such as electrical power, water services… have a complete flexibility to be located in all the available floor lay-out and can be considered as “infill”.

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- NEXT 21 – Osaka Gas Experimental housing: http://www.arch.hku.hk/~cmhui/japan/next21/next21-index.html

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OPEN AND SUSTAINABLE BUILDING – OPEN BUILDING CONCEPT

POSSIBILITIES, EXPERIENCES AND DIFFICULTIES IN STATE-SUBSIDISED HOUSING

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ABSTRACT

The construction of houses and, in particular, state-subsidised housing in Spain is a totally TRADITIONAL industry, characterised by its severe lack of innovation.

For years, the processes employed have required neither innovation nor optimisation. Why bother? What profit was there in it? The market absorbed everything, and moreover, the construction costs and processes were clearly defined and amply tried and tested. Improvements did not lie in this part of the process, but rather in the land, and focused mainly on increasing economic profits.

Nor did customers demand innovation. But do we really want a house just like our parents’ one, with the same layout, albeit at a smaller scale, with fewer square metres, lower ceilings, fewer common areas, less light and smaller balconies, etc.?

Barriers in the path of the Open Building Concept in State-Subsidised Housing

As with any houses, the Construction Process here is basically a (more or less controlled and managed) accumulation of heterogeneous sub-sectors, based on traditional construction systems in which it is never entirely clear on whose shoulders the responsibility for the "global development idea" actually falls: the Development Company? The Architect? The Building Contractor? The Facultative Management?

The Construction Process is based on extremely antiquated systems: the basic construction materials for housing are reinforced concrete structures and brick façades and partition walls. The basic brick and mortar construction system was already being used in Mesopotamia 5,000 years ago. The only difference today is that the mortar is better, the clay is fired at a higher temperature and reinforced concrete load-bearing structures are used.

It is a highly manual, almost craft-like process, which depends greatly on the skill of the "craftsman".

Is it possible to build more cheaply, more flexibly, more quickly and/or more safely? Is it possible to build …………. DIFFERENTLY?

As Albert Einstein once said: "If you want different results, then don't always do the same thing"

Some keys for this change are as follows:

- It is necessary to INDUSTRIALISE processes.
- CUSTOMERS are HETEROGENEOUS, and will live for many years in what we design today in just six months and build in two years.
- There is a great deal of REGULATORY RIGIDITY which prevents flexibility and innovation.
- There are clear ECONOMIC LIMITATIONS.

It is necessary to INDUSTRIALISE processes.

Not only by "prefabricating" elements (although this is part of it), but also by industrialising construction processes themselves.

At VISESA, we have carried out a study comparing the construction of a traditional block of flats with the construction of an industrialised one. The conclusions of this study are summarised below.

With the industrialised structure, better results were obtained in the following areas, in comparison with the traditional one:

- Greater distance between pillars (better Su/Sc ratio).
- No waste.

- Minimum manual movement of loads (375 parts in one standard forging as opposed to 14,050 in a traditional joist and overhang one).
- Controlled risks: derived from mechanical movements.
- Reduced execution time and personnel (average of 13 people).

The principal disadvantages observed in relation to the industrialised structure were as follows:

-
- Larger and heavier concrete sections.
- New construction process (novelty factor, lack of experience).
- More expensive in the current industrial framework.
- New stakeholders involved in the process: industrial players.
- Transport and lifting equipment required.
- Rigidity of elements and sections.

The following improvement areas were identified:

- Industrialise more elements. Dry unions.
- Eliminate “in situ” concrete work.
- More comprehensive and complete Building Project.
- Integration of the industrial sector.
- Change of mindset in parts of the process.
- Safety is different, new measures are required.
- The focus needs to be on the result, not on the action.

Whether we like it or not, we need to accept that CUSTOMERS are HETEROGENEOUS.

There are a series of barriers in the path of the Open Building Concept in current processes and systems of state-subsidised housing, stemming from the fact that users do not intervene in the current design or building processes. Consequently, we do not develop for the customer, and we do not design or build for the end user.

Every user has their own set of needs and customs and their own way of life, which may vary over the years. Why should the current system offer a blanket solution for everyone? Why should we all live how someone else thinks we should?

We have forgotten Vitruvius’s first pillar of architecture: UTILITAS. Instead, we focus on VENUSTAS and take FIRMITAS for granted, as something guaranteed by norms and regulations.

How can we integrate users into the process?

- By viewing the Customer as the central figure, around which the rest of the stakeholders involved in the construction process are gathered.
- By knowing WHAT HE / SHE WANTS: satisfaction surveys, FOCUS GROUPS, working teams with designers, etc.
- By enabling the customer to CUSTOMISE: integrating him / her into the design process and giving him / her the opportunity to choose the interior qualities of his /her home.
- By ensuring FLEXIBILITY of use, through a choice of materials and by enabling users to choose their lifestyle and explore different ways of inhabiting the same space.

There is a great deal of REGULATORY RIGIDITY

There are numerous regulations operating in the residential sector: basic, technical, planning, regulatory, etc.

Furthermore, state-subsidised housing designs are subject to Design Bylaws, which impose certain basic conditions and specify maximum and minimum surface areas, price per metre of useful floor area, ventilation and minimum lighting, etc.

Many of these regulations are more stringent that those which apply to non subsidised housing, and some can even be incompatible. Consequently, the regulations for subsidised housing are at least twice as rigid.

These building projects are also subject to the approval of a bylaw supervision service, which is responsible for awarding them what is known as “Calificación Provisional” (provisional approval).

At the end of the building process, they are again subject to a review which, if they pass, entitles them to the “Calificación Definitiva” (definitive approval), after which they can be sold.

However, as well as approving their sale, the “Calificación Definitiva” also prohibits users from changing anything in the house. In other words, it prohibits them from customising their home … throughout the whole life of the house and therefore, throughout the whole of the user’s life also.

Many sectors and services are subject to their own rules and regulations: RAILWAY, ACCESSIBILITY, FIRE FIGHTERS, GARDENERS, GARAGES, INSTALLATION ROOMS, etc.

Any improvement in this field would necessarily involve making the design bylaws, regulations, processes and administrative procedures more FLEXIBLE.

It is also necessary to have different products and services for different users: Allocated Rented Houses and Flats, Limited Price Housing, Mobilisation programme for unoccupied houses, etc.

There are clear ECONOMIC LIMITATIONS

In the field of state-subsidised housing, sales prices are established in accordance with the useful floor area, multiplied by a modulus based on income brackets.

Useful floor area is sold alone, and energy savings, innovation, good or bad construction or design are not taken into account.

Moreover, PAYMENT methods are also regulated and systemised, leaving little margin for flexibility.

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THE ENVELOPMENT OF URCOMANTE SOLAR DECATHLON EUROPE 2010

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INTRODUCTION

"The envelopment of Urcomante" is a research project aimed at the University of Valladolid's participation in the international competition called Solar Decathlon Europe 2010.

The competition presents the challenge of designing a prototype house that is self-sufficient in energy thanks to the implementation of photovoltaic solar panels and then building it in what has been coined the "Solar Village" in Madrid. This location, by the Manzanares River, is where the prototypes of the 19 participating universities will be exhibited and will compete. This phase of the competition will be held in June 2010.

During the competition, the prototypes will be subjected to 10 tests, earning their scores based on objective and subjective criteria. These criteria include evaluating aspects such as architecture, engineering, solar power systems, industrialization, etc.

Unlike the American competition, the European edition has added two significant tests, sustainability and innovation to act as cross-related themes.

In 2008, the University of Valladolid began developing the prototype. Formed by a group of professors and students from different disciplines and professional profiles, the project has established a research agenda which is open and adaptable to the rules of the competition.

Two research directions define the project:

1- Preliminary strategy based on the definition of a virtual individual, "an open user"
2- Development of a manufacturable prototype

DEFINITION OF "EL URCOMANTE"

We embarked on a journey in search of a real contemporary inhabitant, the pursuit of an individual and his union with this type of architecture, with new energy and the concept of the life cycle. Does this inhabitant exist? Will he exist?

We define this individual according to a series of profiles of individuals with personal characteristics fit to the current lifestyle, and who could anticipate future styles. From each of these individuals, we have studied their spatial needs, their relationships between spaces, qualities, relevance and meanings of their existence.

In conclusion, a group of individuals emerged that matched each other’s profile in many respects, nevertheless, keeping in mind the necessity of each individual for changing spaces at different times, with varying functions. Despite their socio-economic differences, the following individuals are among whom the most matches found:

URbanita metropolitan, **CO**smopolita, e**M**prendedor solitario, dilet**ANTE**, inmigr**ANTE**.

(**M**etropolitan **UR**banite, **CO**smopolitan, a**M**bitious individualist, dilett**ANTE**, immigr**ANT**)

The inhabitant evolves with our project. He learns. He becomes aware. He becomes human.

Urcomante: the virtual and variable inhabitant is said to be one who combines or can combine the needs and peculiarities of the following tribes: urbanites, cosmopolitans, ambitious individuals, dilettantes and immigrants. Somebody that is aware of the environment and sustainability. Somebody that is contemporary, ecological and humane.

DEVELOPING A PROTOTYPE

As discussed in the architectural design report, a fundamental concept of the project is flexibility which can provide a response to different situations of occupation throughout the lifetime of the building, with different programmable solutions.

In the spirit of this, the interior is an open, multipurpose and changing space, recognized as the grand living area of the project into which the functional modules converge. Designed to create convertible and adaptable spaces for the end user of the building, these modules allow the occupants to engage in their activities privately.

In the competition prototype, the bedroom-study, bathroom and kitchen will be configured. Formally constituted as parallelepiped forms, these modules, whose inward-facing sides link to the large central functional space, can move from one side to another. Depending on the needs of the inhabitant’s spatial needs, these modules can be opened or closed obtaining different functional configurations.

Modular System: grids and frames

There has been a growth study of the prototype on a 60 cm grid of the floor plan, and establishing a system of zones or bands of varying dimensions.

The design of the "support" in this case differs by the implementation of time-varying areas associated to daily use linking it, taking into account a brief 24 hour cycle. In other support systems or frames, these flexible areas allow for the configuration within the medium to long term, in this case adopting a system that allows one to use the same space for differ purposes, while joining it with a "room" or another.

The multifunctional space is shared with the rest, allowing for the configuration of the prototype to be around 45 m2 with functional uses that could be equated to a larger living area of around 60 m2.

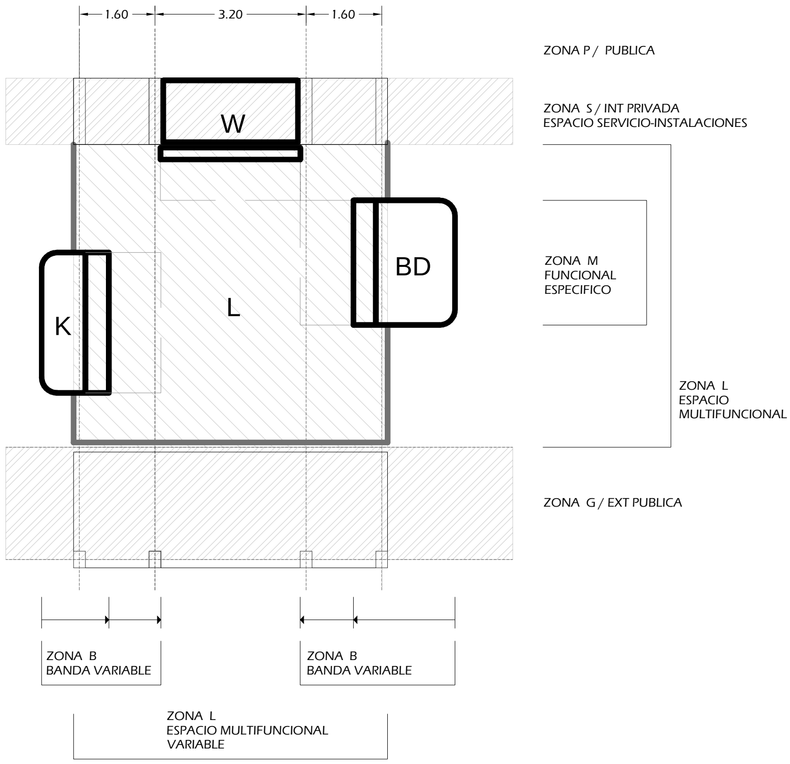

Figure 1: *Support Grid*

DEGREE OF INDUSTRIALIZATION: LEVELS AND HIERARCHY

We propose an open system that allows industrialized compatibility or integration of different components both in its technology as its provenance. The goal is to have a model that incorporates a construction system capable of incorporating the user when it comes time to defining and making project decisions.

The system is organized based on hierarchical levels:

Level 1. Support Structural and formal base - 3D Module

We define a structural and constructive system that can support different envelopment solutions and provide a variety of growth models (horizontal-vertical)

At this level, formal modifications with certain geographical adaptations can be made in relation to roof inclination, orientation, etc.

Level 2. Envelopment Geographic adaptation/Architectural integration

The envelopment gathers and unites systems of operation and possible functional or work spaces. It is intended that a project strategy is reached that organizes the incorporation of the necessary technologies into a three-dimensional element that, at the same time, gives shape to the inhabitable space.

This envelopment, or the third skin, provides the home with all basic needs and essentials for its operation which can be understood as an organ essential to life and the sharing of space; the initial contact point for interaction with the environment responsible for collection, protection, circulation and respiration.

The three-dimensional perimeter should create an open system allowing the incorporation of technology components from different sources.

The search for compatibility should be a project objective. The broad variety of solutions offered by the current market, those that can imply evolution and the increase in energy-saving performance, requires constructive and language compatibility. The architectural integration will depend on easy of assembly, maintenance or replacement of components throughout the long life of the building.

At this level, the decisions should be made based on a climatic conditions study of the location where the building shall be built in order to integrate passive or active strategies within the design.

The growth in the building's height warrants the use of collective systems with high levels of efficiency and placing them in a common area in which case the envelopment functions as an integral system for its own operation. At the same time, a conditioned space is provided that can be incorporated as an inhabitable area.

In these collective configurations the energy system could be customized by end users within a range of options presented by the technicians.

This would lead to savings and an energy efficiency from geothermal systems, buried air heat pipes, etc.

Level 3. Functional Modules

Functional Modules: independent units allow the modification of the building throughout its useful life. These 3D modules which are designed and built in workshop (off-site) are attached to the envelopment (on-site) during construction depending on the user's needs.

The livable "boxes" are presented on the prototype with a photovoltaic envelopment on the exterior and with partitions inside that act as walls to help configure the interior space. These partitions have been equipped with a hidden mechanized system which allows them to slide silently requiring very minimal energy and low maintenance.

Although kitchen and bedroom modules have been developed, other possible solutions that modify the character of the building have also been considered in order to adapt to the specific use of the building as well as to prolong the its useful life.

Catalogue: bedroom-kitchen-study-storage-office-bar

DEGREE OF ADAPTATION OR USER INTERVENTION

Level 0: support system, technical structural decisions, production or commercialization

Level T: technological constructive options, by climatic adaptation, market availability of the products, cost reduction, stock

Level U: open system to user decisions (Urcomante), configurable program, choice of finishes available through catalogue.

It is believed that other levels urban decision-making exist beyond those associated with the building process. Studies have been proposed regarding solar exposure on lots, the provision of trees, green space relevance or use of pavement for pedestrians or vehicles with TX Active photocatalytic effect aimed at the reduction or control of harmful emissions into the environment.

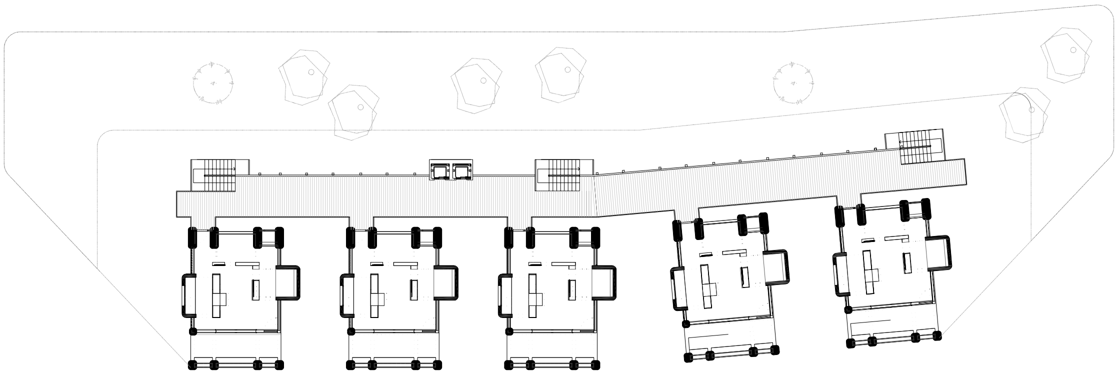

Figure 2: House grouping

CONSTRUCTIVE SYSTEM: DIMENSIONAL COORDINATION

The structural system of the prototype has been developed with a direction of industrialization supported by a 2D structural module which allows its configuration in 3D modules and enables different typological configurations, both on floor plan and in height.

The main structure is a mixed combination of beams and pillars, walls and framework, and lumber strips with a low-energy-embedded profile, which binds to specific or catalog components.

Metal fittings out of catalog are combined, using three types of metal brackets. A U-shaped and two half-brackets (left-right) that allow the union of pieces with slight dimensional changes.

KLH provides the structural system of cross-laminated wood panels with large format dimensions and varying thicknesses and an odd number of layers. In our case all the elements of the structure -beams, columns or diaphragm walls of the technical units- are resolved with the same type of board, allowing the use of a single board thickness of (108 mm).

The consideration of fiber direction of the panels is a condition of the redesigning of 1D or 2D parts (pillars or beams, walls or framework). This redesign can be done with specific software and industrial pattern cutting which optimizes the use of boards, reducing cut-waste, lowers the cost of the structure and implies an immediate control of the recycling process.

Cutting boards with CNC technology facilitates the modification or adaptation of elements in the workshop to the different types of parts and different hardware requirements. During the cutting process, each piece is routed with the necessary recesses or holes for installation with the appropriate predefined precision or tolerance.

Initially, the prototype formally presented difficulties in developing a high degree of industrialization with standardized parts. However, with the possibilities available through the construction system and the flexibility of the design, cutting and assembly processes this will allow us to make modifications or adjustments to parts in advanced stages of the project. In this sense, the design process in relation to the definition of unions facilitates the incorporation of different standardized parts from different suppliers, as well as incorporate parts specially designed for assembly-disassembly necessary given the modular nature of the prototype designated for competition.

This is also considered when transporting 3D elements or the assembly of 1D or 2D elements in situ.

This model of industrialization, open to project-based modification, favors the further development of typologies and groupings based on formal or spatial flexibility. We begin with a structure type that can permit, with slight changes or the addition of new parts, an adaptation of the module for new typologies.

The prototype is set to a 2D system of double gates that allow it to separate into 3D modules. Because of this, we designed a system of pipes and metal plates that allow placement by crane.

FUTURE DEVELOPMENTS

We are currently conducting a study of potential configurations, beyond the configuration originally called for by the rules of the Solar Decathlon Europe 2010 contest, which could house the main structure that is provided by the envelopment

What we are seeking is a total architectural integration, responding to a problem of architecture with a unique solution, consisting of a succession of layers, filters and artificial atmospheres combined with the aim of providing living conditions within the prototype for the protection of the Urcomante.

Future research beyond the approach taken for the competition is oriented based on the following objectives:

- Develop a three-dimensional, modular and industrializable system that allows for various marketable buildings configurations.
- Individual stand-alone dwellings, townhouses or paired versions.
- Optimization of the structural system, maximizing the work done in shop, and minimizing the intervention on site with easy transportation and assembly.
- Optimizing energy costs during the life cycle of its manufacturing, construction, assembly, consumption and maintenance.
- Increase the number of industrializable construction elements of the prototype, representing an improvement in quality of the final result. This means greater customer satisfaction, greater construction efficiency and lower production costs based on a workforce reduction.
- A more specialized construction will be an improvement in workplace safety and less accidents and a positive social impact.
- Definition of specific modules, spatially and formally, for every situation, for better adaptation to the needs of users. Options under consideration: library, office, greenhouses, etc.

Figure 3: *South view*

NEXT21 – an experiment
(30 minute documentary film)

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ABSTRACT

With the aim of creating a green, social, energy-efficient and adaptive urban living environment fit for the challenges of the 21st century and its demands, Osaka Gas commissioned the experimental residential complex `NEXT21` in Osaka in 1989, built in 1993.

15 years into its existence and three consecutive five-year cycles of ongoing inhabitation experimentation, the 30 minute documentary `NEXT21 - an experiment` looks back on the context and conditions of that visionary and pioneering multi-disciplinary design process.

Due to the mounting collective concern for the threat of climate change, ecology and sustainable building have once again regained public attention since the oil crisis of the late 70’s. The challenge for designers today is to use this momentum and to transform it into a widely supported and effective sustainable development of the built environment. The precondition is to not only to start working on it with enthusiasm, but also to look back to extract valuable lessons from the richness of our recent past; results of realized pioneering projects and still ongoing experiments.

The NEXT21 project in Osaka is one of the rare Open Bulding projects that did manage to capture the imagination and still up to today remains a fascinating building. Its complex design process was determined by the succesful cooperation of a group of professionals from different disciplines.

An interesting question we asked was: what does this project have that the others don’t? What is it’s X-factor? Can understanding the mechanisms at work help us create better buildings and so widen the support for sustainability?
To gain insight in the X-factor and it’s creation is what motivated the making of this documentary and it is our opinion crucial for the successful proliferation of ecological and sustainable building.

The documentary is currently shown at the Architecture Film Festival in Rotterdam and distributed on DVD by x!mage (www.x!mage.nl) and Architectura and Natura booksellers (www.architectura.nl)

Keywords: NEXT21, future housing, flexibility, sustainability, evaluation.

TECHNICAL SHEET

HD video, 30 minutes
Language: japanese/dutch
Subtitles: english
16:9 PAL
Year: 2009

Directed, filmed and edited by Beate LENDT
Production Gerald LINDNER, Beate LENDT

Interviews with

Yositika UTIDA, professor emeritus, Tokyo University
Seiichi FUKAO, professor Tokyo Metropolitan University
Mitsuo TAKADA, professor Kyoto University
Shinichi CHIKAZUMI, architect, Shukosha, Tokyo
John HABRAKEN, professor emeritus, MIT
Saburo TAKAMA, Scientific Air Condition Institute, Tokyo
Naomi TACHIBANA, professor Musasino Art University, Tokyo
Hiroshi HORIBA, architect, K&H Coelacanth architects, Tokyo
Midori KAMO, researcher, Osaka Gas
Mr. and Mrs. SAKASHITA, residents of NEXT21

Supported by

Jos LICHTENBERG, professor Eindhoven Technical University
Ype CUPERUS, professor Delft Technical University
The Netherlands Architecture Fund, Rotterdam
Senter Novem Innovation Fund, The Netherlands

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THE NEW JAPANESE HOUSING POLICY AND RESEARCH AND DEVELOPMENT TO PROMOTE THE LONGER LIFE OF HOUSING

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ABSTRACT

The new law which promotes the longer life of housing in Japan passed the Upper House of the Japanese Parliament on October 28, 2008. In the author’s last paper for CIB W104 in Noordwijk in October 2009, the technical guidelines of the new law were introduced. In this paper, the author explains the outline of the ongoing research and development to prolong the life of apartment buildings in Japan which follows the establishment of the new law.

Keywords: housing policy, long-life of housing, occupancy records, adaptability, infill improvements

INTRODUCTION

The average life time of newly-built detached wooden houses in Japan was almost fifty years. There are various reasons for the short life span of Japanese housing. Fires following the Great Kanto Earthquake that struck the Tokyo area in 1912 caused a huge loss of building stock, so only a small amount of old houses remain in the Tokyo Metropolitan area. The rapid economic growth that followed the Second World War enabled the Japanese to afford to live in larger houses with modern facilities. Many people rebuilt their smaller temporary houses built just after the end of the war.

Present-day Japan faces three problems: 1) people cannot enjoy the feeling of wealth they should as members of a mature society, 2) the falling birth rate and aging of society are increasing the welfare burden, and 3) global environmental problems and waste problems are becoming increasingly severe. To overcome these problems we must transform society from its existing state, a consumption society which builds and demolishes, into a stock society which builds good objects and takes scrupulous care of them to preserve them for long periods of time. The goal of extending the life span of housing is to overcome these problems.

The new law which promotes the longer life of housing in Japan passed the Upper House of the Japanese Parliament on October 28, 2008, following deliberations in the Lower House in the preceding week. The concept of this law was presented by former Prime Minister Yasuo Fukuda in 2007. The Law started its implementation on June 4th, 2009. The Government started the pilot projects in 2009 by subsidizing the private sectors' R&D to make the housing in Japan longer (200 Million Euro a year). The new law aims to supply long-life housing in Japan from now on, in addition to using the existing houses much longer.

Technical guidelines of the new law

In the author's last paper for CIB W104 in Noordwijk in October 2009, the technical guidelines of the new law were introduced. The technical guidelines explain the technical details required for extending the life span of housing. There are nine chapters in the technical guidelines, and an appendix as;

Chapter 1. Durability of the material; Deterioration measures;

House structures should be able to be used for several generations. They should be designed so that the period their structure can be used continually under maintenance conditions considered normal is at least 100 years. It should be counted on to be usable for between 150 and 200 years under appropriate maintenance.
Example: In the case of reinforced concrete (RC) construction, one of the following types of design should be taken.
□Water cement ratio of 45% or lower.
□Water cement ratio of 50% or lower and covering thickness (of concrete) increased by 1 cm.

Chapter 2. Structural design; Earthquake resistance

Make it easier to repair damage caused by an extremely uncommon earthquake to ensure the continuous use of the house by reducing the level of damage caused by earthquakes.

Either build it as a base-isolated building or take measures to reduce deformation caused by large earthquake force at or below a specified level.
Example: The ratio of the safety limit deformation of each above-ground story to its height should be 1/100 or less (in the case of wooden construction, 1/40 or less) during a large-scale earthquake.

Chapter 3. Ease of maintenance and renewal

Measures necessary so that the maintenance (cleaning, inspection, repair and update) of the interior finishing and facilities which have shorter life spans than the building structures can be carried out easily should be taken.
□The building should be designed so that private piping and common piping are easily maintained (Figure 1).
□The building should be designed so that common drainage pipes are easily maintained. It shall be possible to maintain common piping of condominium apartments without entering private parts of dwellings (Figure 2).

Chapter 4. Adaptability

Measures should be taken which permit the modification of room layouts according to changes in the lifestyle of the occupants. Ceiling height of the building frame must be adequate for piping and wiring according to modification of the original room layouts.
Example: A specified building frame ceiling height or higher (2,650mm or higher) must be ensured.

Chapter 5. Universal design for the elderly and handicapped

Necessary space in common halls and corridors must be maintained so that it is possible to perform renewal work to make a home barrier free in the future.
Example: The width etc. of common halls and corridors must be designed to ensure necessary space.

Chapter 6. Energy efficiency; Energy conservation

The performance of the insulation etc. must ensure energy conservation.

Chapter 7. Floor space for each unit

Sufficient space must be secured to ensure the occupants have reasonable levels of living standards.

Chapter 8. Living environment

The maintenance and the improvement of the living environment and the landscape in the surrounding area.

Chapter 9. Long-term maintenance planning

1) Elements necessary for structural resistance,
2) Parts which prevent the infiltration of rainwater, and
3) Water supply and water drainage systems.

The inspection details and periods for the above items must be contained in the maintenance plans.

□Inspections must be performed at least once every 10 years

Appendix: documentation and house records

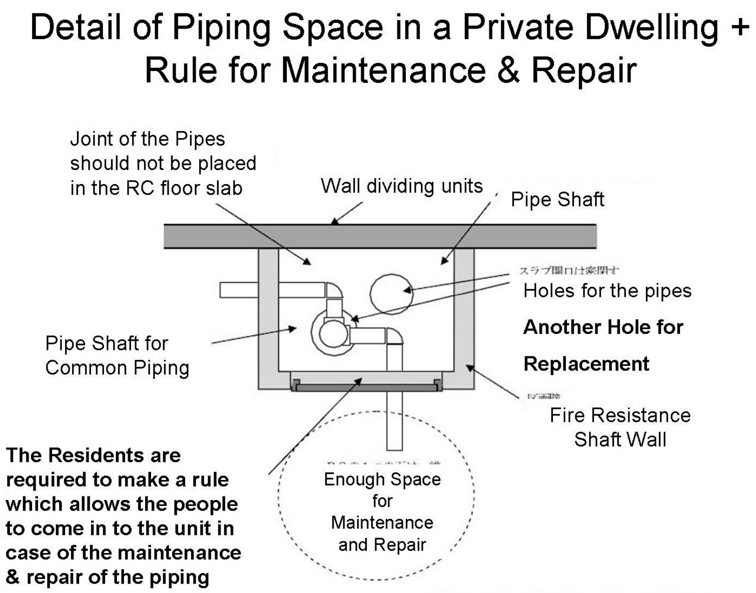

***Figure 1**. The requirements for piping space in a private condominium dwelling*

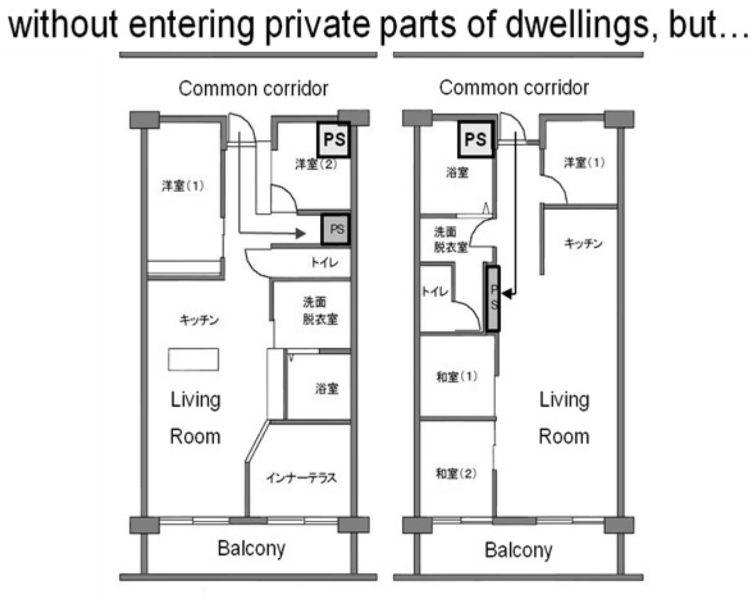

Figure 2. *The common piping of condominium apartments that can be maintained without entering private parts of dwellings.*

Incentive for longer life housing

The client can apply for tax reductions and can receive subsidies by designing and building a house which complies with the new law and technical guidelines. Specific incentive measures have been implemented. 1) When a person has purchased or constructed and occupied long-life-span superior housing from 2009 to 2011, the person is exempt from income tax up to a maximum value of 6 million yen over a ten year period according to the balance of the person's housing loan at the end of each year. 2) When a person has purchased or constructed and occupied long-life-span superior housing, the person receives an income tax exemption equal to 10% of the construction cost which exceeds that of ordinary housing (limited to 10 million yen). 3) The fixed asset tax on long-life-span superior housing is reduced by 1/2 for two years longer than in the case of ordinary housing.

Implementation of the new law to make the life of Japanese housing longer

38,568 housing units have been recognized as long-life housing based on the new law as at the end of 2009 after the enforcement of the law on June 4, 2009. These include 38,029 detached houses and 539 condominiums. As not many condominium developers think that the recognition as long-life housing has much to do with sales promotion, applications for condominiums have been very small. On the other hand, developers of detached houses have taken much advantage of the recognition as long-life housing, and have utilized it for their advertising and sales promotion. The technical guidelines which require that the common equipment piping in the condominium can be maintained without entering the unit make application for condominiums very small (Figure 2). This requirement for condominiums may need to be revised to increase application of the new law.

Governmental support for local small and medium-sized house builders

Most of the detached wooden houses in Japan are built and supplied by local small and medium-sized house builders. Therefore, it will be necessary to provide various supports to small and medium-sized house builders in order to achieve long-life housing in Japan. The government has begun to subsidize at the most 10 percent of the construction cost or up to one million yen for long-life housing that will be constructed by small or medium-size house builders which construct less than 50 units per year. To obtain the subsidy, the housing must meet the requirements of the new law and the technological guidelines, the necessary information concerning the design and maintenance of the housing must be kept, and information concerning the construction process must be publicly disclosed.

Promotion of research and technological development to achieve long-life housing by the private sector

The Ministry of Land, Infrastructure, Transport and Tourism is developing technologies which achieve long-life housing in addition to the enactment of the new law and has started a pilot project inviting the participation of the private sector. This pilot project is based on the idea of “making high quality housing, maintaining it neatly, and using it for long.” There are five categories in this project where applications can be made: “design and construction of a newly-built house;” “repair and maintenance technology of an existing house;” “establishment of the circulation system of an existing house;” “evaluation of developed technologies;” and, “publicity and enlightenment.” 70 percent of the submitted proposals were concerning “design and construction of a newly-built house,” and the large majority was about detached houses. There have only been a small number of proposals concerning condominiums up to now.

The government believes that it is important to entirely reorganize the housing industry in order to better produce and maintain housing, to enhance research and development - especially for condominium housing, and to promote the technological development concerning the repair and maintenance of existing housing. It is also important to consider the uniqueness of local areas and to develop technologies respecting the unique characteristics of each region.

In the U.S. and the E.U., over 70 to 90 percent of houses supplied are secondhand houses, but in Japan, this number is only around 13 percent. The proportion of housing maintenance and improvement in all residential investment in Japan is much smaller than that of America and European countries. It is considered that the amount of housing investment per 1000 of the population in the U.S. and European countries exceeds that in Japan because of the scale of the reform investment. It is expected that the repair and maintenance of housing in Japan will increase in the near future. Technological development concerning the renewal of the infill of condominium housing is indispensable to increasing Japanese housing life.

Government agency research and development

The National Institute for Land and Infrastructure Management started a three year research project to develop long-life housing, and invited researchers from universities to participate. The project has the following four main research topics.

1. The design approach of long-life housing that can be used over several generations.

2. Repair and renewal technologies and deterioration diagnosis technology of existing housing.

3. Management technology for housing which is to be lived in over several generations.

4. Earthwork technology of residential lots.

The changeability and the size of unit divisions are studied in order to design long-life condominiums. The following design methods are studied.

1. The variability of the dwelling unit size according to the changes of needs for housing (Figure 3 above)

2. Changeability of use from a house to an institution (Figure 3 below)

3. Adaptability of common spaces, such as corridors and balconies

In Japan, while analyzing design examples where changeability of unit divisions is implemented, research is also being undertaken regarding associated legal and economical problems.

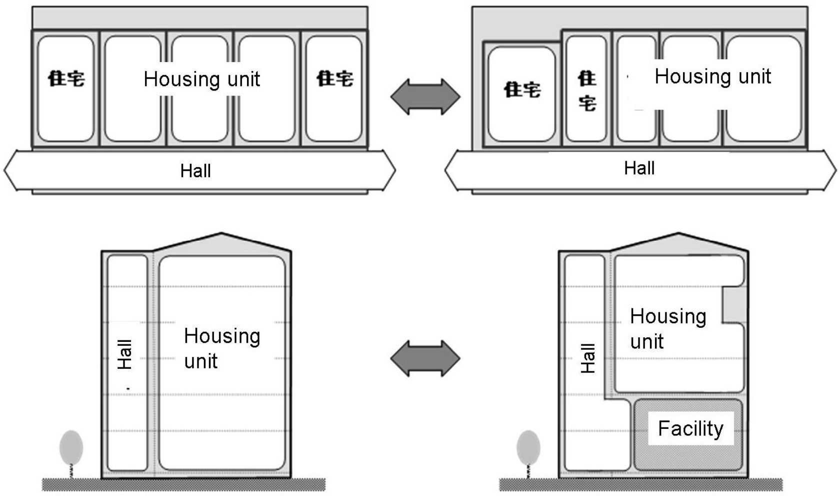

Figure 3. *Example image of a variable dwelling unit and the changes of use.*

Above:
The changeability of the dwelling unit size by the movement of the boundary wall
The variability of the balcony by the movement of the outer wall

Below:
The changeability of the ceiling height of the dwelling unit by the removal of the floor slab
The variability of the width of the outside corridor by the movement of the outer wall

CONCLUSIONS

The approach toward lengthening housing life in Japan longer has only just begun. Real results of design methods and technological developments already started have not yet been seen. Although not enough research on the relationship between city planning and building life span has been conducted, it seems that there is a strong relationship in regard to the development of post-war Japanese cities. Again, not enough research has yet been conducted regarding the influence of social systems such as the inheritance tax system on the longevity of a house. The lengthening of the life of a house is believed to be useful to reduce the consumption of natural resources and the economical burden of housing expenses for families. Therefore, wide-ranging research including the improvement of social systems is necessary to achieve the objectives of the housing policy in Japan.

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SUCCESS AND FAILURE IN FLEXIBLE BUILDING; FLEXIBLE INPUT LEADS TO FLEXIBLE OUTPUT

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ABSTRACT

In the present demand-driven market, consumers play a key role. Players in the house-building market, as in other sectors, need to listen to the consumer's requirements – and these are continually changing. The real estate sector is rather rigid in its practices, yet those working in it will need to respond to the fluctuating wishes and demands of their consumers. One possible response is to adopt a flexible building strategy. Industrial Flexible Demountable (IFD) building has recently been a subject of debate in the Dutch construction sector. This is a special type of construction involving experimental projects, experimentation being the first step in optimising a renewed production process or product. The building process is currently subject to various construction-related and organisational obstacles. This means that, in some cases, the objectives (which are focused on consumer-oriented building practices) were not being achieved. It was necessary to identify the problem areas and to consider the available opportunities for optimising the building process in future IFD house-building projects. The results of this study have been incorporated into guidelines containing a step-by-step plan. This plan sets out practical recommendations for market actors who wish to initiate an IFD house-building project. This study’s conclusions and recommendations form the basis for the seven stages that such parties will need to complete before starting on such a project.

Keywords: Industrial, Flexible, Demountable, Sustainable, Housing, Construction

INDUSTRIAL FLEXIBLE DEMOUNTABLE BUILDING

One of the themes currently featuring in the Dutch construction sector is Industrial Flexible Demountable (IFD) building. A national experimental programme was established in 1999 with the objective of encouraging industry, as well as the supply-side and the demand-side of the market, to adopt IFD building. The programme itself was the brainchild of the Steering Committee for Experiments in Public Housing (SEV). It was they who organised the recruitment and selection of projects. Part of the cost of these projects is financed by grants from the Ministry of Housing, Spatial Planning and Environment (VROM) and the Ministry of Economic Affairs (EZ). A wide range of institutional and incidental clients, such as housing associations, project developers, retail companies, manufacturers, and other companies, submitted 69 projects. Several projects are devoted to consumer-oriented construction. This means freedom of choice for the initial user and adaptability to changing housing needs throughout the lifecycle of the building (Bouwmeester 2004). IFD Building can be defined as follows (Crone 2007): IFD building is a construction method for creating flexible housing, in which the user is free to choose the size of the dwelling in question, together with details of its layout, built-in facilities, and finishing. In addition, such dwellings can be adapted to changing housing needs while their users are in residence. During the construction stage of the property in question, use is made of industrially manufactured products that can be easily assembled or disassembled on site. Clients are motivated to participate in IFD programme for the following reasons (figure 1):

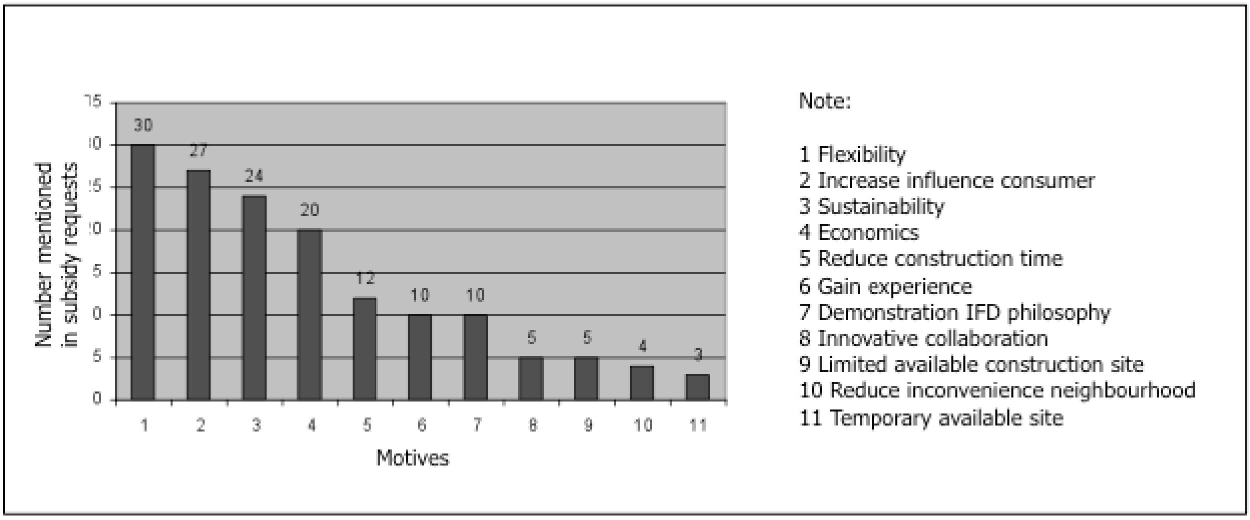

***Figure 1**: clients' motives in opting for IFD Building (Decisio, 2006)*

An initial survey on the basis of this publication (Crone 2007) led to the following preliminary conclusions:

- Many IFD house-building projects failed to achieve the original objectives which underpinned these projects at their inception;
- Obstacles in the building process caused projects to be suspended when only half complete, gave rise to construction delays, or led to a different end-result than that intended;
- In many cases, the IFD concept did not progress beyond the experimental stage. No further development took place.

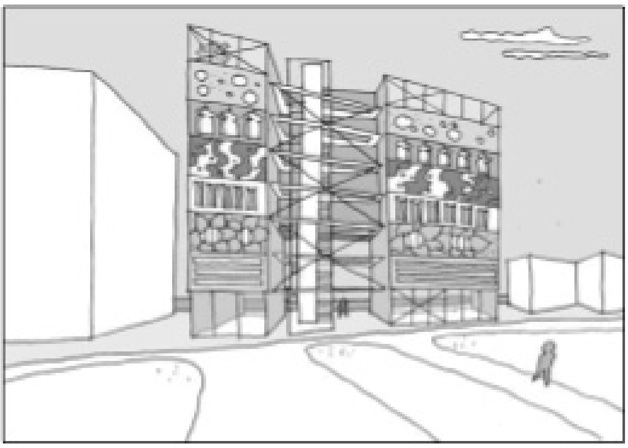

Figure 2: *suspension of the IFD project 'De zeven hemels'(The seven heavens)*
Figure 3: *Smarthouse; just a demonstration home*

- Lack of familiarity with the IFD concept

It appears that relatively few people are familiar with IFD building. The major clients are well informed in this regard, however. In addition, the limited use of IFD building makes its acceptance more difficult, especially among small businesses and construction companies. IFD building is a "generic term involving many and varied solutions, lines of development and manifestations" (Desicio BV 2006).

- Technical aspects of building

The choice of smart construction techniques was an important aspect of the experimental IFD house-building projects. A search was conducted for refined building techniques and systems capable of achieving the desired degree of flexibility. This was not restricted simply to product or building-component level, it also addressed the level at which products, components and activities were coordinated. Obstacles arose because, in some cases, innovative systems at building component level were still insufficiently mature (floor-, wall-, installation-, and façade systems) or because there was a lack of innovation at the level of the overall concept. "Nevertheless, these obstacles to IFD building and to innovations in construction also represent challenges for the future" (Decisio BV, 2006).

- Structure and organisation of the building process

While building technology itself is undoubtedly an essential element in achieving a flexible dwelling that is capable of meeting the needs and demands of the user, the associated organisational aspects are no less important. Consumer-oriented construction and the use of innovative construction systems affected the structure of the building process itself. Exploratory talks (Grace, 2008) revealed that the organisational aspects of IFD building had a major influence on the final result. Both project-based thinking and process-based thinking are important here. How do you keep a grip on cost, quality and time in an IFD building project? This required a different approach to the process.

Number of IFD Projects

Office building:	11
Hospital:	3
Homes:	34
School:	1
Other:	12

***Figure 4**: Number and nature of IFD projects*

PROBLEM DEFINITION AND RESEARCH AIM

IFD house-building projects are still in the experimental stages. Existing obstacles to the building process mean that the aim – to build in a consumer-focused manner – is not being achieved. How can one create optimal conditions for a building process involving an IFD house-building project such that the aims – focused on consumer-oriented building and specified at the start of the IFD house-building project – can be achieved? The aim of the study was to provide insight into ways of optimising the building process in IFD house-building projects, by removing as many obstacles as possible and by exploiting all available opportunities. The results are intended for real estate developers, architects, builders, materials suppliers and end-users who wish to create flexible homes the IFD way.

A questionnaire was sent to real estate developers, architects and construction companies involved in twelve IFD house-building projects. The purpose was to obtain an insight into the aims specified for IFD house-building projects, and to discover which of these aims are not being achieved, and why. This survey formed the basis for the case studies. Five IFD house-building projects were studied in detail and the parties involved were interviewed (figure 5).

***Figure 5:** The five detailed cases: Smarthouse (Rotterdam), De Zeven Hemels (Rotterdam), A+ dwellings (Etten-Leur), Het Masker (Veenendaal), Terbregse.nl (Rotterdam)*

Objectives at the start of IFD projects

At the start of IFD house-building projects, various objectives are established in relation to Consumer-oriented building, Industrial building, Flexible building, and Demountable building (see also figure 1). The main objective of these IFD house-building projects was consumer-oriented building. The IFD concept was seen as a strategy that enabled consumers to influence projects in an efficient and manageable way. Various aspects of the flexibility objectives were developed on a project-by-project basis. Most of the objectives with regard to flexibility were at the level of the dwelling's volume, layout, built-in facilities, and appearance. The individual projects each interpreted these objectives in their own way, in addition to setting objectives of their own. The agreement was that each project would draw a distinction between freedom of choice for the initial user (concerning the dwelling's size, layout, built-in facilities, finishing and appearance) and adaptability in the later stages of use (adjusting the size of the dwelling by adding or removing various parts, changing the floor plan, façade elements, extensions), through the use of detachable building components.

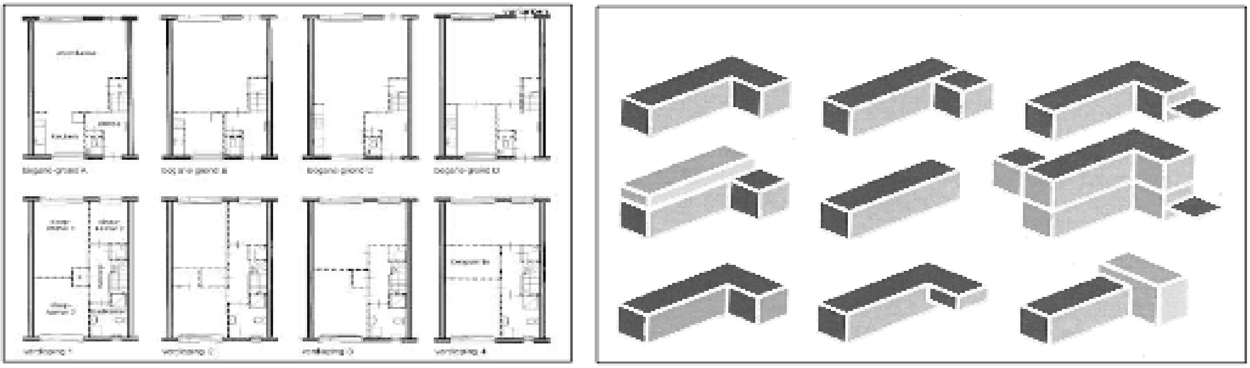

Figure 6: *Flexibility in dwelling layout (left: A+ homes) and in the volume of the dwelling (right: Smarthouse)*

Prior agreements concerning such things as standard dimensions, details, and fixed prices per product or per m^2 make it possible to provide guarantees concerning the end product. Efforts to accelerate the building process focus on making the maximum use of the available production technology, involving fixed agreements on dimensions, suppliers and implementation, all of which make it possible for industrially prefabricated products to be assembled and fitted on site. The use of factory-like production processes under controlled conditions makes builders independent of weather conditions, while providing a more comfortable working environment.

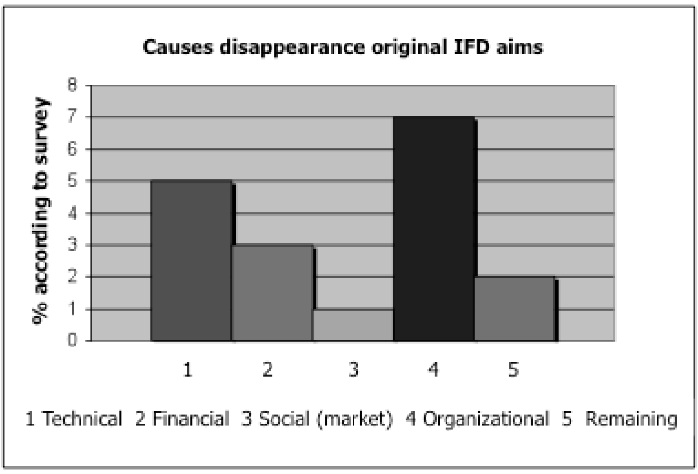

Figure 7: *Reasons for erosion of original objectives, segregated into five clusters*

OBJECTIVES NOT ACHIEVED - AND THE REASONS WHY

The various parties involved indicated that, in practice, some objectives are not achieved (Grace, 2008). The principle causes put forward to account for this were: impediments in the development and construction process, projects that folded before they could be realised, lack of scope for creating a more efficient building process, product innovation that was mainly at component level rather than at the level of an overall concept, inability to provide guarantees due to a lack of coordination and cooperation between the various parties involved. The three most common reasons for failing to achieve objectives were technical, financial or organisational in nature (see figure 7). On the basis of five projects, a further analysis was carried out to identify the objectives formulated at the start of the project, those that were ultimately achieved, and the reasons why the remaining objectives were not achieved.

Smarthouse

The Smarthouse concept was aimed at a very specific target group, to wit private buyers with their own plot of land and an interest in specifically tailored architecture. However, there was very little demand for dwellings of this kind. While the Smarthouse had been developed for a clearly defined target group, a deteriorating housing market caused demand to ebb away before the concept could be realised. Smarthouse combined the extensive freedom of choice that is normally associated with an individual construction contract with the advantages of a dwelling selected from a catalogue: a sleek design and a streamlined building process involving serial construction. In this way, it was possible to develop products with a fixed construction time, cost, and quality.

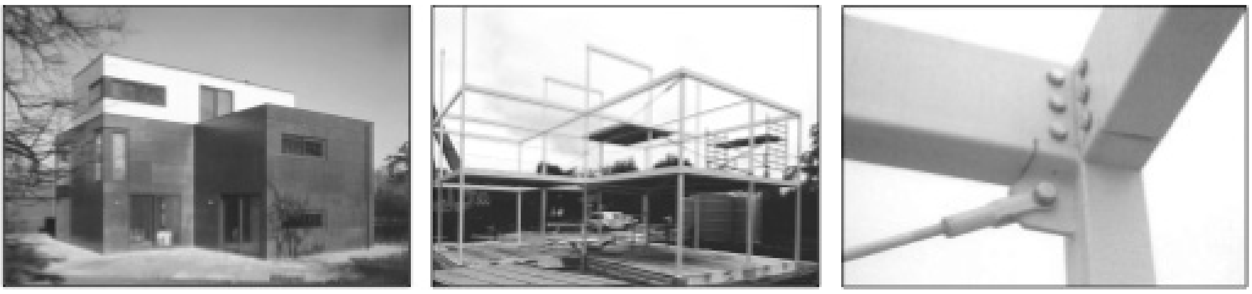

***Figure 8:** Smarthouse; the objective was to build detached IFD dwellings using standard building technology and organisational principles. Ultimately only a single prototype dwelling was constructed. Further developments of Smarthouse homes failed to materialise.*

Seven Heavens

The Seven Heavens (Zeven Hemels) concept involved some very extreme aspects of design and construction, virtually all of which were highly innovative in nature. This was an entirely new concept, IFD building. This involved novel aspects such as a building system based on a steel-skeleton that had never before been used in practice, an unknown end product in the form of a flexible apartment block with eight different façades, unknown buyers (no potential clients had yet signed up), a new form of cooperation (a single basic-frame architect and seven different architects specialising in built-in facilities or in the finish of dwellings).

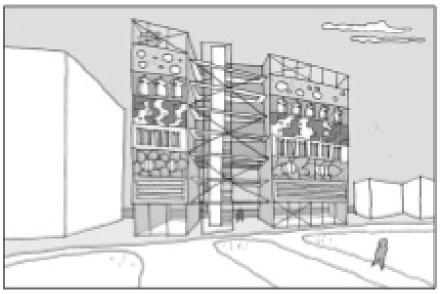
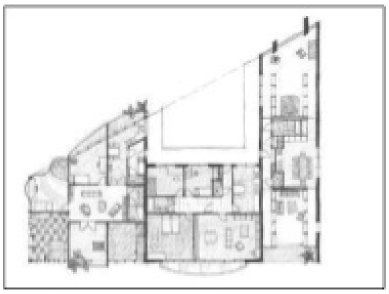
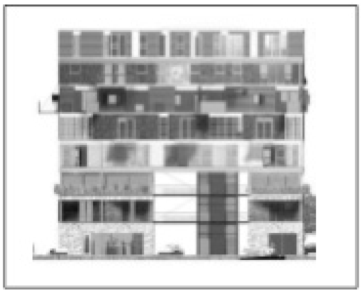

Figure 9: *The goal was to respond to users' specific requirements by offering them complete freedom of choice with regard to their future dwelling's facade and layout. This project never got off the ground*

Market research carried out in the initial stage revealed that the project was excessively ambitious, both in view of the assigned site and of the new concept of IFD building. There was a lack of coordination between the principal on the one hand and the architects (basic-frame architect and seven architects specialising in built-in facilities or in the finish of dwellings) on the other. This meant that the project was not viable, and that it ultimately had to be abandoned.

A+ dwellings

The A+ building system concept was already in place prior to the start of the IFD programme. However, its application in housing construction was an innovative aspect. The A+ building system makes it possible to implement a range of different housing plans and to adapt these plans to fit changing housing needs. However, the users (tenants and buyers) did not become involved until after completion. Accordingly, any design modifications to meet the needs and demands of future occupants could not be fleshed out in the construction stage. Inevitably, traditional ways of thinking and working had to make way for more innovative approaches. While innovative construction systems were used, there was no coordination with those involved in the associated organisational and building work.



Figure 10: *The objective of the IFD project A+ dwellings was to create homes that are adaptable to the composition of families and to changing housing needs. The Infra+ floor contributed to this flexibility*

The Mask

Not only has The Mask (Het Masker) project been completed but it also achieved the flexibility objectives. The choice of building system substantially influenced the building process. The result was a totally different process. The preparation stage was much more intensive than had been expected, which meant that coordination between the various disciplines involved was crucial. However, the various parties failed to contribute and coordinate their expertise. The residents made full use of their freedom of choice during the construction process, at the levels of dwelling volume and layout. As the dwellings in question are rental properties that are managed by a housing association, future adjustments to changing housing needs are expected.

Figure 11: *The scope of The Mask was the development of housing within the housing benefit limit while giving users the freedom to design their own home*

Terbregse.nl

The Terbregse.nl project was completed as a direct result of previous flexibility projects by the same developer. Previous in-house experience in building flexible homes in an industrial and demountable way was harnessed in this project. The nature of the approach to consumers contributes to the freedom of choice and degree of adaptability of the dwellings. The first step, involving the registration of future residents, is followed by a 'Dream House' day, after which general wishes are translated into specific design features. Next, comes the layout of the house, plot selection, the exchange of contracts, and construction. Integrated design was the most important stage in the construction process, and was already well developed. This made it possible to achieve a good rapport between the parties involved, as a result of which the implementation stage went very smoothly indeed. The only issue was that some users were too late in making their views known, which meant that the flooring system could not be adapted to individual requirements.

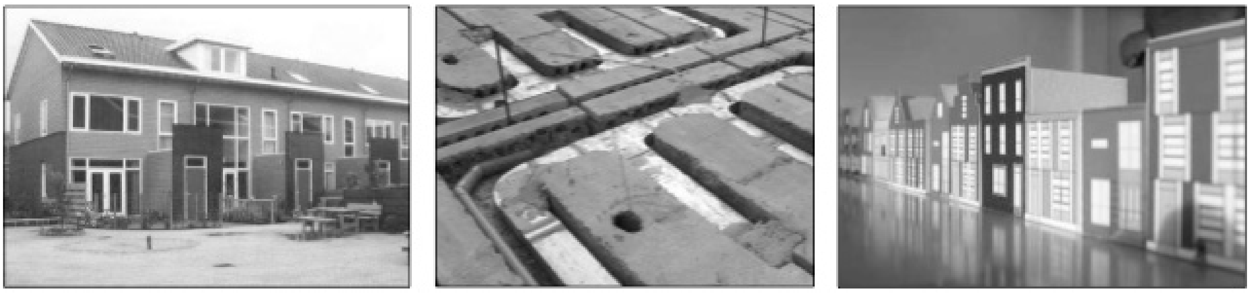

Figure 12: *Nijhuis (a developer and building contractor) had been building in accordance with the IFD concept for some time before the SEV came up with the IFD innovation programme. They had already come up with solutions to problems that they had encountered in previous projects.*

CONCLUSIONS AND RECOMMENDATIONS

The study has shown that some predetermined goals for the experimental IFD projects were not achieved during implementation. This is mainly due to the building and organisational aspects of the building process associated with IFD house-building projects.

The production of flexible housing that allows initial users the freedom of choice to design the dwelling to suit their own requirements and that guarantees adaptability to changing housing needs as time goes by, calls for a new approach to building processes. The use of industrially manufactured, removable building elements allows dwellings to be completed in much less time than is possible using traditional building processes. The preparatory stage, however, is much more intensive. Furthermore, the design work and the technical implementation are fully integrated, and run concurrently. When attempting to optimize the construction process, it is vital that the following aspects be addressed:

• Defining the target group for whom dwellings are being constructed is the basis of a successful project. This involves market research and an understanding of the needs and requirements of the target group in question.

• The premise and the objectives are formulated on the basis of the selected target group and the agreed definition of the “IFD building” concept. These will have to be monitored throughout the entire process.

• Consumers tend to have traditional views. They want to know what the end product will look like. Given the extreme flexibility of these dwellings, there are few standard aspects that can be used to show what the final product will look like. Accordingly, buyers often prefer a traditionally built house. The development of a demonstration home, or prototype, can help to address these concerns.

• Before all aspects of the building process have been determined, the degree of user involvement should be determined. This might relate to their ability to influence the end-result, for example, or to the process of drafting the schedule of requirements, the design process, and choice of building system.

• Many problems arise due to inexperience (and a lack of familiarity) with innovative products and processes on the part of those involved.

• The expertise of each of the various parties should be deployed at the appropriate stage. Traditional ways of thinking and working will have to make way for an integrated approach.

• Integrated design offers the opportunity to achieve an optimal end product. The expertise of the various parties involved is deployed as part of a joint effort to achieve a design and to work out the relevant technical details. This requires close coordination and harmonisation between the various disciplines.

• The intended degree of flexibility will have to be translated into a design. This presents opportunities with regard to the technical aspects of building. For example, the design of a load-bearing construction that can be divided into lots, integrating flexible floor and wall systems into the design, or the creation of overcapacity.

• The shift of intensity from the implementation stage to the preparation stage means that coordination of the various market actors is crucial. It is preferable to work with fixed co-makers, in order to optimise the coordination and cooperation of the various parties. Fixed agreements can be made with them at an early stage of the building process, concerning price, quality, logistics and the supply of products.

• The full potential of product flexibility can be employed to cater for changing housing needs while the dwelling is in use. However, these need to be monitored and supervised to avoid the erosion of knowledge over time, concerning what is and is not possible.

SEVEN STEPS IN THE GUIDELINE FOR IFD HOUSE-BUILDING PROJECTS

The study's conclusions and recommendations form the basis of the IFD House-building Project Guidelines. These consist of seven steps that must be completed before the development of an IFD house-building project can commence.

Step 1: Market research.
Launch market research in the initiation stage. On the basis of the results obtained, select the appropriate target group and the associated living requirements for which the flexible dwelling is to be built. This provides a better guarantee that the new homes will be sold.

Step 2: Draft the initial guiding principles
The principles to be drawn up involve generating a definition for the concept of IFD building, the development concept of flexible housing (e.g. private contractor, catalogue-style construction, or a concept involving a specific building system), and the approach to future users (for the user, with the user and/or by user).

Step 3:Formulate objectives
Formulate objectives in the initiation stage that can be subdivided into a central or general objective of creating value (or added value) for the user, and peripheral objectives specifically aimed at industrial, flexible, and demountable building. Monitor and check these objectives throughout the remaining stages of the process.

Step 4: Select method
In the initiation stage, select the method to be used during the development and building process. Allowance should be made for the amount of freedom of choice available to the residents during the development stage and for the degree of adaptability while the dwelling is in use. Choose an innovative building system that is best able to provide the desired flexibility. Suppliers' expertise may be useful in this regard. Determine an organisational structure and identify the parties involved and their individual responsibilities within the process and in terms of the end result.

Step 5: Monitoring flexibility in the design stage
Structure the design stage such that the principles and objectives are translated into a design. From the point of view of market research, the identification of user needs and the schedule of requirements, guarantees must be given during the design stage concerning the freedom of choice available with regard to house size, house layout, installation, built-in facilities, and finishing. Adaptability while the dwelling is in use should also be monitored, such as adding or removing various parts of the house, or making changes to its layout or appearance.

Step 6: Structuring implementation stage
Structure the implementation stage such that the flexible dwelling can be completed quickly, without encountering any obstacles. This might involve implementation logistics, on-site assembly techniques for industrially manufactured prefabricated building components, and working with fixed co-makers. This involves cooperation between the contractor and specialist subcontractors and suppliers. The advantage of established teams is that the representatives of the various disciplines are used to working with one another. Each other's knowledge and expertise are utilised to the full.

Step 7: Monitoring flexibility options

Create flexibility options while the dwelling is in use and ensure that these can actually be implemented should the need arise. If a dwelling remains in the ownership of a corporation, then the latter is responsible for making the options for adaptation or change as clear as possible. When the user owns a dwelling, the latter must be provided with a logbook in which the various modification options are described and explained.
A final important recommendation relates to experimenting with innovations, both at building-component level and at the level of an overall concept. This offers an opportunity to identify potential obstacles at an early stage. Experimentation involves learning from experience, optimising, and perfecting. Setting up a demonstration home can be part of this procedure.

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MANUBUILD demonstration building in Madrid – From concept to reality

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ABSTRACT

The ManuBuild Open Building Manufacturing System, a co-funded 6th Framework integrated project - is a sustainable building approach that is non-material specific and holistically incorporates Design, Business Models, Manufacturing Methods and Technologies and ICT Support as well as Training and Education. This system enables construction to act as a flexible, agile, value-driven and knowledge based industry and most of all to be highly customer-centric, efficient and competitive.

ManuBuild was created in response to a need to address challenges in the industry in terms of sustainability, modern methods of construction, greater control over process and marrying good architectural practice with offsite construction. These ambitious targets were very much in line with the Municipal Housing and Land Authority (Empresa Municipal De la Vivienda y Suelo de Madrid - EMVS) vision and engagement in fostering sustainable and innovative development, focused on end user needs. EMVS is showing how these challenges have been addressed as well as proving, testing and validating the concepts of ManuBuild through the creation of a building which is delivered as a commercial development and currently under construction in Southwest Madrid.

In this paper, the authors will mainly focus on the demonstration building development. The 25 renting apartments of one and two bedrooms for young people, which forms part of a social housing development for EMVS, are distributed in one block, including an underground semiautomatic car park with 115 parking spaces. The demonstration emphasis is on architectural flexibility of apartment layouts during construction and the life cycle of the building and on using off site manufacturing to reduce site assembly time and to increase the quality of the build.

The process adopted in designing and constructing the building through off site manufacturing will form the main body of this paper.

Keywords: ManuBuild, sustainability, social housing, architectural flexibility, off site manufacturing.

OVERVIEW OF MANUBUILD – THE DEMONSTRATIONS

ManuBuild - Open Building Manufacturing- is a European industry-led collaborative research project on Industrialised Construction, part-funded by the EU, under the 6th Framework Programme, involving 22 partners from 8 countries across Europe. The project ambitious targets are very much in line with the Municipal Housing and Land Authority (Empresa Municipal de la Vivienda y Suelo de Madrid - EMVS) vision and engagement in fostering sustainable and innovative development.

End users, private & public developers- such as EMVS-, contractors, suppliers, research institutes, software companies and research & training organisations are represented at the project consortium.

The main objective of the ManuBuild System is to produce uplifting, sustainable and cost-effective customer-oriented buildings, through radical integration and industrialisation of the design, production and delivery processes, as well as greater involvement of the customer. The goals are:

- Shift from traditional craft based to manufactured construction
- Promote the open sourced components
- Adopt advanced manufacturing methods
- Integrate ICT to aid open building manufactured construction

The system addresses the whole building process from design to completion, through a completely new business model, benefiting from manufacturing methods & technologies and advanced information communications & technologies. From the design point of view, the aim is to develop and introduce concepts, methodologies and new products for open building manufacturing, offering customer choice, design for manufacture and construction flexibility. The integrated manufactured solutions encompass new methods and technologies that enable the delivery of value-added, innovative and optimised technologies for both on-site and off-site open building manufacturing. This allows radically increased productivity, improved health and safety, and reduced construction time and costs. ICT infrastructure and tools support open building manufacturing, allowing building designs to be configured by the various stakeholders involved, along with seamless information management and delivery. The results are a holistic business and organisational models to deliver performance based, customer centric, whole-life, value-driven solutions tailored to suit open building manufacturing creating more efficient and better targeted services to the market.

Finally, the wider uptake of ManuBuild concepts is supported by a developed framework for European human capacity underpinned by a proactive and innovative approach to training and education. This includes new academic courses and flexible, accessible training and education material for the industry.

***Figure 1**: ManuBuild in Carabanchel & Invited teams visit to plot in 2006 (Madrid, Spain)*

The viability of the ManuBuild vision is being proved on a number of commercial environments of real construction projects: two in the UK (low rise housing and a medium rise apartment), one in Sweden (a medium priced four storey 16 apartment building) and one in Spain (a social housing development), where new technologies applied across the whole lifecycle of the building -from design to services - and new ways to address customer/end-user needs such as design for living, design for openness and customization are being demonstrated. These developments, built to ManuBuild principles, provide examples of how the construction industry, its customers and supply chain can move the industry from a mainly craft production and closed way of working, towards the vision of an open system building manufacturing approach.

EMVS is showing how these challenges have been addressed through the erection of a building, delivered as a commercial development and currently under construction in Southwest Madrid, Spain. The demonstration emphasises architectural flexibility of apartment layouts during the whole life cycle and use of off-site manufacturing to reduce site assembly time and to increase the quality of the build.

MANUBUILD SPANISH DEMONSTRATION: EXPLAINING THE PROCESS

The Spanish demonstration building development is currently under construction in southwest Madrid, a newly developed urban area. The 25 renting apartments of one and two bedrooms for young people form part of a social housing development for EMVS. The dwellings are located in a medium rise block, including an underground semiautomatic car park with 115 parking spaces. The emphasis is on architectural flexibility of layouts and on using off-site manufacturing to reduce site assembly time and to increase the quality of the build.

The two competitions

The EMVS called two international architectural contests in March and November of 2006 for the ManuBuild Demonstrator. Both competitions were based on 5 points of ManuBuild Philosophy: End User Involvement, Open Building, Activity Space Approach, Design for Flexibility and Design for Manufacturing.

Figure 2: *First competition launch & jury session, March-May 2006*

The invited teams were familiar with industrialisation, technical innovation, sustainability, especially with energy efficiency and environmental adaptation. Thanks to the two competitions, the EMVS obtained 15 different architectural proposals of European well-known practices, for the same plot, same climate and conditions in Southwest Madrid, which illustrated different solutions for the Manubuild demonstrator.

The aim of the first competition was to set the scene for the 2nd restricted call - which included as a starting point the results of the first one. The winner of the second competition would be the Spanish team of architects to design and build the 25 public housing units at the "Ensanche de Carabanchel". The proposals satisfied the real estate program & sustainable common practice of the EMVS, as well as the objectives of Manubuild outlined below:

- Use of Off-site components such us quick and easy assembled modules, compatible & exchangeable elements, standard connexions, easy to move parts, universal assembly methods and dimensional coordination
- Dwelling flexibility such us possibility of layout reconfiguration to allow adaptation to occupants evolution & needs, easiness for the finishes & installations renovation and future maintenance.
- User's participation, such us design & configuration oriented to the client, future changes at low costs

Regarding sustainability, the incorporation of energy efficiency criteria, renewable energies, bioclimatic design, proper use of the land, construction systems that reduce waste and increase the life-cycle of the building and dwelling, environmental friendly materials (recycled, recyclable, healthy) was compulsory.

The proposals needed to address as well the positive enforcement of the image of the industrialised systems & buildings through conscious design for the end user, & manufacturing, spatial innovation and contemporary formal image.

First Competition March 2006

The first competition was launched in March 2006 and the aim was to obtain proposals of high quality on flexible layouts typology, within the Mediterranean scope and implementation of industrialized, opened and sustainable constructive systems. The end user should also be at the centre of the process.
Twelve European teams from different countries were invited to this restricted competition and 9 entries submitted:

- CTROL [Space] HOUSING Piercy Conner Architects (Uk)
- 6769FR Amin Taha Architects (Uk)

- SKY GARDEN Feilden Clegg Bradley (Uk)
- CUBIC Willems Van De Brink Architecten (Nl)
- WATERFLOW J.M. Lapuerta y C. Asensio (Sp)
- SIETEALCUBO F. Jurado (Sp)
- 20 AÑOS NO SON NADA Estudio Carlos Ferrater (Sp)
- 9182736455 Surface Architects (Sp)
- UDHAB Llewelyn Davies Yeang, P.F. Longoria, T. Díaz Magra Uk/SP)

Figure 3: *First competition technical session, May 2006*

All the proposals provided different and challenging ideas for the Manubuild Madrid Demonstration, focussed on industrialisation of the construction process , use of off-site components and modules, flexible layouts adaptable through time to the changing end users needs and adaptation to the cultural and climate conditions of Madrid..

CTROL [Space] HOUSING, from Piercy Conner Architects (UK), was awarded first prize. The proposal focused on the pragmatic and the sensual and looked for the common factor of flexible, sustainable and industrialised homes through a greater degree of control and increased responsiveness, to enable the end-user more choice and diversity; technologically to facilitate leaner, more efficient fabrication and construction; or environmentally, to allow a building to be effective in varying climates and situations. The aim was to create flexible, sustainable industrialised homes that can be manipulated, adapted and controlled throughout their lifecycle. They proposed light industrial buildings as good examples of controllable and controlled elements, proving flexible, sustainable and durable, adding sensual qualities that most people look for in a home such as warmth, tactility and smaller scale detail, designing a dwelling which was not only pragmatic and efficient but also sensually interesting and responsive. Ctrl [space] proposed contemporary homes that were experientially rich and customisable despite being modular and economical (Manubuild T2.2, 2007)

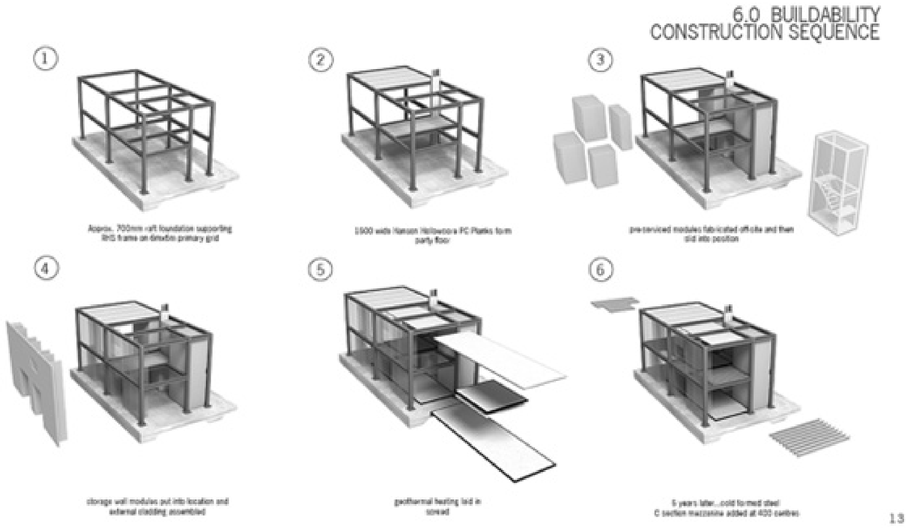

Figure 4: *CTROL [Space] HOUSING, from Piercy Conner Architects (UK)*

The 6769FR proposal, from Amin Taha Architects (UK), won the second prize. Their approach was driven by the Manubuild raison d'être for 'open-manufacturing'. The team looked at the existing products in the market place throughout Europe and drawn out the strategy based on Open-Plan structural volume, Standard system components but material flexibility, Inhabitant desire & flexibility, Flat stacked transportation, Structural sandwich panel walls & floors, Pre-wired walls and Fully prefabricated, plumbed and wired bathroom, wc & kitchen units. To anchor the development within Madrid and this site specifically, the external sun-screen device were used as one of the principle design generators. The perforated metal brise-soleil screens highlighted the intended domesticity of the programme, while maintaining the aspirations for components that can be mass produced and prefabricated off site.

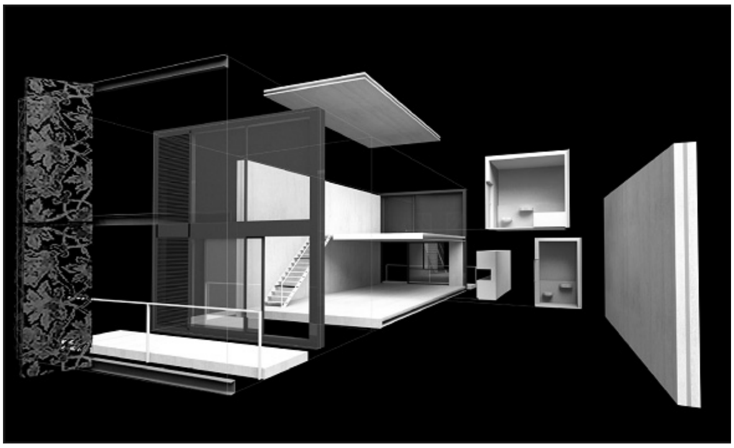

Figure 5: *6769FR Amin Taha Architects (UK)*

The third awarded proposal SKY GARDEN, from Feilden Clegg Bradley (UK), explored three conceptual ideas critical to successful high density urban living. The scheme was developed around the use of stacked prefabricated shipping containers, with houses and gardens at all levels, and natural cooling by ventilation combined with thermal mass. The result: a living, breathing building.

The spaces held between the stacked Verbus modules blocks were used as allotments/gardens available for use to the inhabitants of the two adjacent levels. Six sky gardens were provided vertically throughout the building. The sky gardens offered safe environments for inhabitants to interact.

By spacing the modules vertically, air was allowed to flow between the units where unfired clay was used as a thermal store to aid cooling day and night throughout the summer, performing as a Breathing wind tower.

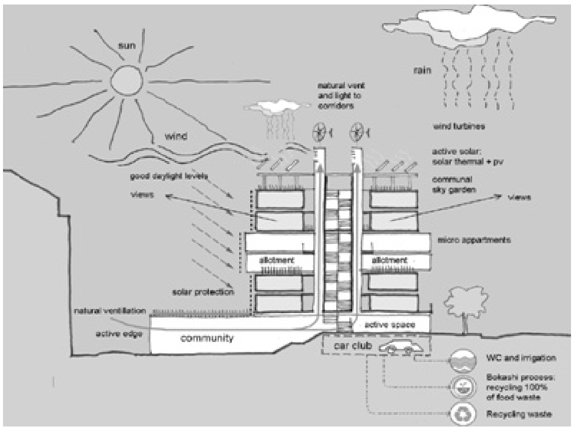

Figure 6: *SKY GARDEN, from Feilden Clegg Bradley (UK)*

Second Competition November 2006

The objective of the second restricted call for ideas was to obtain design proposals with a high degree of spatial and technical quality for a middle rise housing development at the “Ensanche de Carabanchel” area, as a “demonstration project” to showcase the results of the R+D European project ManuBuild.

The proposals submitted needed to be sustainable and fulfill both the real estate development programme of the EMVS and the objectives of the ManuBuild project, and in particular particularly with regards to the flexibility of the dwellings and the degree of industrialisation attained. Regarding the flexibility of the dwellings, the objective was to be able to reconfigure the residential units, adapting the dwelling to the nature of the family unit, taking into account the potential changes that can occur as it evolves in time, as well as lengthen the life of the building in general while reducing the future maintenance tasks.Therefore the criteria used to assess flexibility were the level of involvement of the users in their residences, the need or not of specialized help, the different solutions/options available for each type of residence, the possibility of reconfigure the floor plan of the units, and the capacity of the building to be updated through time to new technologies, renewing finishes and services, life cycle and maintenance.The teams were asked for the full development and design of one residential unit to showcase the possible configurations and variations offered (floor plan, level plan, façade, etc.) as well as the degree of intervention of the future user.

The objective was to build “residences for people”, in which the future users feel the dwelling as a “home” rather than a “house”. The ManuBuild approach to design of the dwellings, based on the activities they will sustain, was to be taken into account.

The teams were asked to include a rational for the degree of manufacturing involved as well as the percentage of innovation attained (as compared with a traditional/ conventional residential building). The quality of the final image and the formal and spatial aspects of the proposal were essential in order to dispel the negative image of industrialized building of past periods. The architectural team needed also to submit a proposal for collaboration with the ManuBuild project in order to be appraised of the results of the research being currently conducted and to be able to incorporate the results of said research into the building (processes, systems or products).

Sustainability was an essential part of the proposal, therefore the projects needed to incorporate energy-efficient criteria, renewable energy sources, bioclimatic design, the appropriate use of land, building systems that minimize waste generation and improve maintenance tasks and the buildings and units' useful life cycles, the use of environmentally friendly materials (recycled, recyclable, healthy). Eight Spanish teams were invited to this restricted competition and 6 entries submitted:

- 3^3 (TRES AL CUBO) César Ruiz-Larrea Cangas – 1sr prize
- BOX Ortiz y León Arquitectos – 2nd prize
- HACER PATENTE Antonio Fernández Alba – 3rd prize ex-aequo
- JARDÍN DE AIRE Pich-Aguilera Equipo de Arquitectura – 3rd prize ex-aequo
- PRET-A-PORTER Fresno-Casas Arquitectos
- TODAY (31+19) AUIA Arquitectos, Urbanistas e Ingenieros Asociados

The evaluation report listed the technical advantages and disadvantages of the 6 proposals submitted, based on the competition criteria. :

The proposal 33 (TRES AL CUBO) from César Ruiz-Larrea & Associates won the first prize. The team proposed innovative systems regarding off-site, sustainability and energy efficency, such as a smart industrialised façade with Pv & Thermal panels. Standarisation was addressed as well as a flexible layout, good geometrical variation & mass- customisation. The contemporary design of both dwelling and building was of high quality and the use of structural & spatial grid of 3x3 a good example of dimensional coordination. The project and challenges addressed represented a good opportunity to collaborate with Manubuild team.

Figure 7: *3^3 (TRES AL CUBO) Ruiz-Larrea & Associates (Sp)*

The BOX of Ortiz y León Architects won the 2nd prize. They proposed the use of shipping containers, a Variety of suppliers, accessible services for maintenance, good end user choice and good off-site vs on-site balance.

Figure 8: *BOX Ortiz y León Architects (Sp)*

HACER PATENTE from Antonio Fernández Alba, - a flexible proposal with all the services grouped on the North façade- shared the 3rd prize ex-aequo with JARDÍN DE AIRE from Pich-Aguilera architects team, a contemporary formal proposal with good level of buildability and open for standarisation.

Figure 9: *HACER PATENTE Fernández Alba & JARDÍN DE AIRE Pich-Aguilera (Sp)*

WINNING DESIGN: DESCRIPTION AND PHILOSOPHY

The wining design for the Manubuild Spanish demonstration building -currently under construction- emphasised on architectural flexibility of layouts and on using off-site manufacturing, as the competition brief required.

Ruiz Larrea & Associates were selected in January 2007 to developed the design, detailed project and be in charge of the construction.

The proposal – as said- focused on industrialisation and open building, through modularisation and optimisation of the space and building systems , linked to the energy performance of the dwelling and the end user participation.
The main objectives proposed were as follows:

- Structure Industrialisation and open building components

The structure proposed is a three dimensional steel grid 3mx3mx3m, completely manufactured off-site and erected on site, as well as the façade, which also works as a customisable energy shield. All the parts and components – including the moveable partitions- will be from open catalogues to allow interchangeability.

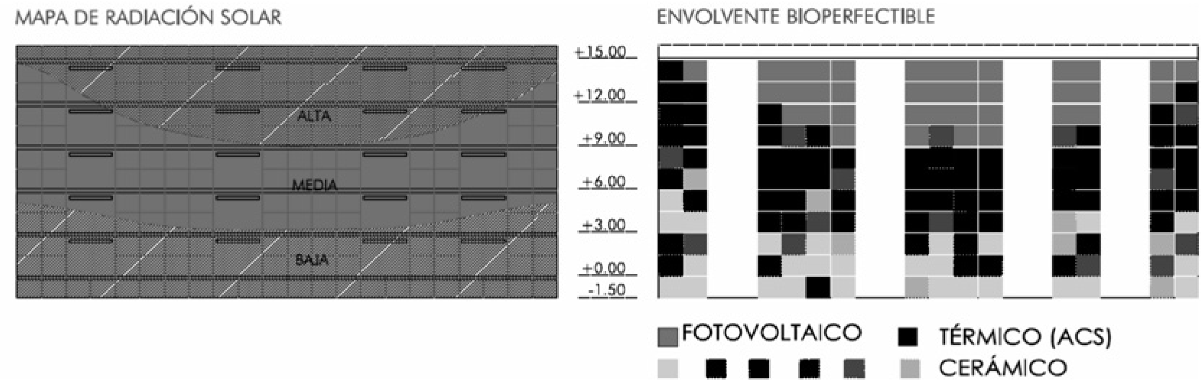

Figure 9: *Off-site Energy active façade*

- Services industrialisation

All the services will be brought on site as an off-site service core. Kitchen and bathrooms will be grouped and a technical floor will allow flexibility of changes. A water recycling system will be installed in the service modules.

- Typological flexibility

The proposed dwelling is made of 3 spatial areas: living space, 2 bioclimatic modules that help to improve the internal conditions, and a service area, where kitchen and bathrooms are located. This allows 3 different types of dwellings based on the same layout typology: a single user studio, a 2 bedroom apartment for young couples or students and a 3 bedroom apartment for families. The layouts are completely reconfigurable.

Figure 10: *Flexible layout typology & different areas: 1-living, 2-bioclimatic, 3-services*

- Energy industrialisation

The dwellings have two different bioclimatic industrialised spaces: a south facing gallery to capture the sun and heat in winter and a shadowed space facing north with vegetation and humidity to ensure a reduction of summer conditions.

CONSTRUCTION PHASE

Figure 11: *North façade in November 2009 & South façade in April* ***2010***

The construction phase started in early 2009 after a public bid among different contractors. The Spanish demonstration - a 25 renting apartments of one and two bedrooms for young people- forms part of a social housing development for EMVS. The dwellings are located in a medium rise block of 5 floors, including an underground semiautomatic car park with 115 parking spaces. Even if the winner proposal has been adapted to real market and plot conditions, the emphasis still is on architectural flexibility of layouts, off-site manufacturing to reduce site assembly time and to increase the quality of the build and end-user involvement, all linked to sustainability and building performance.

Figure 12: *Manubuild Corus steel module penthouse & semiautomatic car parking*

The building will be completed by early June 2010 and showcase the integration of different technologies- manufactured structures of concrete & steel-, off-site components and materials- such as bathroom pods-, total flexibility of the dwellings layouts, the implementation of a totally manufactured off-site solar & PV panels façade as well as the integration of an off-site semiautomatic car parking.

Figure 13: *Bathrooms pods on site*

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We would like to thank all the teams involved in the two competitions for their challenging proposals and hard work , the Manubuild partners that provided support and trust the development of the demonstrator, all the Ruiz Larrea team for their engagement, the EMVS staff for their support since 2002, the European officer in charge Mr. Cristophe Lesniak and specially the Dragados site manager Jose Luis García , his assistant and team for their compromise. It has been and still is a challenge and an integrated effort.

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THE QUALITIES OF THE BASICS: BASE BUILDING DESIGN

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ABSTRACT

A building can be understood as an integration of two parts, a base including structures serving multiple users and frame physical conditions for inhabitation, and an attachment including all the elements changing in times and determined by users. The skills of designing a base, rather than a complete building is beyond traditional architectural discourse and yet to be understood. The paper firstly introduced the concept of base building, the significance and its relation with the separate components – the Infill. Then it describes the qualities of the base buildings characterized by permanency, adaptability, simplicity, organized public spaces, and efficient service systems. The paper analyzes buildings designed by Baumschlager Eberle (BE) by focusing on four base systems, namely the structure, operable facade, common spaces in hierarchies, and low energy service system. It demonstrates the sustainable approaches of architecture: long lasting, high comfort with low energy. It concludes that the qualities of the architecture ensured by the initial design are mainly embedded in the base buildings. A skillful base building design with high quality opens a new horizon for the architecture.

Keywords: base building, support, architectural quality

1. INTRODUCTION

The base building concept is derived from the concept of Support. “A support structure is a construction which allows the provision of dwellings which can be built, altered and taken down, in dependently of the others.” (Habraken 1972:59-60) a Support is an unfinished building, ready to be occupied by variable infill. However, the layout and size of individual occupancies – dwellings, offices, etc. – are not pre-determined. The Support is the permanent, shared part of a building which provides serviced space for occupancy. (Kendall and Teicher 2000:32)

A Support can not be inhabited, or become a building without Infill. “Supports” are the shared and serviced structures that would contain dwellings made out of “infill”, much as a bookcase (a shared infrastructure) contains books (decided independently) that can be taken out and put in separately. “Typical support elements include building structure and facade, entrances, staircases, corridors, elevators and trunk (main) lines for electricity, communications, water, gas, and drainage.” (Kendall and Teicher 2000: 33), While typical Infill elements include external wall elements, internal partition elements, floor elements, storage elements, doors, kitchen elements, bathroom elements, and so on. (1972: P 63) Age van Randen provided four categories for Infill: (1) spatial layout, (2) partition walls, frames, doors etc., (3) equipment found in the kitchen, sanitary fittings and appliances, and (4) installation determined by the layout. (1992: 82)

By separating Support from Infill, a building may have larger capacity to adapted different functions and changes of needs through out the life span of the building. A building, particularly the element of Support can last longer than other buildings. It is especially significant for the sustainable development with understanding that long life structure can reduced the energy and resource consumptions for constructing new buildings, and reducing the waste output caused by demolishing of the old buildings. Among other significances, Habraken addressed that such building may reestablish the traditional relationship between building and people: “Dwelling is after all doing something; it is the sum of human actions within a certain framework, within the protective environment created by man…”(1972: P18 a)

Inspired by the conceptual division of Support and Infill in Habraken’s theory, there has been a great deal of work done, focusing on Infill development and experiments in the Open Building movement (Kendall and Teicher 2000). There is relatively less development and less understanding on the subject of Support, with the exception of a few studies on pre-fabrication technology. In contrast, Baumschlager Eberle (BE) work intensively and exclusively on the issue of Support, whist leaving the issue of Infill, as a technique, almost untouched: “Since I don’t know the actual floor plans of any building I have designed, my interest is in the staircase, and the common space.” These two opposing, strategic directions – Infill development and Support development not surprisingly, are based on the same understanding of the diverse and changing needs and circumstances of our world today. Both recognize that it is the responsibility of the architectural profession to take this diversity and change into consideration. (Jia 2007:9-10)

BE architects focus strongly on the issue of Support, whereas Open Building research focuses on the issue of Infill. This fact may suggest that whilst the architectural practice and research in Open Building appear to be proceeding in differing directions, they remain complementary to each other. It also suggests that the research sphere in respect of Open Building can be widened to include Support, or the base building.

2. BASE BUILDING QUALITIES

2.1 The quality of form

Base building is a form connecting urban and/or planning quality at one hand, and architecture on the other. While Habraken addressed the urban quality of the base building, similar to the streets, plot for constructions, Kendall and Teicher tend to demonstrate the architectural quality of the base building: “a Support is not a mere skeleton. It is not neutral, but is rather enabling architecture” (2000:34). Habraken in his early book “Support: an alternative way to mass housing” suggest that a base building may look like an infrastructure, because the design approach these structures will not via their forms but via their function. Kendall and Teicher argues that the Support is dominated by the local market, architectural styles, climate, building codes and land use rules, investment requirements and other local conditions. “Thus, within its specific social and technical setting, the Support is built using locally appropriate means of design and construction.” (Kendall and Teicher 2000: 34). The building facade, which normally considered as part of the Support in at least Western culture, “reflects cultural conventions (having to do with displays of territory, identity and control) and enclosure integrity” (Kendall and Teicher 2000: 187)

As a base building is to support diversity of functions and events changing in time, the form of the base building is not determined by particular function. It does not mean a base building should not have a particular identity. The quality of the base building has a close relationship with the particular social, cultural and technological background of the specific area in which a building is situated. (Fig.1a) The particularity of form of a base building is still important.

Permanency

“In the first place, there is the fact that support structures will have a very long existence.”(Habraken 1972.84) They provide building ground up in the air, and are permanent like streets. Kendall and Teicher also say that Supports can be constructed in any durable capacity to satisfy diverse and changing demands throughout their useful life. (2000 p. 32)

The permanency of based building should not be confused with traditional architectural conceptions, which depict a building a monumental rather than a changing process. A building constructed with division of support and infill changes faster than traditional building. It is comparatively “short life”, because the continuous adaptation to the changing of needs and interaction with people make the building appear as temporary phenomenon. It is only the Support, not the Infill, remains stable and are expected to last as long as possible.

Adaptability

A base building is built in the knowledge that we cannot predict what is going to happen to it. The more variety can assume in the support structure, the better. (Habraken 1972.61) Therefore a base building design is not a load-bearing structure skeleton design. The skeleton is entirely tied to the single architectural project, and single predetermined functional scheme of a building. While a base building is largely designed for variety of uses and changes. The capacity of adaptation to undetermined programs is the key dominating the quality of design. “The most important thing in this respect is that the support dwelling offers an endless range of possibilities….a dwelling is no motor car and no dwelling need be the same as any other. The motor car allows us perform a single act: we move from place to place. But a dwelling contains at least one whole life. (Habraken 1972:65)

Simplicity

From and construction of a base building must be of the utmost simplicity (Habraken 1972:62). Habraken suggested a most primitive base building structure with parallel planes running one above the other and carried on columns. A simple and consistent structure is stronger. A neutral form is more adaptable than a specified one. An economic consideration also requests simple structure. (Fig.1b) In contrast to completed buildings, a base building “should not have the complicated detailing, nor the precise finish, nor the short-term existence of the factory product”.

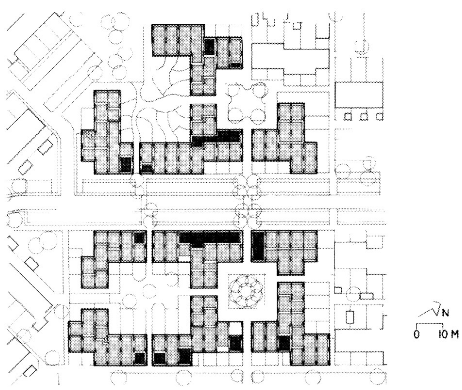
The quality of the public space

In contrast to the infill elements which largely controlled by the individuals, the base building is in public domain with a quality that architectural design plays important role. In a building complex, the public space may include the in-between out door space, staircase, entrance of building, corridors, etc, and the sequence of all these spaces. (Fig. 1 c) As the quality these spaces may attach to particular context, there is not much writing from the researches in Open Building. However, Habraken did remind that the location of these spaces should not undermined the capacity of private domain. He suggested that all vertical circulation should preferably be on the outside of the structure. (Fig. 1 d) The support structure will produce long ribbon-like forms. “If we try to achieve the greatest freedom of use, staircases and lift shafts would be obstacles when placed inside the structure.” (Habraken 1972:67)

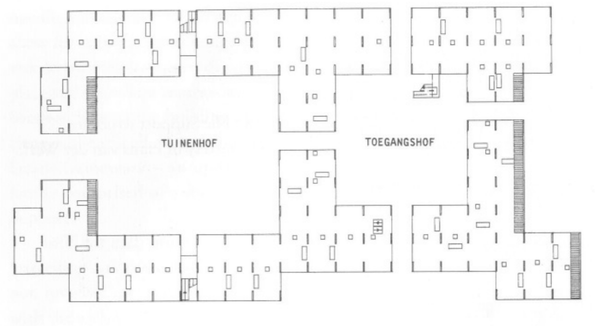
The quality of Mechanical system and Energy saving

In OB projects studied by Kendall and Teicher, the building mechanical systems are organized both on Support level and Infill level. The horizontal distribution of pipes and electricity are found more in the infill level. The vertical ducts are most likely in support level. (2000: 188) It is true, that they even pointed out that the dwelling unit heating and air conditioning equipment is not generally part of the Support (Kendall and 2000: 33).

a. The form of the base building showing local context and users’ input on the construction of the facade panels



c. Base building form the public spaces



c. Simple and continues parallel structure system separate from

d. Service systems, staircase and corridor structure

Figure 1. *Papendrecht in Holland, designed by Frans van der Werf, and Werkgroep KOKON in 1977, represented a typical early Open Building with design approaches related to the vision of Habraken (photos credited to S .Kendall)*

3. ANALYSIS ON THE BASE BUILDINGS DESIGNED BY BE

The Austria based company Baumschlager Eberle started by designing small, reasonably-priced, detached houses, in 1980s, and slowly developed a typology for mass housing developments with compact, flat–roofed buildings, with which the team distinguished themselves in Vorarlberg. Today, they are involved in the construction of many, large, multi-storied buildings, including, hospitals, office blocks and industrial buildings, schools, community centers, and shopping centers, throughout many European countries and now in China. Their buildings, especially mass housing projects, represent a clear and matured combination of two distinct systems with a high architectural quality, the base building and infill, which constructed in two phases.

3.1 The quality of form

Their architectural characteristics can be summarized as having a “strict economy with respect to material and artistic/architectonic means and a keen of cultural and social responsibility.” (Frampton 2003: 19) They paid strict attention to ensuring that highly skilled of craftsmanship was employed, in respect of the materials used and the quality of construction. Actually, their tectonic achievement deserves the highest recognition on a world-wide scale. (Frampton 2003: 19)

Their architectural characteristics can be summarized as having a “strict economy with respect to material and artistic/architectonic means and a keen of cultural and social responsibility.” (Frampton: 19) In their own words, they gained a wide knowledge of buildings, especially in respect of housing and they paid strict attention to ensuring that highly skilled of craftsmanship was employed, in respect of the materials used and the quality of construction. (Fig. 2a)

In respect of the urban site, that is already functioning well and contextually supplying an appropriate, useable vocabulary, then they see there is no point in creating something absolutely new. Their objective is to maintain the existing structures and to re-interpret them. However, in an open context, in which there are no suitable points of reference, a much more subtle set of instruments are employed to arrive at a viable solution. Through the careful comparison of all the residential buildings they designed in Vorarlberg, it was found that variations to compact floor plans, a typology used in many buildings, are simply the result of particular circumstances, ranging from the type of site, the clients, the users the objective and the function of the building.

3.2 Permanency

BE is also known for winning several important green architecture awards in Europe. . "What does sustainable architecture mean? … it is clear to me that design is not about creating new things, but rather about creating a building, which will last at least 200 years." (Dietmar Eberle, Lecture delivered at HKU on the 24th October: 2003)

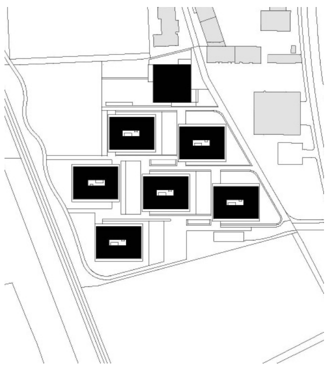
In order to achieve a sustainable building ('lasting at least 200 years,' to quote Eberle) with the efficiency of embodied energy, the building should be conceptually and technologically separated into five systems according to the life cycle of materials, the spatial and structural hierarchies, and social responsibility. This conception echoes Habraken's thinking on the separation of 'Support' and "Infill", although Eberle has never used the term, Open Building, per se. Life cycle is the key issue to separate systems (Table 1) Organize the building in such a way that we don't mix up these systems, changes are easy with a large flexibility when we integrate separate systems.

3.3 Adaptability

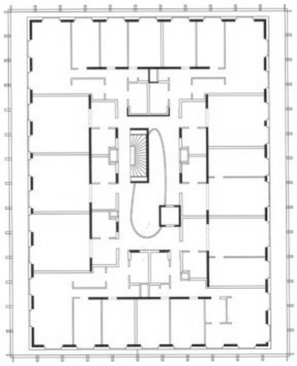
The concept of support in respect of the two architects already mentioned, includes the outer wall, the inner access (staircase, landing, and corridor) and the utilities (kitchen and bathroom) in a building structure.

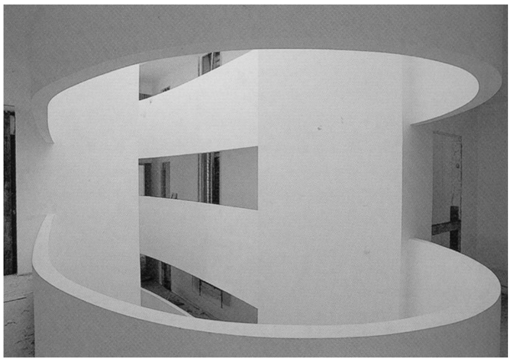
Basically there are two very simple built structures in the plan. In the middle of building there is a stairwell surrounded by closets and ancillary rooms. On the outer fringe there is a surrounding wall, which serves as structural as well as an enclosure. There are no divisions of rooms between these two structures. To omit or to add a room, all one has to do is to remove or insert a partition wall. This is a highly significant development in respect of ground-plan typologies: there is a fixed service zone and there is also the possibility of adapting the living area to individual requirements. Very diverse domestic arrangements can be realized in such an apartment. It is left entirely up to the individual to decide whether he or she wants to have any room at all, or a number of rooms of equal size.

a. Situated in a Austria Alpine context, the shading devise on the facade is constantly changing by the users pending on climate and needs of privacy.



c. Buildings were grouped carefully by making vistas and in between public spaces





b. Simple and double layer (outer wall and inner core) structure *e. Service, and staircase inside building as articulated public space*

Figure 2. *Lohbach housing in Austria, designed by Baumschlager Eberle in 1998 showing a typical high quality and low energy housing characterizing the design office*

3.4 Simplicity

Most of their projects are found in a simple compact form which successfully bringing ecology, economy, beauty and high craftsmanship into a whole. A compact form (Fig. 2b) is ecological and economical firstly because it has less façade. Less facade uses less material and it means it embodies less energy. Less façade and a compact form also mean better insulation, the loss of energy for heating can be minimized. The compact form provides a convenient solution to the problem of constructing many apartments, and permits an optimal ratio between the area of the internal space and the area of the façade.

The facade is neutral and independent from the functional diversity of the interior spaces. Structure layouts are simply repetitive with carefully articulated dimensions for in-between spaces consistently running through out all the plans and building blocks. A typological plan form consists of a service and vertical circulation core in the middle of the plan, a structure outer wall and a continuous open space in between, is implemented in many projects with adjustments to fit particular context.

3.5 The quality of the public space

Normally staircases with semi-public space had to be constructed in an extremely economical style, for very compact typologies. In Baumschlager and Eberle's work, this aspect receives particular attention. They saw it as an area of great potential for architects – that of substantially improving the inner zone of a building by creating an atmosphere that delineates the transition from the public to the private spheres. (Fig. 2 c)The staircase has a skylight and a small, enlarged, landing through which each apartment can be accessed. (Fig. 2d) With careful detailing of the space, choice of material, and type of construction, a simple economic social housing scheme, can be transformed into a sophisticated dwelling of greatly improved ambience.

These architects see the façade of a building as being of particular importance, since it is the structure, which provides the key to saving energy, the complicated inter-relationship between the exterior and the interior, the private and the public, as well as being responsible for creating the crucial syntactical enrichment of the public outdoor space. It is expensive to build, with high embodied energy, technically complicated and difficult to maintain. Therefore, it is treated as part of the support, which according to

Habraken, is designed by the architects according to the collective decision made by community. It is not an area where individual or private needs dominate. However, they also see that it is important and crucial for the users to be able to operate and be in control of part of the façade, i.e. to adjust the lighting, ventilation, shading, and views. Consequentially the outlook of the building changes according to the actions and the wishes of the buildings' occupants. In this sense the façade accommodates the most flexible elements in the building and changes constantly. A variety of technologies and materials have been applied, which have resulted in intensifying this flexibility.

3.6 The quality of Mechanical system and Energy saving

Because architects have to deal with the particularity of each project, they prefer to have a wider choice of technological solutions. They are interested in the integration of a technology, which has multiple possibilities. It may suggest that research carried out on a specific technology, or on a specific method of integrating that technology may have its implementation limitations. An instrument or tool for multiple purposes may be an alternative for Open Building research. (Jia 2007:14)

BE is also well known for its green building design. Although the energy saving effect is largely derived form the architectural design, new technology device are also implied and improved the comforts of living on the one hand, reduced the heating and cooling energy consumption on the other. The technical system used the heat stored by the people living in apartments, and utilities -which contain or release heat, thereby reducing the need for additional heating. Ventilation is regulated by mechanical means; the heat extracted from the exhausted air is used to heat the fresh, but cold air blown into the building. The system also contains heat "conductors" which can harness heat energy from the earth. It is also used to cool the air in summer. Whenever necessary, this basic heating system is augmented by conventional heating systems so that the desired room temperature is actually achieved. Using this system the level of energy consumption required for heating can be reduced by up to 70%. (Waechter-Böhm 2000:29) The Pop Moma in Beijing uses active ceilings for heating and cooling purposes as well as the controlled ventilation of the buildings are based on state-of-the-art technologies. In combination with a specially designed façade designed to enhance exposure to daylight. (Fig. 3)

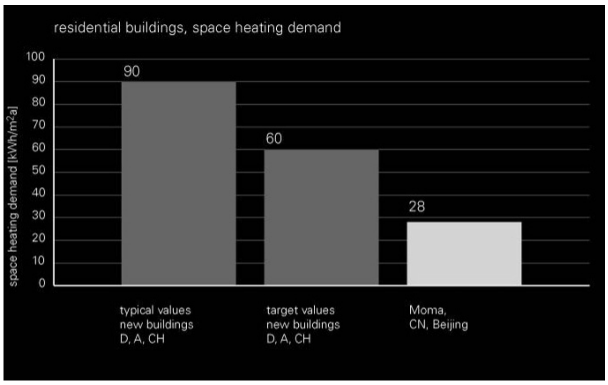


Fig.3 *The heating and cooling system based on earth heat, and performance of energy saving in Moma Beijing*

4. CONCLUDING: TOWARDS SKILLFULLY DESIGNED BASE BUILDINGS

Open Building is going to change the concept, techniques and methodology of architecture. Distinction of base building systems from the infill sets the significant departure from the traditional perception of building as scenographical monuments. The base building is the platform where varieties and changes and interaction with people in the life time of the building can take place. According to the theory of Open Building, the quality of base building includes, if not limited to, architectural and tectonic quality, permanency, adaptability, simplicity, public spaces, energy saving service systems. Among them the architectural and technical quality, and the design of the pubic space requires design skills partially borrowed from traditional architectural discipline. “As a result, it will become far easier for architects designing Supports to refocus on traditional; aspect of architectural; for and public space, on the building’s tectonic qualities, spatial experience, facade and definition of public space and urban character.” (Kendall and Teicher 2000: 191) However, the energy saving systems integrated with the buildings in both Support and Infill levels requires also new knowledge and skills to order to achieve a sustainable future. Baumschalger Eberle (BE) provided meaningful cases for further study.

Acknowledgement

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THE STRATEGIC ROLE OF INTERFACES BETWEEN LEVELS IN COMPLEX BUILDINGS DESIGN

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ABSTRACT

Looking back to the history of healthcare design we can find many different theories and methodologies that attempted to face, through design solutions and design process management, an increasing functional and technical complexity, as well as a demand for flexibility and innovation. The Open Building approach has demonstrated that it can provide very useful tools in this field (Kendall S. 2004). The concept of environmental levels has been successfully used to carry out an improvement in the realization processes and in the technological systems concept (Building Futures Institute. 2002). Some of the most remarkable practical applications concerned the management of project, tender, and construction phases, are focused mainly on relationships between base or support level and infill or fit out level. Both levels were exactly characterized by specific requirements and different flexibility degrees.

In this paper we will discuss the use of the basic principles of environmental levels in complex building project development. We think that a proper use of environmental levels principles can be useful in managing the complex and dynamic spatial systems of hospital buildings. We will especially argue that, in complex buildings, levels appear to be not so easily separable unless we define their interface conditions. Interfaces can be seen as new entities or physical spaces were it is possible to recognize and manage the main relationships between different levels and facilitate the understanding of transitions for all kind users and designers. The assumptions will be supported by a summarized analysis of two case studies in our national context.

Keywords: Complex Systems, Levels, Interface, Hospitals, Refurbishment

INTRODUCTION

All buildings are constantly increasing their complexity and there is no doubt that modern hospitals are highly complex buildings. More than in any other kind of building, in hospitals we have to face many spatial and technical entanglements with many different users and professionals involved. Hospitals need to evolve and upgrade continuously, a fact that presents a high demand for flexible plan configurations and adjustable technical and spatial layouts. These issues lead to a constant search for new approaches and design methodologies that should be multidisciplinary, open, and dynamic to be more effective in managing policies, procedures, processes.

According to this aim, the Open Building strategy identifies, as one of the most important tools, the principle of Environmental Levels. It is based on the organization of the design, construction and management activities through a system of separate and independent decision-making levels and phases. A clear separation is considered one of the most important conditions to simplify the intelligibility, the concept, the realization and the managing of a complex building in which levels are often under the control of different parties each of which seeks maximum autonomy (Habraken, N. John. 1998).

But as we focus on complex systems, we can observe that, sometimes, the interactions between levels brings about a number of relationships, functions, requirements, connections not easily definable as a simple separation or communication entity (the gate).

The borders of each Level or territory tend to be osmotic and spread out a multitude of new issues and requirements that don’t belong just to one or another level.

They often assume their own spatial and functional character and complexity as a filter zone, a checking point, a boundary area, a reception or a service building, a communication node or a terminal. These places of interface become the scene where users, professionals and stakeholders, who are dominant in two or more distinct levels, negotiate and participate. So in a collaborative or in a distributed design approach the places of interface are a core problem for improving communication tools among many professionals such as the architect, the structural engineer, the clinicians etc.

So, in complex buildings, the interface assumes a strategic role to avoid entanglements between levels and to save their mutual independence and autonomy.

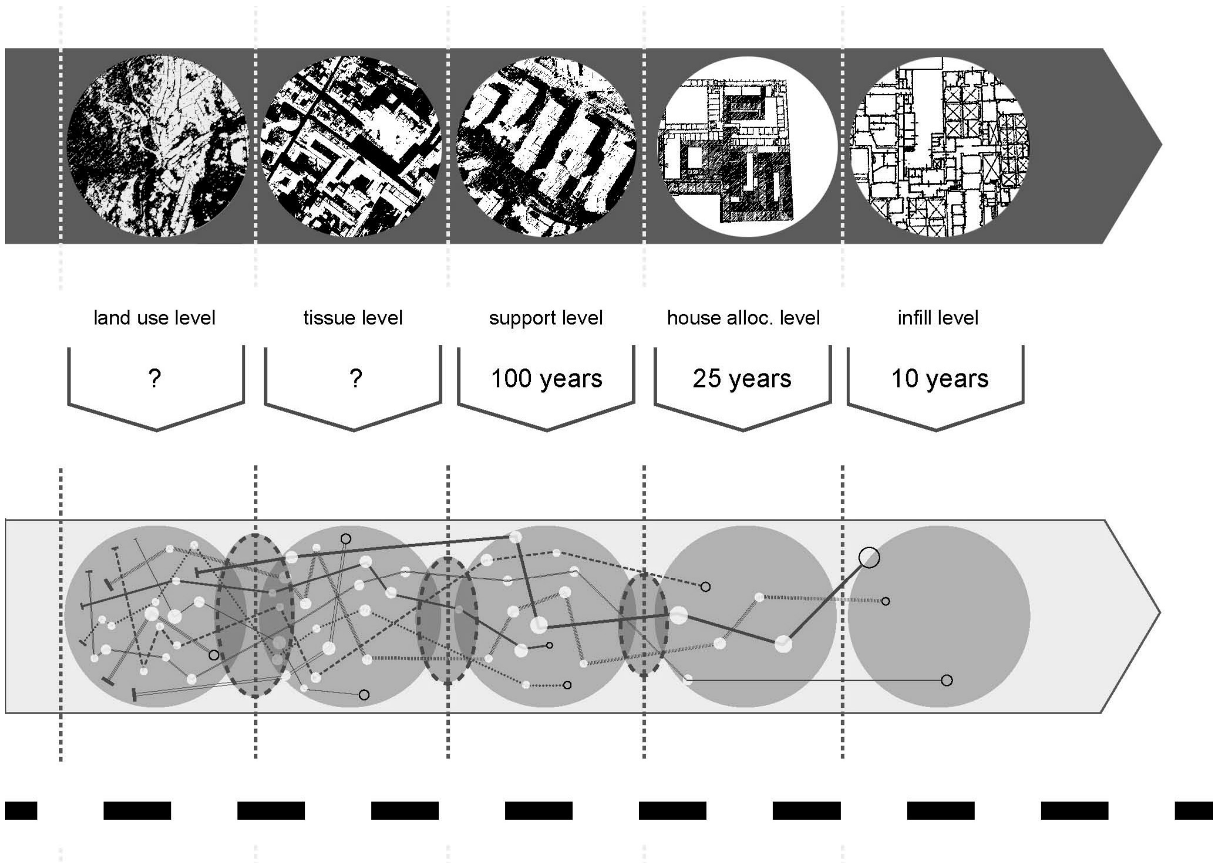

Figure 1: *A scheme of flows and interfaces (below) compared with an open building levels diagram (from the Principle of Environmental Levels from Kendall Open Building Concept CIB W 104 2004-2006). Red ellipses between the circles of levels represent the increasing complexity of interface; the red arrows represent the multitude of flows which go through the levels oriented and organized by many specific kinds of switches and devices (white points)*

THE INTERFACE PLACES IN HEALTHCARE BUILDING TYPOLOGIES

The principle of environmental levels and their interfaces can be used for a review of the traditional approach to hospital typological models. We can try to re-interpret many different hospital layouts or configurations as a) separate block models, b) aggregate models or c) the "box in box" models (Torricelli M.C. 2005). The ability to meet changing has been a first consideration in hospital design from the middle of the 20^{th} century (Llewelyn Davies R., 1960). But levels and interfaces can be new useful tools to interpret and manage with more effectiveness aspects such as flexibility, continuous changes, and the intelligibility of spatial configurations. Thus, we see the strategic role of interface as we defined above. This could be better explained by seeing how contemporary hospitals, according to the most recent tendency, shape their relationships with the urban level. We have two independent systems with a border and different rules, but all transition points, that were at the beginning only gates and check points, are increasingly becoming a miscellaneous of intermediate spaces with a number of functions, services and facilities which involve a number of different activities and users. All these -both urban and hospital spaces- can be considered as complex built interfaces.

THE APPLICATION OF ENVIRONMENTAL LEVELS IN THE HEALTHCARE BUILDINGS REGURBISHMENT PROCESSES

When we look for the application of the levels concept in residential buildings we can find interesting and successful examples in many places worldwide (Kendall, S, Teicher, J. 1999). We also see that application of the levels principles can reach an outstanding efficacy in new healthcare building processes as in the INO hospital in Bern case. So the question is if it's possible to use the principle of levels and interfaces to manage and improve the renewal processes of existing healthcare buildings. And in this case which issues seems to be more useful or need to be further investigated? As a first attempt we thought that it was necessary to interpret, through the lens of these two basic principles, one or more existing healthcare building in our specific context.

TWO STUDY CASES IN FLORENCE: THE HOSPITAL OF SANTA MARIA NUOVA AND THE HEALTHCARE DISTRICT OF CAREGGI

In Florence we have a polycentric healthcare system. It is composed by four hospitals. Two of them (S. Giovanni di Dio e "Ponte a Niccheri") are more recent (built between 60' and 80') and are situated on the periphery of the city. The main healthcare district of the city is located in the area of Careggi in the northern part Florence, with many different buildings grown around a block plan since the beginning of the 20th century (Marzi L., Iadanza E., 2005),.

S. Maria Nuova is one the oldest hospitals in Florence, built in the 13th century. It is the only one remaining in the inner part of the city (Centro di Documentazione per la Storia dell'Assistenza e della Sanità Fiorentina, 2002).

The two "historical hospitals" grew during the years in a chaotic way, without a masterplan but mainly according to needs and preferences that arose at different times.

An extensive program of rehabilitation started at the beginning of 2000, based on a mid and long term perspective for these last two healthcare building.

For our purposes Careggi and Santa Maria Nuova can be considered as significant examples.

They are complex healthcare buildings; they require different programs of intervention and methodology; they are historical buildings, though in a different way and at a different dimension; they show two different kinds of relationships and entanglements with the urban surroundings (one is positioned in the historical city while the other is in a peripheral area); they are both subject to an articulate, long lasting and complex refurbishment process; they must change continuously their configuration during the construction phases; the position of many functions; the principal and secondary paths and flows, etc.

READING THE INTERFACE BETWEEN TISSUE AND SUPPORT LEVEL

As a first step of our analysis we have attempted to compare the basic separation between the tissue and the support level in both cases. In figure 1 the hospital area is emphasized and around its boundaries we find many different kind of spaces that are of public use while they are undoubtedly to be considered as a part of the hospital area. Squares, services, gates, shops, cafeterias, loggias, museums, belong to the tissue of the town (under the control of the municipal planners) but at the same time they are an important part of the hospital system. Access and check points, bus stops, parking, sign systems, info-points, receptions lead and organize a multitude of flows (users, emergency, clinicals, and logistics vehicles).

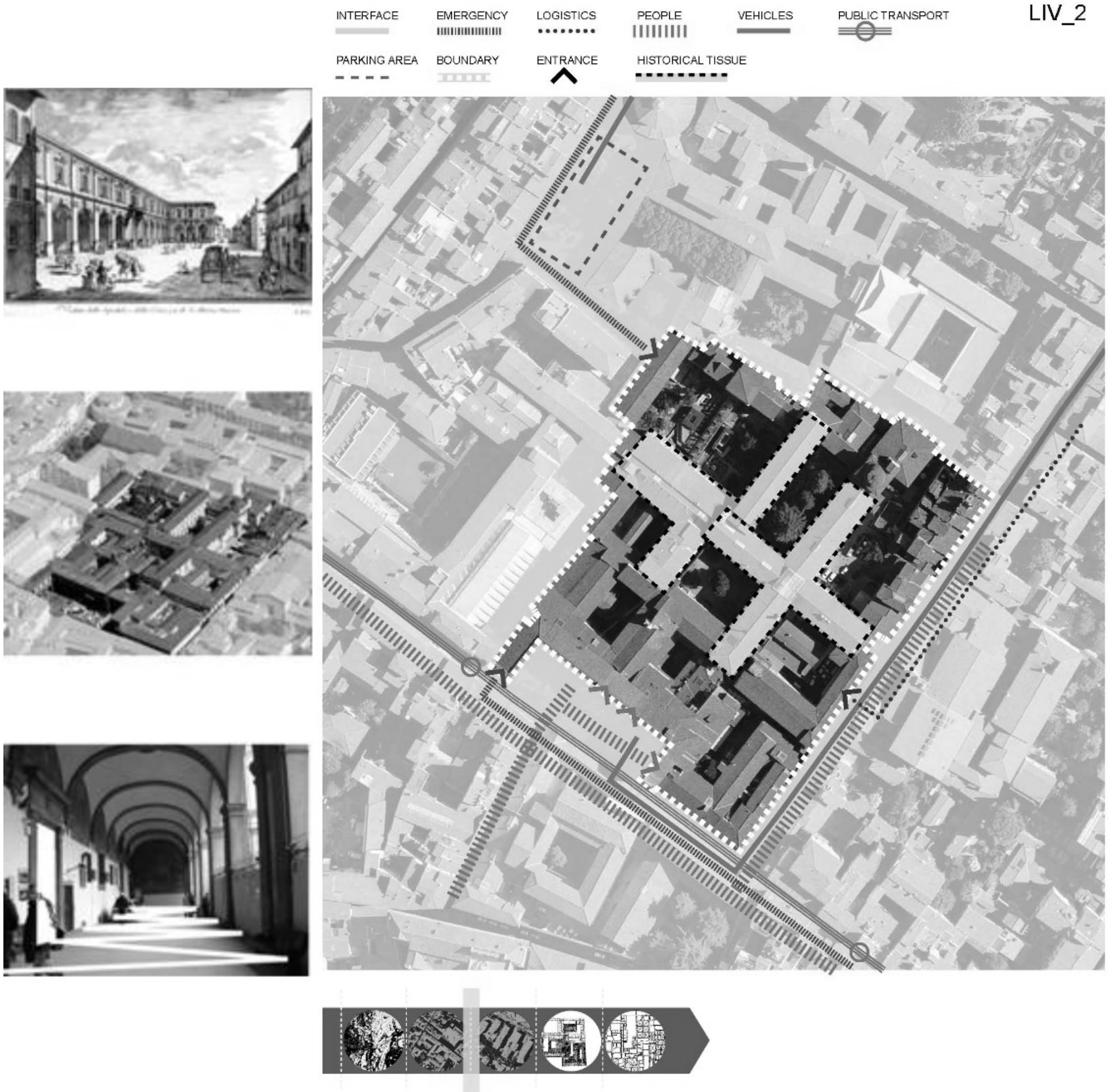

Figure 2 The *Santa Maria Nuova hospital site, its boundaries and main flows. Left: the hospital area and the Ammannati's loggia*

All the elements above mentioned define a complex interface between the tissue and the support level. In these areas the levels tend to become interdependent, not only spatially, but also for control of planning and regulations. Hospital plans the access of users, the different controls applied to different way to enter the hospital, the different degrees of emergency or the way in which entries are programmed. Municipality plans the transport system to the hospital, parking and no parking area, thoroughfare and no thoroughfare area, control of impact of the city in relation to the hospital and vice versa, regulations about conservation or transformation of the urban tissue, etc. Others bodies are competent for planning actions at the interface between the hospital support and the tissue level as for example the fire authority, the civil protection. This intermingling becomes more evident in the healthcare area of Careggi which is organized on a large-scale grid of streets that brings together a series of blocks. The boundaries are here much more extended with many new functions and uses on the margins. If we consider only question of the main entrance to the hospital complex (a fundamental point of interface) we can observe how it has evolved from a simple gate system (with a very few services) to a complex building were flows are concentrated and addressed to many specific paths and were we find miscellaneous public, urban and hospital functions: shops, transport terminals, parking, covered squares, public gardens, as well as hospital administration, reception, info points, teaching, research, etc. The question arises about the definition of these spaces as an urban place or a healthcare place, a tissue level or a support level. We think that in a large scale it could be better defined as a complex interface between both levels, under the control of different parties, who must continuously negotiate and agree on the requirements of interfaces.

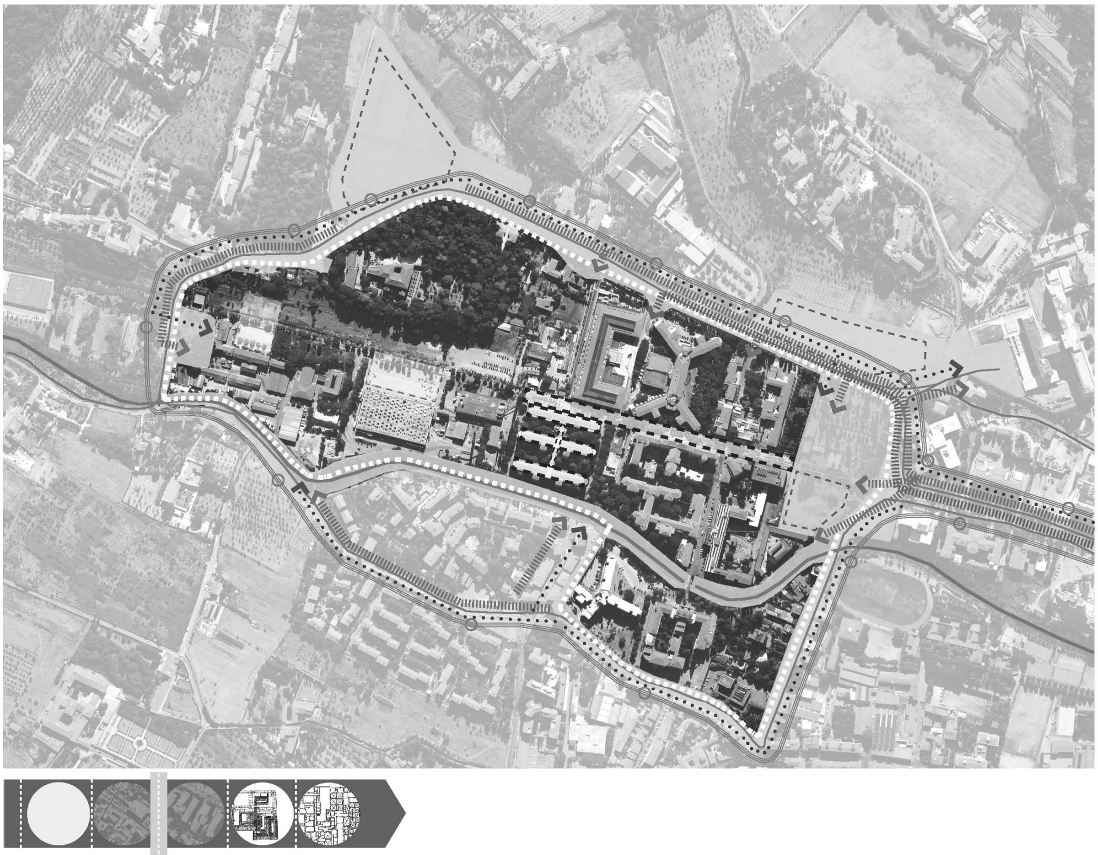

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***Figure 3 The** Careggi area and its interface with the urban tissue*

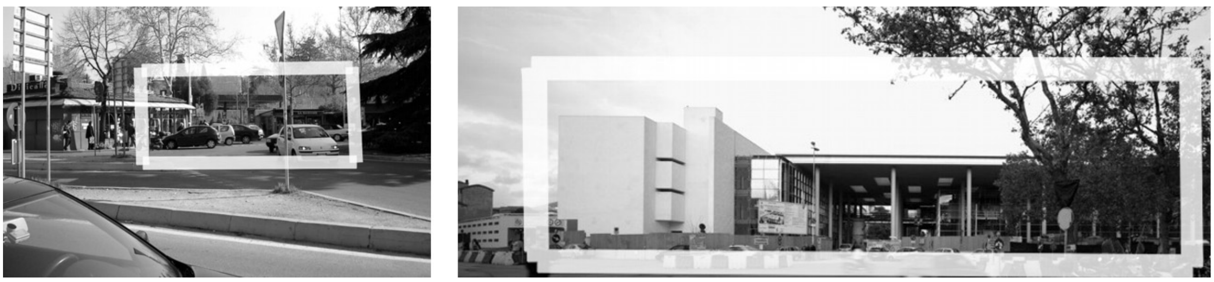

***Figure 4 the** old main access to the Careggi hospital (left) and the new multifunctional building under construction (right)*

READING THE INTERFACE BETWEEN TISSUE, SUPPORT AND FUNCTIONAL ALLOCATION LEVELS

Focusing to the relationships between tissue, support and functions allocation levels, some aspects needs to be enhanced. The interface between these levels is characterized by an incrementally increasing number of different flows which must be regulated and oriented from one level to another.

Figure 6 *The Santa Maria Nuova Crosses and the cloisters can be seen as interface rules between functions allocation and support. Left: two corridors around the main cloisters with their orientation devices and a new addition in a courtyard.*

The spatial configurations must be intelligible in the flows from the tissue level to the support and the functional allocation level. It needs strong traces and well articulated architectural elements.

In existing and historical buildings we can recognize them through the many changes occurring during the buildings life. In the Santa Maria Nuova Hospital, two crosses (see figure number one and four) are easily recognizable in the plan configuration. They are the ancient nucleus of Santa Maria Nuova and they remain intact despite many transformations.

In Careggi the path system is determined by the 20th century grid of streets, which depart orthogonally from a central axis and are even more easily recognizable. The grid of Careggi - as the crosses and cloister sequence of SMN - can be considered the permanent spatial order that allows the intelligibility of the space and the regulation of interfaces between levels during the hospital's transformations.

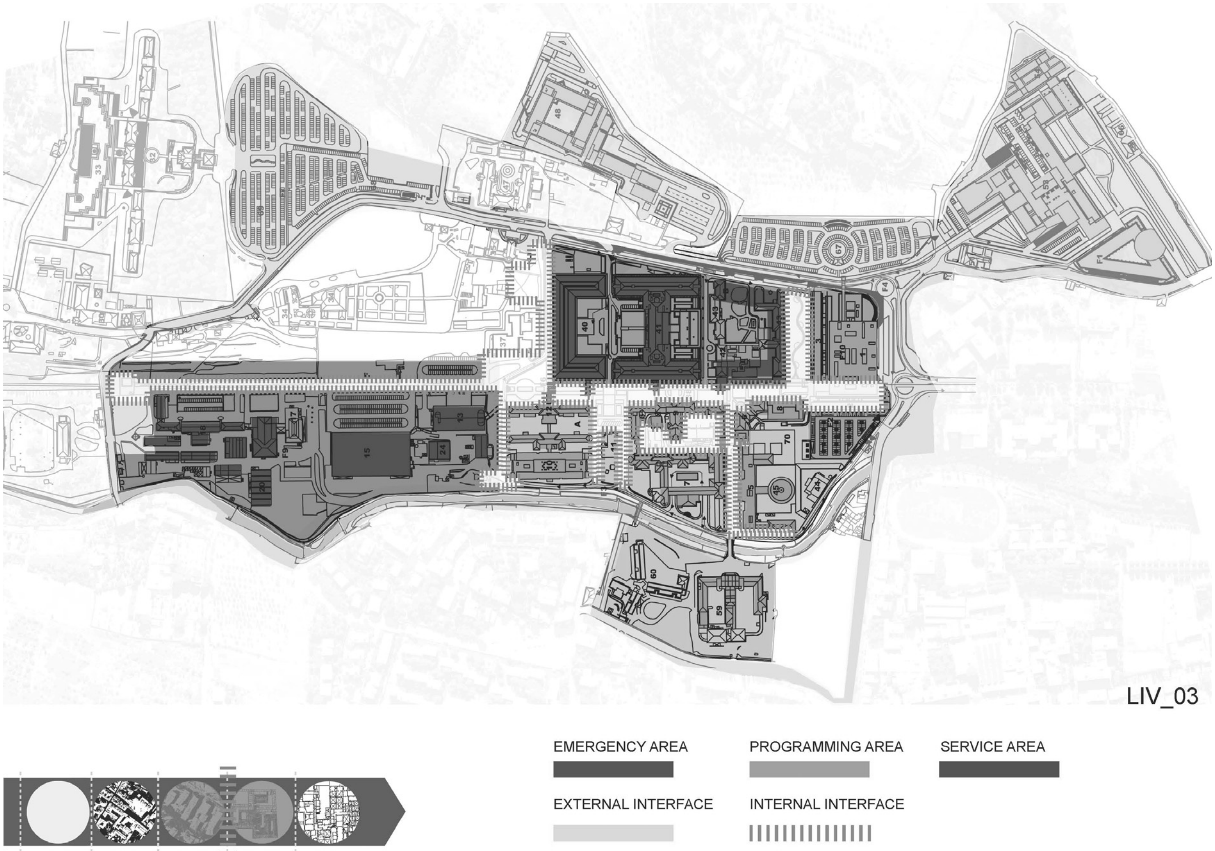

***Figure 7** The Careggi hospital renewal program and the interfaces between the specialized zones*

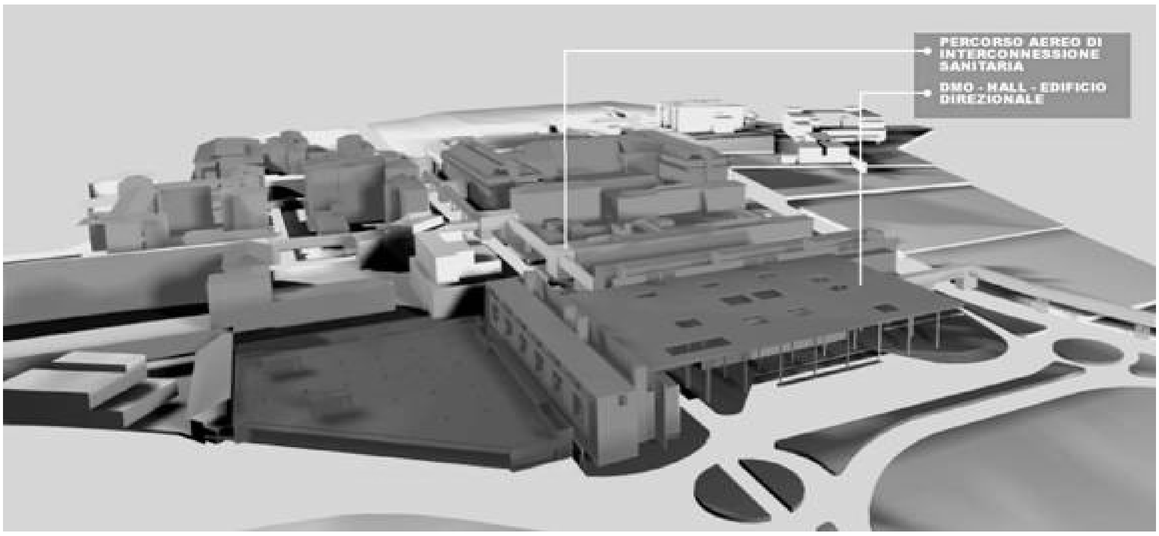

***figure 8** The Careggi the new" entrance door" and the new aerial path which interconnects the blocks*

CONCLUSION

The application of the theory of levels to the rehabilitation of existing complex buildings shows that the role of interface adds another dimension to the management, technological and functional aspect advanced by the theory of environmental levels. The concept of interface is the key to understanding the organic system of rules which regulate, throughout different levels, a multitude of strategic aspects. These include the shaping of spatial and plan transformations in a continuous changing scenario, the organization of the multitasking and interdisciplinary decision making activities in the design processes, and the severe problems in managing the use of spaces and maintaining their intelligibility while they continue to evolve and adjust.

About the latter issue, if we aim to save functionality while buildings are changing and adapting to new plan configurations, it seems to be obvious that we need to recognize and enhance some spaces and some primary plan signs. We saw that some elements in building layouts can be read throughout all the changes occurring during their history. They are strong traces and guide posts for orientation and path organization during the development of the construction and re-organization phases.

The capacity of complex buildings in saving their functionality during interventions and continuous changing, and the related possibilities to adjust flexible and variable configurations depends on a clear intelligibility of levels. We have many flows in a complex building.

Flows go through different levels. The architectural and spatial signs, routed on common language rules, facilitate the interpretation of space by the users, the sharing of decisions by the private and public administrations, the cooperation in control by the hospital and the municipality. These rules can be derived, in the built environment, by the permanence of signs consolidated in the urban tissue and in the configuration of spaces at different levels. These signs are for examples the main routes, the area to stay (loggia, cloisters).

ISSUES FOR O.B. THEORY IMPLEMENTATION

The application of levels to complex building refurbishment actions can follow the Open Building logical scheme. We should identify levels with the aim of reaching flexibility, variability, interaction between a multitude of professionals and distribution of control. But this can be done with more efficacy if we implement the methodological and theoretical tools that are useful to manage the problems of interface between levels. For instance, the use of levels in existing and historic buildings cannot be done only on functional, technical, operational and control and decision management basis but it needs additional criteria which are related to how spatial configuration sign are perceived at every level. The solution and the project of the interface between these “signs” can be useful to facilitate all the transformations needed during the time. This could be done in every phase of the development of a project maintaining the intelligibility for users as well as giving an operational frame for the control of the decision making actions. These involve the architectural quality of some significant spaces that make the spatial configuration of a complex building intellegible in their paths, in their transformations, in their internal and external relationships.

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RECYCLING HOUSING PROJECTS, A SUSTAINABLE ALTERNATIVE

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ABSTRACT

This research studies one of the main problems facing European cities over the next decade: the obsolescence of housing projects. In Spain, that phenomenon refers to the social housing developments constructed by the Franco regime between 1957 (when the Ministry of Housing was founded) and 1975. There is a patent need to intervene and transform these parts of the city that house 60% of the population, and the small or large-scale projects already under way will become an increasingly important part of public investment.

This research project focuses on the development of operative tools to establish criteria for efficiency, not only in the financial area, but also in the social and environmental sense, with investments intended to renovate the existing city. It also helps to create opinion, offering information on the real possibilities of recycling housing projects and providing solutions that can reinforce housing policies from an experiential viewpoint. In order to carry out this project, we have established a coherent strategy that involves methods of analysis, diagnosis, communications and proposed interventions.

Over the two years that this project has been under way, with the participation of five Spanish universities and a German one, initiatives have multiplied and a working framework has been consolidated around the ambitious objective of transforming reality by accepting the determinants in order to make our cities into spaces that foster coexistence and favor a fairer society, assuring a better future to the thousands of people that live in these projects now considered obsolete.

Keywords: sustainable development; social housing; dwelling recycling; city marketing.

INTRODUCTION

THE CHALLENGE OF OUR CITIES

This project arose as part of a research network seeking to combine the initiative and efforts of different schools and institutions to address one of the main problems that European cities will face in the coming decade: the obsolescence of housing projects. In Spain, that phenomenon refers to the social housing projects constructed by the Franco regime between 1957 (when the Ministry of Housing was founded) and 1975.

There is an obvious need to intervene and transform these parts of the city—they house 60% of the population—and even though small or large-scale pilot projects have been under way for some time, this activity will definitely constitute an increasingly important part of public investment.

In light of this imminent reality, our research focuses on the development of operative tools for establishing **criteria of efficiency, not only in the financial area, but also in the social and environmental sense**, with investments intended to transform and rehabilitate existing housing projects.

A few years ago, in the midst of the housing boom, we began discussing the recycling of housing projects. At that time, we put a great deal of effort into trying to explain the need for an alternative to the irresponsible consumption of land. On the basis of fundamental questions of sustainability, we proposed recovery rather than demolition, thus avoiding the generation of tons of solid residues, taking advantage of extant infrastructures and solving problems of social integration.

Today, it is no longer necessary to convince anyone. The crisis has burst the real-estate bubble and it is increasingly clear that the environment cannot forgive the abuse it has suffered.

Acting on the existing city has become a priority, as official data shows. This year, the “E Plan” budgeted 10,188 million Euros for 470,000 rehabilitation projects. That is more that a third of the total public-works budget of 19,404 million Euros, but we should remember that this is partially due to the considerable workforce required for rehabilitation work. That investment is expected to increase by 75% next year. So the goal is no longer to raise awareness or convince the decision makers. Now we must find the best way to carry out the work itself.

RECYCLING VERSUS REHABILITATION

Recycling housing projects constitutes a radically new approach that is much more ambitious and demanding than conventional rehabilitation. Recycling involves beginning a new cycle of life on the basis of the old one rather than simply patching up immediate problems or partial and superficial aspects. Recycling is the opposite of embalming what is already dead, which would be tantamount to prolonging at any cost situations that have become untenable, either because of the degree of construction-structural decay, or due to an unacceptable initial layout.

Given the gravity and complexity of the situations those housing projects are now facing, as well as the results of urban development in recent decades, it is only possible to propose **a new manner of acting on the city**—a manner that fosters cultural renewal. We must opt for innovative values involving **creativity** and a global perspective that make it possible to work in a coordinated way at all scales. This is the only means of achieving sustainability in the broadest sense of the word, that is: environmental, financial and social sustainability.

Doing so calls for the creation of new rules of action and the development of **new management models** with the cooperation of involved parties in order to insure the viability of the recycling projects. Fundamental in this process is recognition of the fact that **we are not beginning with a utopia, but rather with a crisis situation** that calls for a combination of the following elements:

-Political support that favors and fosters research and intervention programs. Institutions are already aware of the gravity of the problem and are therefore positively inclined towards the search for solutions and cooperation. Possible proposals could include the introduction of new management formulae, modifications of social-housing regulations to meet the new needs of the citizenry, and a revision of land and housing legislation.

-Private capital investment, because the current situation, in which the burden of recovering and rehabilitating this urban fabric falls almost exclusively on the public administrations, is unsustainable. A free alternative must be put forth. Experience has shown that acting exclusively on social housing impedes neighborhoods from fully developing. If we want to help eliminate ghettos, there must be something to attract private capital. Achieving this calls for the fostering of adequate conditions and fluid dialog. A study of the **Density/Intensity** equation will help to reduce costs in times of crisis.

-**Citizen participation** is crucial to the success of the operation. The exclusive market-state combination is detrimental to sociability. Account must be taken of the users themselves, as they are the true protagonists, and are frequently responsible for these housing projects' transformation processes. Reality is the only starting point that will allow circumstances to be improved, but there must be an awareness of identity and recognition of the specificity and values of each place. Only the application of the principle of subsidiarity will make it possible to eliminate the paternalist welfare support that has already proved inadequate. Strategies of **City marketing** are being developed and analyzed to destroy prejudice, introduce culture and bring out the wealth of difference that comes with globalization and, through immigration, the effective elimination of borders.

INTERACTING SCALES

The recycling of housing projects addresses their complete development, involving coordinated action at different scales structured around **a contemporary and sustainable interpretation of the culture of inhabiting**. This points to:

- **New models of urban planning** that strengthen interior growth with attention to the zoning of public space and the implementation of infrastructures and equipment. Support for qualitative growth rather than the unsustainable consumption of territory that characterizes recent urban growth.

The systematic degradation of these housing projects' physical surroundings calls for new architectural answers and new urban development, including a reconsideration of applied urban categories and a study of the networks of public, rehabilitated or inserted spaces that affect systems of relation. Zoning failures must be recognized and conditioning factors accepted in a realistic and positive manner, along with the peculiarities and identities of each housing project as a part of the city.

This innovative approach, without which recycling would not be feasible, is an ambitious challenge that necessarily implies a planning model capable of overcoming the linear and two-dimensional planning approach of past decades with new transverse strategies of sustainability, innovation, cultural renewal and social cohesion. This new concept of urban planning is already under development and it involves new urban management that introduces the key concept of tri-dimensionality, architectural quality and the economics of creativity while studying a regressive redistribution of urban space.

- **New housing models** capable of responding to the needs of citizens and aware of social evolution, accessibility requirements and the flexibility needed to guarantee spatial quality and the implications of intensive use.

The house is a space in transition, due, in part, to the reality of outsourcing, an expanding phenomenon that must be taken into account in social housing. Making professional work possible at home, in a single flexible space, is a challenge that must be faced in this 21st century. There is need for quality homes that combine spaces for intimacy with those for shared living; spaces that are qualitatively generous, with varied and redefinable spaces that are optimal for their users. Inasmuch as the true protagonists of the spaces we design are not architects, but rather their inhabitants, there is need for a revision of housing codes.

- **New construction models** that address the challenge of sustainability. The obsolescence of these housing projects is most noticeable in their technical aspects. The pressing challenge of zero consumption and zero emissions implies the need for serious research into new installations with adequate transformation technologies and systems. Recycling as an alternative to replacement responds to the grave environmental effect of massive residue associated with the demolition and subsequent reconstruction of these large housing projects, most of which have concrete structures. Environmental costs must be analyzed in order to redefine society's habits. Rehabilitation not only avoids the generation of solid residues and rubble; it also reduces the generation of CO2 in new structures by 70%.

Innovation begins with the breaking of habits and our sector cannot operate on the basis of pure opportunity, as if it had no social responsibility whatsoever. The current situation is largely due to the fact that, for years, construction has functioned exclusively as an economic mechanism used by other markets as a source of finance. It is necessary to reconstruct, rehabilitate and recycle the economic structures that support the sector in which we work.

A COHERENT STRATEGIC OUTLOOK

Given these situations, which emerge today like the tips of icebergs, our challenge is **to define a coherent strategic outlook** capable of launching a new life cycle based on the existing one, accepting the determinants without renouncing excellence and working to achieve a quality future for our cities.

I. Analysis. Analytical methodology

The first step in this process is to get to know the state of the question—what economists call visual awakening, exploration and field work. Working on previous construction demands precise knowledge of the situation in which action is being taken, and acceptance of the contemporary city as a complex reality to which generic solutions cannot be applied. It is therefore necessary to establish methodologies for analysis and for the evaluation of results in order to tailor interventions to each case, taking into account the particular problems presented by each of these highly varied housing projects. Rigorous analysis is a sine qua non to avoid generalizations and prejudices and successfully carry out a project.

What is needed is a study with an all-encompassing view that considers the diversity of scales and factors involved in the process and makes it possible to determine priorities and support the necessary intervention in each case. This calls for an interpretation of data that uses obsolescence indicators not only to study weaknesses but also, and most importantly, to identify strengths on which to base the urban recovery strategy's multiple facets in order to meet the proposed goals.

The actual property must be studied to gain the fullest and most complete knowledge possible of the housing project to be recycled. And here we should emphasize the need to respond to real problems and real situations, as this requires an analysis not only of the material elements but also of human and non-human relations, all within our shared environment, that is, the ecology. Our intervention will only succeed if we are willing to accept reality’s more disagreeable aspects, to bury the fantasy of science-fiction utopias from the 1960s, and to accept the complexity of the contemporary city.

For our detailed analysis, we must use the multiple tools and material available to us. The most valuable information about both the technical aspects and the concrete circumstances of a housing project’s construction appear in its original building plans, but that information must be verified and contrasted with the reality through field work.

In order to know the socio-demographic conditions, we can draw on the valuable information provided by the National Statistics Institute, which allows us access to a considerable amount of data and offers tools for drawing up personalized tables and cross-referencing data according to the users’ needs.

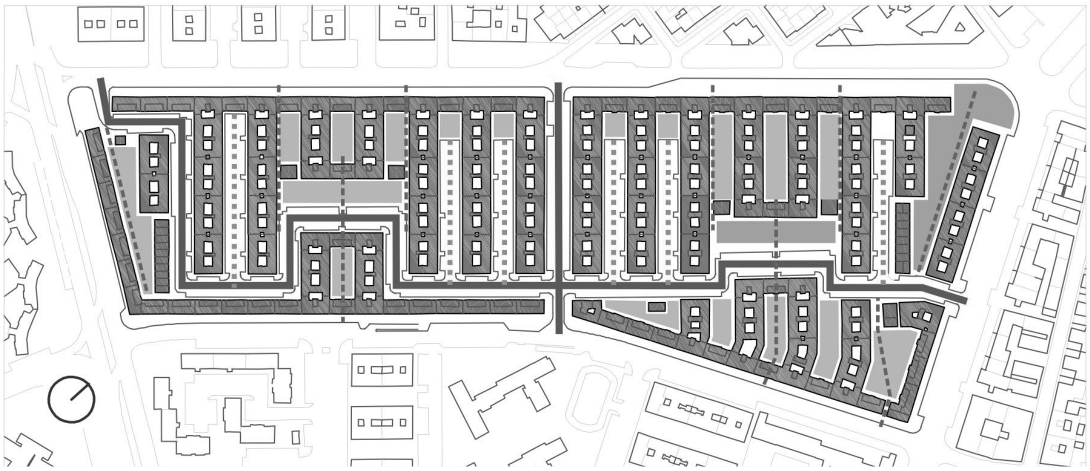
Other sources of information include neighborhood associations and other local institutions with first-hand knowledge of the real situation and problems of the housing project, as well as the plans of previous interventions and associated studies.

Our analytical methodology focuses on the following aspects:

Identifying the housing projects and delimiting their extension on the basis of original building plans. Historical aspects and social and urban-planning origins.

Defining the historical and social context in which these housing projects originated, identifying the motives leading to their creation, the spatial geographic framework in which they were built and their original relations with the city, as well as the evolution of this relation over time. These aspects can help us to understand the motives leading to the housing project’s present social and physical situation.

Identifying the organisms that promoted each housing project, the conditions imposed on the project, the budgets assigned to it, and so on; as well as analyzing the historical urban-planning regulations relating to the housing project being studied.



Physical-spatial components: a study of urban morphology focusing on urban fabric, free spaces and green zones, communications infrastructure, other urban infrastructures and services, building, public equipment, commercial equipment and economic activity.

Architectural: detailed study of the different types of residential, equipment and housing structures. Analysis of extant housing and comparison with current standards of habitability. Knowledge of the building systems employed and evaluation of those systems’ flexibility in the face of modifications and reforms.

Socio-demographic analysis: a brief analysis of the neighborhood's social situation, a summary of socioeconomic indicators with an emphasis on those aspects that affect the use of housing and urban space. These considerations are fundamental because an important part of the situation and problems of these neighborhoods is often due to the systematic growth of inequalities that erode social cohesion and coexistence, with exclusion emerging as a primary aggravating factor.

The second step is **the interpretation of data** to determine indicators of obsolescence that help establish a criterion of investment efficiency (not only financial), a study that rigorously determines priorities and supports the need for intervention. The objective of this analysis, as mentioned above, is not just to study weaknesses. It is more important to identify strengths that will be key elements in the recovery. It is only possible to build on a positive basis.

If there is no consciousness-raising, there will be no possibility of receiving capital investment, nor favorable policies. Without diagnosis, without a clear determination of what is at hand and why the situation is as it is, it will be impossible to find solutions. Only a **precise diagnosis** that draws on clear and accurate knowledge of reality, avoiding architectural and social generalizations and prejudices, will make it possible to define solvent intervention strategies aimed at optimizing results. Therefore, given the magnitude of the investments that will be dedicated to interventions in these housing projects in the coming years, it is of maximum interest to define those indicators and criteria of intervention that can lead to concrete actions that precisely and rigorously resolve and minimize problems.

II. Communication

Often, technicians, artists and the scientific elite seem like poorly tuned televisions. We lack shared tools, links and vocabularies, and even worse, we lack skills for communicating with society and responding to its demands.1

Ideas emanate like shockwaves from research groups and diverse think tanks at universities and institutions. We transmit these ideas through conferences, exhibitions, publications and even documentaries, though the main conduit is the classroom involvement of professors and students committed to this research in various European architecture schools.

The objective of this project is therefore to establish adequate communication with society by combining the initiatives of different universities and institutions to generate a theory that lays the foundations for a change in the model of urban development in force in recent decades. A shared discourse must be generated—a global discourse that leads culture to favor innovative values based on sustainability and creativity at all scales of the city.

Excellence cannot be imposed, it can only be demonstrated, so that it convinces on its own. But for this to work, it will be necessary to break the inertia and prejudices and make the effort to achieve a collaboration that can only come of efficient dialog.

[1] C. Diaz Moreno y E. García Grinda. Breathable. p.9, ESAYA, Madrid, 2009.

III. Intervention

As a result of analysis and effective communication—sometimes both happen at once—concrete multidisciplinary and creative proposals can be developed. The complexity of our time obliges us to undertake this task and we will have to blaze new trails to do so. There are risks, and we must be bold enough to explore our respective parcels of the universe without fear of innovation, changing our routines and our inertia. We must learn the secrets of teamwork and put our faith and effort into interdisciplinary action.

Our interventions must be precise and rigorous in order to minimize problems. And more than ever before, invisibility will be a value.

These interventions will not focus on the materiality of objects—they must be understood as means and never as ends unto themselves (there is no room here for a star system)—but rather on the establishment of adequate relations among citizens. In these interventions, not all of which will be architectural, there has to be a place for invisible acts with a high capacity for transformation.

CONCLUSIONS

This research project rooted in the world of academia combines the initiatives of different schools and institutions to generate a theory the lays the foundations for a change in the model of urban development in force in recent decades. Through shared discourse, it seeks to weave a network of knowledge that can have a transformative function, leading culture to favor new values such as sustainability and creativity in order to guarantee a better future for our cities.

After two years of research, this project has established a solid framework with a multitude of initiatives and working areas intended to determine specific tools, methods and criticism for recycling housing projects.

Reflecting on the city not only helps to create opinion, it also generates information on the real possibility of recycling housing projects. It offers solutions that support housing policy from an experimental perspective, helping to transform reality by accepting its determining factors in order to make our cities into convivial spaces that favor a fairer society and insure a better future for the thousands of people who live in housing projects currently considered obsolete.

This is an ambitious goal, but as Marguerite Yourcenar put it: **we are all obliged, in the brief span of our lives, to choose between indefatigable hope and prudent hopelessness.**

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URBAN RECYCLING: AN APPROACH TO A SOCIAL DWELLING REFURBISHMENT SOFTWARE DESIGN

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ABSTRACT

In order to making it feasible to transform the already existing residential living urban tissues, intervention on three different levels is needed: legal regulations, industry and market. Actual regulations concerning social dwelling are conceived in terms of new buildings, an obsolete construction technology and a family model that does not reflect the enormous diversity that actual life standards demand. This happens to be detrimental to, and greatly limits, the accomodation of these suburban areas renovation processes to their real needs, as it forces intervention using the same projectual approaches as in new dwelling construction. This research article analyzes different experiences and interventions in the field of social dwelling, with the aim to identify procedures that have generated easier to adapt typologies, or where the strategy to sincronize projects with the inhabitants of the comunities' ways of life has proved to be more successful. Starting from these theoretical devices the investigation approaches the definition of “recycling programs” that, once installed within the social dwelling “hardware”, would update it to the new needs, with the interactive participation of inhabitants and technical advisors.

Keywords: social housing; multi-family dwelling; new life standards; flexibility; dwelling regulations

INTRODUCTION: The concept of 'recycling' applied to the built city.

The built city is a living organism in constant transformation. However, this artificial crust that people inhabit doesn’t have the capacity for self-regeneration that characterizes living beings. The consequence is the high presence in urban territory of obsolete structures that, having been abandoned or reused, coexist with the new ones. In the case of the residential fabric, this obsolescence occurs at a small scale: it is necessary to venture into it to discover its deterioration.

The city centre remains apparently intact, but what is often discovered after these balconies that once displayed colorful pots of geraniums, hanging clothes, and morning chatter, are uninhabited spaces: 15% of urban dwellings are in fact empty. The generic city and global environment, introduced through corporations and franchises, has shifted residential use into other areas of the city, occupying the old houses as if they were hermit crabs. In social dwelling neighbourhoods, we find a level of obsolescence only understandable considering its origin, under what circumstances and for what purpose they were built. Some of these neighborhoods that were built in the outskirts are nowadays within the city, which has enriched the opportunities of its inhabitants for participate in urban life. But, in many of these cases, the rehabilitation and 'self-recycling' processes have not been enough to avoid their degradation.

What do we mean when we speak of 'recycling' in a built environment? If we apply his more orthodox definition, we refer to the action of processing a used material in order to re-use it. The internal transformation of the historic center, as well as the systematic alteration of the residential buildings by their inhabitants (by installing antennas, external air conditioning units, closure of galleries, etc), are ways of ‘self-recycling’. We can read the disfunctions of an obsolete urban tissue in these processes.

NEW CHALLENGES FOR XXI CENTURY

The term 'globalization' refers to a level of achievement that implies a new organization worldwide. Marshall McLuhan, Canadian philosopher specialist in everyday life, first used the term 'global village' to describe a transnational environment created by technology that has produced a great impact on social behavior and structure of daily life throughout the planet. The new social space emerges and develops on a rhizomatic built territory, modifying its operational system, just as the software changes the usability of the hardware on which it is installed. Telephone, television, telecommunication networks, electronic cash, computer games, multimedia technologies and virtual reality, etc, supports that enable the interaction distance between people, digitally represented in the interfaces as numbers, usernames, profiles, contact or avatars.

Globalization 3.0

According to Thomas Friedman there have been three ‘globalization eras’ throughout History. By 2000 'Globalization 3.0' arose, and we are still immersed in it. It is characterized by the power of individuals to collaborate and compete in a worldwide basis. Today, any service is likely to be outsourced anywhere in the world to offer faster delivery and more efficient procedures. The same phenomenon occurs in an entrepreneurial key at urban scale, and its consequence is a decrease (and disappearance) of urban centers by combination of two factors: 1. business moving to the big shopping malls and business parks on the periphery, and 2. a progressive increase in online production networks, which leads many professionals to installing their office or working space close to, or within their homes. This fosters reconciliation between work and family life, while enriching the life of neighborhoods originally conceived as dormitory town by zoning derived Town Planning theories.

New environmental awareness

A second phenomenon that is called to characterize this first half of the century is the global change of attitude towards our environment, after centuries of industrialization and technology during which 'junk space' has grown exponentially while everyone unconsciously seemed to look away from the problem. While in Spain we eagerly await the emergence of a new "Sustainable Economy Act," we have the nearest example of France. "The Grenelle de l'Environment" is a debate launched on July 6th 2007 which brings together governmental representatives with various organizations at the national and local levels (industry, labor unions, professionals, NGOs), in order to unifying positions on echology and sustainable development, and fixing measures to be undertaken to ensure that all social and economic fields evolve in a synchronized way. In the field of construction industry and housing a goal has been set to establish low-energy standards in new constructions and to fix incentives for existing homes renovation and low carbon new building construction. This translates to an unprecedented investment in social housing HLM.

Intergenerational city

As Anne-Sophie Parent -Director of the European platform AGE- has said, "Society today is more focused on the individual than in the Community." We have evolved from a communication model based in relationships between communities and families, to a different one in which individuals directly interact. This fact, a consequence of lifestyle and communication preferences, tends to create a society of as many elementary particles -and therefore housing- as people, leaving the most vulnerable unprotected: those who can not fend for themselves. Associations such as AGE or Intergenerational Network defend the recreation of that feeling of belonging to a multi-generational community in which people learn from each other and support each other, to achieve a more cohesive society and a highly fulfilling development. The goal is the development towards an 'inter-generational' city model ('age-friendly city'), based on the following values:

- Promoting 'active aging', providing opportunities for older people to be useful to society.
- Accessible city, in which infrastructures and services are designed from the handicapped' point of view.
- Combine living spaces and those of the community, to promote participation activities and social inclusion.
- Encourage the generation of services that meet the needs of the community and bring health care closer to neighborhoods.

New family models

Nowadays in Spain an increasing heterogeneity of the urban inhabitant is being stated, due both to the mixing of different cultural influences, and to the diversification of household types. Statistics reveal a society very different from that of thirty years ago. Despite the stagnation of the population, the number of occupied dwellings increased, while the average area per household is reduced and the average people per household is decreasing, as the trend amongst couples between 25 and 35 is delaying offspring. In addition, late marriages often mean longer stays at the parental home, due to lack of response from the housing market. Some data collected from the INE (National Statistics Institute):

- Average age of first marriage: from 1975 to 2004 increases in 5 years to stand at 31.24 in males, 29.17 in women.
- Children born from unmarried women: increased from 2.03% in 1975 to 25.08% in 2004.
- Out of total households, 20% are sole proprietorships, 25% are made up of two people, 42% are of 3 to 4 people, and the remaining 13% are made up of 5 or more. (2001)

The housing market, encouraged by public advocacy pilot initiatives, begins to respond to the needs of groups that are not well suited to conventional programs in the public promotion of social housing, and begins to offer diverse housing solutions. We can now find initiatives that aim for mixed uses and mixed housing solutions, responding to diverse groups in order to avoiding overlapping and ghettoization.

Spain's social housing neighbourhoods status.

Spanish People have the right to enjoy decent and adequate housing. Public authorities shall promote the necessary conditions and establish appropriate standards to make this right effective, regulating land use in accordance with the general interest to prevent speculation.
Spanish Constitution. Article 47, Title 1.

The housing situation is closely linked to the property market, having been in recent years one of the main drivers of investment and wealth creation in Spain. The fact that social housing is understood as a market product has alienated the needs of the urban population and also generated social exclusion through mechanisms of real estate mobbing that on a larger scale generate gentrification processes in certain locations. This phenomenon occurs especially in historic centers, but can occur in outlying areas affected by speculative interests. The negative influence also comes from the sale and occupation of housing units in newly built neighborhoods, with uncomplete urbanization and scarce public institutions and facilities, a situation which -if prolonged in time due to lack of development- may become a marginalization factor.

The report "Urban Inequality in Spain" confirms the concentration of the most 'unequal' areas (with major deficiencies in terms of construction status, development degree, and presence of services and facilities) in the outer suburbs of cities. This inequality negatively affects the lives of the citizens living in the slums of social housing at multiple levels, both in terms of life standards and of development opportunities. The inhabitants of 'unequal' urban areas are concerned about the lack of effective evolution of the situation in their neighborhood, where housing image reflect the degree of urban degradation of the neighborhood – at an even greater extent than public space. According to the report "The population of the area of intervention of the Ministry of Public Works and Transport in Almanjáyar, Granada: is in the living conditions of households, despite the positive evolution of some indicators and the improvement of some others we will soon see, where marginalization and exclusion that affect people are better revealed.

Moreover, according to statistics presented in 2001 by the FUNCAS Foundation, unnocupied housing in Spain rose by 25.48% in the last decade, reaching 3.01 million units. Most of the empty flats, 41.2%, are found in the main Spanish cities and their metropolitan crowns, Barcelona and Madrid being the cities with the highest proportion of empty housing types in the national ranking. The statistics also indicate that 18.5% of empty dwellings of the Spanish stock is not in good condition, and calculates an average age of 38.7.

INTERVENTION STRATEGIES AT THE BARRIADAS

Demolitions: A solution to marginality?

Demolition operations have marked the history of social housing slums in major urban centers on the first world. The 1972 demolition of Pruitt-Egoe in St. Louis (Missouri), designed by architect Minoru Yamasaki and masterfully portrayed by Godfrey Reggio, marks the end of the Modern Movement, The failure of the intervention was asured since its conception, and the reason should be sought not in architecture -33 buildings of 11 floors that followed the canons of rationalism- as in other factors: a racial zoning strategy, low environmental quality in common spaces, no facilities and no public transport services, and general degradation due to its abandonment.

As François Chaslin recounts in his article "War in the suburbs", the first demolition of a social housing neighbourhood in Europe did not come until 1978 in a suburb of Villeurbanne, as a political response to episodes of urban violence in the ‘grands ensembles’, which have been growing since the late 60's to today. However, the so-called 'suburban evil' was predictable from the beginning: vast farmlands, often elongated, poorly equipped and poorly served by public transport, strangled with networks of roads, railways and power lines, bordered by vast stretches of cemeteries and industrial areas (...). But do not forget that it was in these residential tissues where the European architecture of the 70 and 80 found one of its most prolific sites of experimentation in collective housing. In the work of architects such as Emile Aillaud (Tours Nuages in Nanterre), and Renee Jean Renaudie Gailhoustet (The Maladrerie in Ivry-sur-Seine) Candilis, Josic & Woods (Toulouse le Mirail) or Alison & Peter Smithson (Robin Hood Gardens), we find living examples, many of them under threat of demolition, of an architecture that strives to offer its residents the ideal support to enable them to recover the habits neighborhood of small towns.

Social housing planification in Spain: renew vs rehabilitate

In Spain, we have been silent witnesses of the ‘renovation’ process of Fuencarral Absorption Villages A and B, designed by architects Francisco Javier Sáenz de Oíza and Alejandro de la Sota, by the Housing Institute of Madrid (IVIMA). A complete demolition and replacement by new buildings for collective housing was held in the village, following the ‘Decreto Ley 100/1986’, 22th octobre. The argument could have led to the demolitions could be the precarious origins of these villages, that were conceived as an urgent response to the need for thousands of immigrants in the 50s, who lived in shacks in the suburbs, and built in record time, with cheap materials and without basic public services. This process has inevitably involved the relocation of inhabitants and families in temporary housing to accommodate them again later in the new housing with new neighbors and other urban settings. This fact has irreversible consecuences to the delicate social networks built over decades, affecting the neighborhood identity, sense of belonging, and subjecting people to severe stress levels, especially to the groups of elders.

Demolition operations are nevertheless part of the recently approved plans strategies. In Spain, housing plans are focused on major issues such as access to housing, reducing energy demand or the revival of economy and housing market. In terms of investment and aid to rehabilitation, interventions involve issues such as heat sealing or accessibility, without promoting a deeper level of transformation. The new National

Housing Plan and Rehabilitation (PEVR) affects more than 1 million homes and declares the rehabilitation to be it's main strategy. The expected boost PEVR 'rehabilitation' and 'renewal' of 470,000 housing units included in ARIS (Comprehensive Rehabilitation Areas) and ARUS (Urban Renewal Areas) as well as promoting the conversion of free housing stock, nowadays frozen by the economic crisis, in social collective housing (VPO).

AN APPROACH TO A SOCIAL DWELLING RECYCLING DESIGN SOFTWARE

Introduction to the'software recycling' concept.

Never demolish, never subtract, but add, transform and use always.
Anne Lacaton & Jean-Philippe Vassal
If we consider built city as the 'hardware' and the mechanisms that allows, at different levels and scales, to upgrade it to the new needs, as its 'software', we could design recycling strategies as specific programs to 'install' at the dwellings in order to 'reset' them. Depending on their nature, we find different types of software: system software, programming or application, so as their periodical 'updates'. In this way, we might consider diverse 'software updates' applicable to collective social housing. We analyze two cases as examples: the need of flexibility and the improvement of energy efficiency.

Program 1: Strategies from citizen participation
Working with a community and not for the community.
(Antoni Muntadas)

A recycling operation is characterized by a need of a direct knowledge of the inhabitants, instead of being based on a simple approach through social reports or statistics. The dialogue and interaction with the users and the analysis and observation of their peculiarities and ways of life are a necessary part of the work methodology. The parameters for adapting the project to the real needs of transformation must be investigated in each case, and will be translated into mechanisms of action at the arquitectural project, which from now on call 'recycling mechanisms'. From this point of view, time devoted to meetings and work with neighbors is crucial, as it permits getting them involved in the process, which is a key to the success of the operation and subsequent maintenance of the building. Some the cases of participatory processes that have analyzed are:

1. A recycling project at the San Matías neighbourhood
(Juan Domingo Santos; Granada).

The performance shows a neighborhood interaction strategy based on the continuation of exchange mechanisms between neighbors inherent to the historical center of Granada. The architecture project proposed understands the invisible web woven by relations, verbal agreements and exchanges between neighbors which, consolidated over time, that have led to situations like 'engalabernos' or passages that cross the 'patio' of a neighbor to provide access to a different property. The architect describes the design process resulting from the participatory action this way: There are architectural interventions that (...) add interests outside its own problems, as if the sum of events may involve a contented way of life between the inhabitants, and in which architecture is the tool that serves to give a shape to the continuing agreements and disagreements.

2. A recycling project at the Polígono Sur (Surco Arquitectur; Sevilla).

Experience in the Integrated Rehabilitation Program of the Barriada Martinez Montanes (built in 1978). The ground floors had been infilled with pints built by the neieghbors themselves, that they used as storerooms. It was proposed to property and community to regain the ground floors, with the aim that they will be devoted to commercial use and generate activity into the street. However, the refusal was unanimous in the first meeting with neighbors, driven by an attitude of deep distrust of the rehabilitation process, derived from a strong sense of institutional neglect. To resolve the conflict, the architects began a process of negotiation, which resulted in the construction of storage on the roof, demolishing the existing pitched roof, after seeking a legal justification, and the installation of semi-transparent boxes in order to use them to park the motorbikes. The neighbors called them 'taquimotos', a name that extended and got popular into this part of the city. The architectural team underlines the importance of moving away from paternalistic management models based on services and handouts, giving an opportunity to others based on the assumption of responsibilities by all actors involved.

3. Recycling project of the Tour Bois-le-Prêtre (Druot, Lacaton & Vassal; Paris).

The tower is part of a complex of buildings (50m, 16 floors) built in the 1960s alongside a north main road. The design proposal is based on transformation and expansion of houses and common areas, according to criteria established by previous research. The implementation project was carried out with the many changes made to the baseline of competition after an intensive study of the needs of families living in the tower, and various meetings with residents to explain the project first level general, then family by family. The new configuration of the building is the result of an overall strategy for expansion of housing reform in facade and core facilities, so that when it comes to the interior layout that each family can choose a la carte. As a result of the various meetings, the architects team concluded that 50% of the families wanted to stay in their homes and 50% wanted to move house within the tower: Some families want more housing small, as they were parents whose children had been marching and no longer needed a big house and vice versa, young couples who maybe would have children and wanted to switch to a larger home.

4. Intergenerational Center Plaza America (Alicante).

Promoted by the Municipal Housing Alicante, the building contains a mixed program consisting of 72 'intergenerational' homes on low renting conditions, a day center for seniors, a health center and a public parking. In the residential part, and in addition to houses, areas dedicated to establishing common services and activities such as: library, computer room, workshop, laundry and recreation area on deck passable, with bowling green and large gardens adapted for the elderly. The program integrates local initiatives targeting the needs of two social groups: elder in need of attention and youths in need of a first home. Both have in common the difficulty of access to quality housing, with a program that suits their needs and price according to their ability. Tenants lease young people get a reduced price in exchange for participating as monitors of some of the activities for the day center. The contract requires 4 hours of weekly dedication, but success is such that young people decide to dedicate much more, creating new pedagogical initiatives that enrich the program originally designed. Young people involved feel happy with the bonds generated with their neighbors and declare to learn much more than their elders, from their experience and wisdom, than what they teach them in activities such as computer design workshops or horticulture.

Program 2: Software for spatial flexibility

The offices are still there in increasing numbers, actually. People say they are no longer needed. Within five to ten years he worked at home oars. But we need bigger houses, large enough to use for meetings. The offices will be converted into houses.
Rem Koolhaas. The generic city.

Collective housing, as the support of homes, is at the same time a static phenomenon, by repetition of habits, and a dynamic phenomenon, by the changing of activities and‘occasional cities’ that appear inside. The introduction of 'non programmed space' both within homes and communal spaces, promotes temporary appropriation by spontaneous activities that are often constrained or neutralized by specificity in the distribution of social housing. Lacaton & Vassal, at their experimental homes in Mulhouse, meditate about the limitations of social housing functional distributions. They decide to greatly reduce the budget of the operation, and the cost difference is reinvested doubling the surfaces: The act of doubling this space does not mean that each room is given twice the meter, each programmed space will have more or less the same surface but we add other spaces that are not programmed, which doens’t have a predetermined use.

Xavier Monteyns and Pere Fuertes propose to think over the residential dwelling, highlighting its capacity to define what some have called ‘the scattered house’. Faced with the image of the building as 'bottle rack', they propose the block as 'spreadsheet', whose cells can be combined to generate different types of home. On the possibility of community spaces in collective housing buildings, Xavier Monteyns says it's outrageous that an experience such as the Unité d'Habitation in Marseille, is not commonly made at present. Indeed, collective social housing in Spain has been minimizing investment in spaces for the community, a fact that at the same time reflects the evolution of society toward individualism and acts itself as a factor that impulses community towards non solidary models.

Below I discuss some examples which that have been analyzed during the development of this research. They are selected in orther to illustrate the components that are needed in the design of a flexible housing:

1. Homes in Carabanchel (Aranguren & Gallegos; Madrid, Spain).

Proposed social housing completed in 2002. Depending on the day or night, the surface of the living room will be transformed. During the day, the walls are collected and the beds are concealed in the niche under the closets and hallways of the backbone. At night, when the space is re-distributed, individual rooms and beds emerge. The architects justify the importance of these mechanisms: Today, the economic factor requires the rationalization and standardization of housing affordable rate. But on the other hand, the increased complexity of our requirements requires flexibility. The future will have to take into account both aspects. For this purpose, the skeleton construction is the right system. It enables streamlined methods of construction and at the same time, the division inside unhindered. If we consider the kitchens and bathrooms, by their facilities, as fixed nuclei, the remaining space can be broken by moving walls.

2. Experimental collective housing (Steven Holl; Fukuoka, Japan).

This proyect is a part of the experimental neighborhood ‘Nexus World’, designed by Arata Isozaki, and situated in the district of Fukuoka Kashii. Introduces the concept of 'swing space', which allows each of the housing is adaptable to the needs of its inhabitants. Holl updates the system fusuma tradicinal, Japanese sliding panel, fixing an axis that allows you to turn on itself and transform the layout of the rooms. Thus, three relaxation components: 1 the area where they live during the day is extended, subdivided into dormitories at night; 2 family rooms can be added or removed through these subdivisions, adapting to the different stages before and after the emancipation of the children; 3 housing changes with the seasons, adapting panels solar control needs. Another interesting aspect of this project is the presence of three lines per apartment, which allows the inhabitant to feel the different gradations of light throughout the day.

3. Sayama Flats (Architect: Jo Nagasaka, Tokyo).

The recycling project of a residential building, the Sayama Flats, by architect Jo Nagasaka (Schemata Architecture Office Ltd.) has been recognized in the 5th edition of the International Prize of the Foundation Bauhaus Dessau (2008) for its search for new standards in the housing design under minimal budget. The original assignment was the reform of an apartment building in Sayama, a suburb of Tokyo. Built in the 70s, the building Sayama Flats is a typical residential building at the time, fallen on the lack of investment in maintenance for three decades. Once identified constructive remedy the pathologies, and given the low budget available for processing, it was decided that the project aims to create a home not specific, that would support open and modifiable by its inhabitants, with the roof reformulated as Community area where you can sunbathe or relax. Thus, each apartment in damp rooms are grouped near the entrance or ‘genkan’, leaving the remaining space as free module oriented south, articulated by opaque dividers panels (fusuma) or translucent (shoji).

The ‘Normas Técnicas de Calidad’ (RD 3148/1978) lay down the conditions that must be taken into account in the design and construction of buildings to achieve a ‘normal’ quality level. Among other provisions, they establish a minimum noise attenuation for external enclosures and a minimum heat transfer coefficient of thermal bridges, aspects that have been repealed by the Technical Code. Some observations on what affects interior partitions:
- The interior partitions are defined by their partitioning of spaces function and contribution to 'terms of intimacy' identified in the NTD.
- When hosting a partition larger diameter pipes or equal to 2 cm, requiring a thickness greater than or equal to 10 cm, except in the case of prefabricated systems.
- The doors are defined by the functions of 'accessibility' and 'privacy' identified in the NTD (Technical Standards of Design).
- In the case of sliding doors, require the possibility of registration and inspection of hidden mechanisms.
- In the case of frameless glass sheets, requires them to be tempered glass, minimum thickness 10 mm, and marked the height of the view.
- The case described by Aranguren & Gallegos shows that it is possible to design buildings of high level of flexibility based on the design rules stablished by social collective housing (VPO) legislation.

The study of limiting factors for implementation of flexible systems in the design of collective housing is revealed as essential: At what point social dwelling design standards legislation limit the flexibility of housing programs, and to what extent the limiting factor is in fact at the market itself, by standardization and repetition without limit distributions use program and responsive to industry the brick. This research is currently under development.

Program 3: Software for energy efficiency improvement.

The success of a software programmed in orther to update the energy performance of housing in Spain is highly dependent on the assimilation of our different climate parameters, which presents a great variability within the country. This adaptation involves a very interesting component of localism to introduce in a field heavily influenced by the standardization and repetition of patterns in different contexts. At this stage of development of research, we focused on an approach to the complexity of the issue, and the collection of information on recycling processes of this type currently in progress in Europe. Spain offers interesting examples in the field of bioclimatic applied to collective housing, but less so in its application to interventions in collective scial housing. Three examples, which represent the key initiatives at European level, have been selected.
The first project follows the German 'passive house' design philosophy, and proposed architectural project design exclusively from the standpoint of technical and constructive focus on ensuring its optimal performance by reducing energy demand by 80%. Later on, I discuss two cases that exemplify the intense transformation of the energy performance of local authority housing in France, which is being carried out today. France has set a target: the introduction of low-energy standards in new construction and the establishment of financial incentives to promote the renovation of existing buildings with high energy consumption. For this purpose, French Gobernment has designed an unprecedented investment in social collective housing (HLM). The program developed by the National Agency for Urban Renewal for the period 2004-2011, includes the 'eco-rehabilitation' of 800,000 rental housing units, the demolition of 250,000 houses and 400,000 new construction of rental housing. The concerted renewal operations concern 270 districts and more than 1.5 million people. The aim is to achieve the commitment in the Kyoto Protocol to reduce emissions of greenhouse gases by 5% between 2008 and 2012.

1. Solanova Project
(Universities of Kassel and Budapest).

The project SOLANOVA (http://www.solanova.org) is a pioneering initiative developed by researchers at the Universities of Kassel and Budapest. Since 2003 develops a methodology for analyzing and processing of large integrated residential buildings (eco-efficiency and solar energy) and heat supply systems. The aim is to develop strategies for renewal of the outer skin of poorly insulated buildings to achieve low power consumption. The theoretical concept was tested in a pilot intervention in Hungary. Heat demand decreased by 80%, providing the remaining 20% by installing photovoltaic panels. Through the integration of solar technology, scientists at the University of Kassel want to show the great potential of this energy in combination with low-energy buildings, as is the case of residential buildings.

2. Intervention in HLM housing block
(Patrick Bidot; Chenôve, Côte-d'Or, France).

The original 1960 building has been covered with a new skin painted aluminum substructure, resulting in each of its 133 new homes unheated space that is geared to the southwest, operates as a buffer between inside and outside temperature. The glass colors vary from blue interior space, so that the bedrooms are filtered by a slightly darker blue and lounges for lighter tones, leaving a blue tone to the handrails of the loggias. Three quarters of the south facade are covered by blind solar panels on a polyurethane foam insulation in orange. The 420 sensors provide an average power of 36 mph. A digital display on the front north blind reports the instantaneous power, the total accumulated and tons of CO2 not emitted into the atmosphere by the solar installation.

3. Transformation of social housing tower HLM (Aura Agency; Malakoff, Nantes, France).

The tore, built in 1967, did not respond more to housing standards: outdated fire safety, building 'energy intensive' (less than 2 cm insulation), stoneware in front off, asbestos, houses with tiny rooms, inaccessible for the disabled, circulation spaces undersized and in need of installation of 60 m2 of solar panels for hot water. Working vertically to replace the core facilities, and horizontally to reconfigure the internal layout and increase the usable area, this reconfiguration generates an additional area that is decided to transform into rental spaces that residents choose to purchase as an extension of their homes, wich helped the finantial viability of the operation. It was decided to close the windows to generate loggias climate control, and replaced the original facade by a system of low thermal inertia. The energy consumption at the end is about 76 kWh/m2·yr, with better than 60% compared to the initial state. The operation, from 855 € TTC/m2, finally turns out to be 35% less expensive than an equivalent new building construction, not counting the costs of previous demolition.

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INCREMENTAL HOUSING IN MEXICO CITY: A TEACHING-SOLVING PROBLEM

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ABSTRACT

In order to face and solve relevant, social problems in both, Mexico City and in the whole country, the Universidad Autónoma Metropolitana, Unidad Xochimilco (UAMX) has been doing research work and has taught undergraduate and postgraduate students for thirty-five years.

This paper is about the UAMX method of teaching and learning how to solve a given social, relevant problem. In this particular case, the method is applied from the architectural and urban design fields to the problem of low-income housing in Mexico City.

Since 1978, teachers and students in UAMX have improved this method by applying it to different case studies. By 1986 and due to the work done after the 1985 earthquake in Mexico, this group of teachers consolidated and became Taller de vivienda (TAVI) Housing workshop.

Since 1999, TAVI has been working with last year undergraduate students, most of whom are now working professionally in solving low-income housing problems. In its work with students, TAVI has settled some basic conditions:
- First: As established by UAMX main goals, both teachers and students interact with teaching, research work and social service.
- Second: TAVI and students always try to work in a site where both inhabitants as well as local authorities, get involved in attempting to solve their given housing problems.
- Third: Inhabitants and TAVI carry out participatory design methods in order to face and solve their housing problems. Most of this work has been done on Mexico City's periphery.

It has been found that in those places there is a dynamic relationship between the changing inhabitants´ ways of life and their natural and built environment transformations.

Teachers have discovered some useful patterns to describe those physical and social relationships in time and space.

Key words: teaching, housing, participation, sustainability and transformation.

INTRODUCTION.

This article is a small homage to the modular system way of teaching and learning, developed at Universidad Autonoma Metropolitana, unidad Xochimilco (UAM X). This method has been adopted by some anglo-saxon educational systems and it has been referred to as “Problem Based Learning” (P.B.L). Since its beginning in 1975, UAM X has been applying the Modular System (M.S.) of teaching and learning.

This article is divided in three sections. The first one explains why and how Universidad Autonoma Metropolitana U.A.M. began and particularly, the unidad Xochimilco (U.A.M.X). This part lays emphasis on the Modular System, (M.S.)

The second part describes how the Low Income Housing Workshop (Taller de vivienda, TAVI) formed and how it works and tackles the problems to be studied. This part focuses mostly on the M.S. as it is applied by TAVI.

The third part shows the relationship between teaching, research work and social service in TAVI. This is done through testimonies given by former students who, while in their last year of the Architecture Programme, were working at TAVI. These students graduated in July, 2001.

THE UAM STRUCTURE.

UAM was born in 1974. Two of the main reasons why it was founded were, on the one hand, the increase of the young population in demand for access to professional studies. On the other hand, the need to have a university whit a a more functional and modern structural organization.

Instead of having the university concentrated in one big campus, the UAM began to work on three campus located in different areas of Mexico City. These campus are Azcapotzalco campus (U.A.M.A) in the North of the city, Iztapalapa campus (U.A.M.I) in the East of the city, and in the South, the Xochimilco campus (U.A.M.X). Later on, in 2005, Cuajimalpa campus is opened in the West area of Mexico City.

Each of the three campus attends to approximately 15 000 students carrying out undergraduate and post graduate studies. Cuajimalpa campus is just beginning.

Nowadays, UAM is the second public university in the Mexican Republic; the first one is the Universidad Nacional Autónoma de México (UNAM).

Each of the campus has an academic structure composed by divisions, departments and research areas. The academic personnel has three main activities: to teach, to do research, and to work on the diffusion and preservation of culture.

Most of the academic personnel have a full-time contract for teaching and doing research work. Nowadays, UAM has 3 700 teacher-researchers.

The academic programmes are divided in trimesters. The undergraduate students have to do a formal research equivalent to their professional thesis. This means that the graduate at the end of their last year of their studies gets his final grade.

Xochimilco unit (uam x).

This UAM Xochimilco Unit differs from the others in two aspects:

The first one is that as a main objective, UAM Xochimilco has to prepare professions that focus on facing and solving social and environmental problems. The second aspect is the Modular System (M.S.) way of teaching and learning.

The following is a simplified way of understanding the basic concepts and processes of teaching and learning in the Modular System.

"Any social and/or natural environment phenomena capable of being taken as an object of study is called transformation object." (T.O.) That way a transformation object (T.O.) becomes the means of teaching and learning from different fields of knowledge and professional practice ". (Velasco, Rodríguez, Guevara. 1982).

Each module is designed and planned, based on the way of approaching a transformation object from a particular field of knowledge and professional practice. This approach is useful to know and understand that each and any social problem has to be understood and solved from an interdisciplinary view.

"It is within each module that students, under their teachers advisory, do a research work as well as a practical proposal or project, related to the transformation object". (Arbesú, 2006).

In each module, a specific problem is selected from the transformation object as the axial structure of the course. That´s why this particular problem is called axial problem. The axial problem defines the place, time and the social group and/or organization to be studied.

The module is a learning-teaching unit where a real social problem has to be studied and transformed. This must be done through the production, transmission and application of knowledge. This particular way of teaching and learning, has been used and adapted to the anglo-saxon educational systems. It has been given the name of Problem- based Learning, (P.B.L.) (Ferreira, 2006).

In the modular system, the social service is the means to relate both, research and teaching to a real problem, (axial problem).

In a module, the social service gives rise to proposals to be applied and used in order to transform a real social problem.

LOW INCOME HOUSING RESEARCH AREA. (TALLER DE VIVIENDA. TAVI)

As it was said before, the academic structure in each campus is made up of divisions, departments and research areas. The low income housing research area is one of the four areas of the Methods And Systems Department, which in turn, is part of the Sciences And Arts For Design Division in UAM X.

TAVI began to work as an area after the September 1985 earthquake in Mexico City. The following days after the earthquake (Sept.- Dec. 1985),students and teachers in the architecture programme, decided to help by working on the reconstruction city programme.

In January 1986, a group of students and teachers decided to continue helping on the affected neighbourhoods due to the needs of several organizations. This was the beginning of TAVI. Since then and up until now, TAVI has been working as a research area and has been covering the three aspects: teaching, research and social service on low income housing problems.

TAVI is working now with undergraduate students doing their last year courses. TAVI´s main objective in these courses is to prepare and enable architects to tackle and solve at a professional level, design and construction problems in low income housing as well as urban environments.

The architecture undergraduate last year courses in TAVI.

In the three modules taught by TAVI during the last year of the architecture undergraduate programme, the object of transformation is “the low income settlements transformation from the dynamic relationship place-inhabitants”.

The three courses had the same operating basic structure. This can be described as follows: Each module has two main parts: the theoretical one (theory and methodology courses), and the practical one (workshops). Both parts have two fields of knowledge: the social and the urban architectural.

Part one. - Theory:

Social Theory and Methodology.- This course is focused on social research methods, particularly the ethnographic ones.

Architectural and urban design theory and methodology.-The main goal in this course is to introduce students in the knowledge of support urban and architectural theory and methods as well as TAVI´s urban and architectural theory and methods. The relationship between social and design course is done through the Habitat´s social production theory developed in the Habitat International Coalition (HIC).

Part two.- Practice:

Social Workshops.- Those workshops are focused on two main goals . The first one is to advise students on the social aspects in the field research. The second aspect is to advise on the appropriate development and presentation of their final thesis document.

Urban and Architectural Design Workshops.- The main goals in both, urban and architectural design workshops, are:

- To define the local urban and architectural traditional patterns through TAVI´s methods.
- To introduce the sustainable theory and practice approach.
- To develop improvement as well as new urban and architectural projects through SAR methods.

Axial problems and objectives in the last three modules or trimesters in TAVI.

The last three modules in the architecture programme are the tenth, eleventh and twelfth ones. The axial problems and objectives of each of these modules are presented here.

Module 10th .- In this module the axial problem is to make a social and spatial (urban, architectural and natural environment) diagnosis of the place and to define the set off projects at both, urban and architectural scale. All this work is done with the local inhabitants´ participation.

Module 11th.- The axial problem of this module is the development of improvement projects and new ones at an urban and an architectural scale, as defined by the set off projects . The local inhabitants get involved in this part, through participatory design workshops.

Module 12th.- The axial problem in the last module in TAVI, has two main objectives. The first one is the architectural, urban and environment final projects. The second one is the final thesis document. Both of them have to be presented and checked by the local inhabitants. After that, TAVI´s students and teachers give the projects and thesis to the community.

TESTIMONIES AND REFLECTIONS ON THE MODULAR SYSTEM.

Here we present the testimonies given by five young architects who did their undergraduate´s last year in TAVI workshop. Their testimonies show, in a detailed way, the relationship among teaching, research and community service work, in the incremental housing workshop at TAVI. These young architects filled in a questionnaire designed by TAVI teachers in order to get their opinions. The questions were these:

- As a TAVI´s student, do you think you could apply the teachers´ lessons to your field research? If so, could you give some examples?
- Do you think there was a relationship between you courses and your research work? Could you tell how it was?
- Was your research useful to understand, tackle and solve any community problems?

- Nowadays, as an individual and as an architect, do you think that your last undergraduate studies in TAVI were useful?

All those questions were e-mailed to a group of architects who are still in touch and maintain a friendship with Jorge Andrade, TAVI´s coordinator and at that time, their teacher too.

On that occasion, the students faced two real low income housing problems: the first one was to architecturally improve a group of dwelling units within a housing complex which had been developed ten years before. The second one was to develop an incremental housing complex for a low income group of people who were living in a highly deteriorated place. This place was densely populated and had neither drainage nor water supplies.

In both cases, the students had to get acquainted with those social environments through field research. This was done by doing interviews and documenting the way of life in those places. This work allowed them to apply all the knowledge acquired through the course.

Those points are confirmed by the following testimonies:

- "In our TAVI workshop during our last year at the university, we got to fully understand and to apply our class lessons into real situations. The experience of working with a community and especially with their inhabitants, was essential to reinforce and complement the knowledge acquired from our teachers. From my point of view, the knowledge acquired through the contact with a real and particular problem, turns out to be a `must´. It becomes essential. (Guillermo)

- "At the beginning, we got in touch with the inhabitants. It was through them that we could get to know and understand their problems. Those problems were behind the architectural ones. This experience allowed us to bring some empirical information to our class. This information was necessary in order to get a diagnosis and after that, to make some architectural design proposals to solve some of their problems" (Carmen).

Both testimonies reinforce the idea that working with inhabitants in a community is essential in order to get students involved in their social and design workshops. This way they managed to relate practice to theory and through that, they related their courses, to their field research and to their community service. They were convinced that it was possible to make positive inputs on the inhabitants´ dwellings and community.

One of the main goals of the modular system is that at least, the field research and diagnosis developed by students, comes back to the community. In TAVI, this is done through architectural and urban design proposals. We can see that, at this moment, the relationship students-real problem through the application of their knowledge becomes a very useful one. The following testimonies reinforce these ideas.

- "The workshop methodology was mainly based on the work with the community. The purpose is to get to know the community problems that go beyond the surface ones. This way we manage to solve part of the problems focused on improvement of their daily lives through architectural proposals (Carmen).

• “I think that an important breakthrough in my last year at the university was to understand how nuclear families become extended ones living together; this was essential to understand how a dwelling unit has to be dynamic and flexible in order to satisfy the different needs of every individual member in each family and their common needs as well “ (Miriam).

Those testimonies show how the social service was used during the TAVI courses as a means to make students sensitive to certain real and relevant problems in low income housing. In this particular case, the community they were studying.

The modular community service is understood as a dynamic educational process which not only generates scientific knowledge, but a permanent social conscience as well.

• “I remember that we developed an architectural housing proposal with a social organization.... Maybe we just did the basic architectural plans. However, I think that this was important because we developed it taking the social organization´s real needs as a basis. As the people were the main actors, their particular views were the centre of our work” (Hector).

• “We learnt to understand dwellings not as objects, but as processes in a constant, flexible and adaptable change. These processes are mainly seen in the low income housing families” (Carmen).

Those students ‘opinions reflect that apart from the acquired knowledge through the community service, the students are introduced to some values and ethical positions about their professional practice.

The following testimony confirms the knowledge that the student said he acquired:

• “I think that when in TAVI in my last year at university, I became sensitive to the low income housing problems. I realize now that the need of housing is a big issue when there are not enough technical, financial and land resources to work on it”. (Carlos)

The TAVI learning process brough the students to understand the complexity of low income housing before making any architectural proposals on it. They managed to understand housing as a process and not as a product, and through that, its relationship with family changes, climate, land ownership and so on. They also became aware that low income housing in Mexico is an important problem to face and tackle.

One of the main goals in UAMX and its pedagogical model is to form future professionals capable to face and contribute to solve social relevant problems in their professional practice.

• “Our last year at university, shows us the other face of architecture which is maybe the more necessary one because it requires architects capable not just to design beautiful dwellings ,but capable of being sensitive to the cultural, economic and social aspects of low income social sectors” (Carmen).

• “Since I graduated from university nine years ago, my professional practice has been 100% related to the knowledge I received in TAVI. (Guillermo)

• “The low income housing problem is a big one in Mexico. We just have to look around us to perceive it. However, this problem is not faced adequately; there is a lot to do. Today this problem continues growing , which in my view, is decisive .

Unfortunately, there are just a few institutions concerned about preparing future architects involved in this subject". (Carlos).

These testimonies confirm that all the academic work along with research and community service, as they were applied through the modular system in TAVI, have been useful. Students have been given the chance to learn in a reflexive way; to learn participating directly with the population in facing and solving their low income housing problems. The modular community service has been a pedagogical tool capable of making students sensitive to real problems on housing. Students have been able to perceive that community service has been a complementary activity to their modular research work. These works allowed them to feel that they were able to make proposals to improve the life standards of the people in the community studied.

FINAL COMMENTS

One of UAMX and its modular system (M.S.) most important objectives is to produce professionals who are committed to the knowledge and solutions of Mexico´s main social problems. On this particular example, the M.S. has been fully successful in both preparing students to solve architectural problems as well as in helping them become aware of the need to develop an attitude and behaviour committed to solving relevant social problems. These in turn, are related to their professional practice. It is important to say that the young architects who through their testimonies participated on this article, have all been working as architects in low- income housing during these last nine years ,since they graduated as architects. The fact remains that low-income housing, along with the improvement of informal settlements, is an area seldom practiced by architects.

This document allows us to say that in M.S. it is possible to relate teaching, research and social service altogether. This becomes an integral process where the research work done by students and coordinated by teachers, produce the necessary knowledge which not only enables students to learn in a real context, but allows them to do a social service for the studied community as well. This process gives students the opportunity to perceive the social service as a way to apply the previously acquired knowledge.

Nowadays, Mexico is in the middle of a socio-economical crisis; about 70% of the population has an income which is lower than 3 dollars a day. Because of that, most of the population live in informal dwellings. However, as in 2006 this problem was officially recognized and accepted a new law concerning this kind of urban process was approved. This, the Housing Law accepts as legal the existence and development of informal housing and settlements; informal housing is no longer illegal. It is therefore necessary to prepare new generations of professionals in order to face the low- income housing issue. It can be said that the young population in Mexico occupies the widest part of the pyramid of age and it seems to be that UAMX modular system, is one of the best ways to prepare them, for tackling some of the social problems of Mexico.

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TEACHING OPEN BUILDING IN BRAZIL

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ABSTRACT

This paper aims to share the experiences of teaching Open Building projects to students, which are taken as a studio of the architectural school from University …. (reference after blind review). The proposals deal with the design of multifamily housing schemes and public spaces starting from the recognition that the built environment is a changing process continually subject to human intervention. The design premises are based on the research of the urban tissue (human activities, spatial morphology, topography, landscape and infrastructure) and of the building (the components that make the space habitable), along with the support and infill systems.
The educational objectives of the studio are tied to the explicit assumptions of Open Building. But also they are meant to interrupt the circularity and the reproduction of knowledge in the architectural schools, which refrain the possibilities of adding instruments of critical analysis and of promoting the autonomy of the student (the disregard of the students’ non-scientific knowledge by the academy environment). It is hoped the arguments brought up here may feed the debate on the implementation of Open Building.

Keywords: architectural education, Brazil, open building.

INTRODUCTION

The semi-artist image and the luxury adjective generally associated with architects, who are immersed in models built by the architecture's field, have been long criticized by authors, such as Muller (2004) and Stevens (2003). Indeed, the notable architect prototype, usually seen as an elitist education product, is no longer useful to contemporary world.

The architect-artists, historically built from the Renaissance to the Modern movement, have abandoned their social functions creating architecture as a product of classification, ordering and distribution, based on the recognition and the legitimacy of the author's 'masterpiece' (the object individuality). In this case, the object and its form assume greater significance, rather than a response to a specific urban complexity.

Although the purpose of architecture is (or should be) to produce spaces in which social relations can take place, its mode of action, representation and meaning has been defined by the economic capital (elitism of ideas) and the intellectual capital (value of drawings), both commanded by the speech of those who hold the power. Stevens (2003) states that the field of architecture moves on complete ignorance of its social functions.

It is intended to show that the student's non-scientific knowledge incorporation in the practice of teaching design can allow other capitals constitution rather than the economic or the intellectual ones. Brazilian educator Paulo Freire (1996) states that experiential and socio-cultural knowledge systems, built upon the student's daily life along time, should be respected and promoted by the Academy. The non-scientific knowledge is essential to the everyday life understanding and it serves to build up new values.

But why this would interest the architectural professors, especially the ones who deal with Open Building teaching?

Questioning architectural educative practices, which generally do not foster critical approaches, means to give up the talent and the notability in order to enhance the autonomy of the student in the application of his/her knowledge built upon his/her social biography, cultural heritage and life education (the habitus, used by Bourdieu, 1999). The relevance of this assessment lies in the fact that the open architecture education process, which will be described here, dialectically builds the ability of "how to think" along with "how to do". In order to do so, the Open Building is taken as a possible approach not only to coherently transform the everyday environment but also to validate the student's knowledge systems.

Open Building takes the aspects of change, distribution of design control and shared values as the ones to be worked with in the studio format of teaching if architects/professors intend to be closer to the everyday environment's reality (Habraken, 2007). However, the desired or needed transformation of the everyday environment presupposes that students (the future architects) must "encompass demands, criteria and considerations that can be social, functional, political, fashionable, administrative" (Habraken, 2007, pp.2); all of them usually mitigated by the functionalist request to a prior form design.

Our point of view is that once the non-scientific knowledge (or what the students have learned along life and their capacity to criticize) can be raised by a broader educative practice, the students might be able to better understand social, political, technical, historical, cultural, economic conditions of the everyday environment prior to the mastery of form. In this sense, the pre-determination of the site, the program and the form cease to be static becoming dynamic and variable (or, in other words, the support and infill systems).

Doing so, student’s criticism rises along with research stimulus (and not with training or domestication), promoted by the Open Building approach. Knowledge becomes participatively shared, not transferred; knowledge is constructed and reconstructed, being apprehended and internalized both by students and teachers. Freire (1996) brilliantly expose such educative premise: students’ autonomy is brought once they assume their knowledge systems and critical capacity.

THE TRADITIONAL TEACHING PROCESS

The academy admission’s exam in Brazil, called vestibular, is generally similar to almost every other university. It basically consists on a multiple-choice test about general high school subjects (such as biology, mathematics, history, language, English, etc.) and one or two essays written in Portuguese. Not surprisingly, high school education system has historically focused in one main objective: students must succeed the university admission’s exam. Therefore most of the students enter the university raised by an uncritical education, based on ready-made responses about scientific issues. The academy builds itself to produce, process and disseminate information and knowledge, but also to legitimize consumption of symbolic goods and to ensure cultural reproduction (Bourdieu, 1996).

This background allows us to understand the generic profile of an architectural student. But before evaluating the results of the open architecture teaching, which has been approached here, it is also relevant to describe what can be characterized as an traditional design teaching process experienced in the architectural courses (ten semesters) in Brazil.

Design disciplines usually start in the third semester with an expositive class, in which professors present to students a chosen site and a (normally invented) prospect to be developed as a project. This prospect involves a thematic issue such as “a school”, “a museum”, “a sports stadium”, etc. Still in the first meeting, the student normally receives a pre-defined program, with a list of rooms or spaces the project shall have and sometimes the dimension areas required to each one. In this case, questioning about what was set by the teacher rarely occurs. The second meeting usually consists on a site visit. The professor along with the students visit the plot to be occupied, and expose his perceptions, not infrequently influencing the students’ response of what the project should be.

From the third semester ahead, excluding rare approaches, the student is expected to start bringing formal solutions to the studio in order to receive personal orientation (or opinions) from the teacher (while the other students work in their own project). The design proposal exclusively answers the site and program’s premises; no research or understanding about the PLACE is required, concerning the social, cultural, historical, economic, political and physical conditions (except, the obvious ones - topography, sunlight, prevailing winds, legislation and heritage).

During the orientation process the teacher usually points out the functional and/or technical problems: both very subjective (taste and style) and objective (patterns, legislation, technical catalogs) issues drive the student, promoting fragile concepts (Sobreira, 2008). This arrangement goes on until the final presentation day when (and just in this day) the students are encouraged to see what their colleagues have developed.

Since learning, from the high school to the university, configures an uncritical and dependent process, most of the students seem to be comfortable with what is given by the professor and understands it as truth. All they have to do is to distribute the program onto the site, fitting it in a gratuitous aesthetic form. The focus is the product rather than the learning process. Considering the traditional process of design education in schools of architecture, that has little intellectual stimulation and/or conceptual weaknesses, it is easy to understand the reasons why the students respond so well to the open architecture teaching opportunity presented here.

TEACHING ARCHITECTURE

Here another approach towards architecture teaching is described which consists of five steps: “understanding the PLACE”, “setting a DESIGN QUESTION”, “diagramming the places’ ANALYSIS”, “the DEBATE phase” and “creating a DESIGN STRATEGY”. Only after the five steps are fulfilled the project phase begins.

First of all, the students shall be concerned about the PLACE (the everyday environment, as named by Habraken). The place is more than the site – it is formed by social, cultural, historical, economic, political and physical conditions, which together exist in a specific and unique area. Nowhere else.

In order to understand the PLACE, students must deeply study it – which means visiting the area, talking to people, getting data and pictures, mapping, reading documents (from the government, university, non-government institutions, literature, etc.), understanding of the local context (people, landscape, labor, materials, traffic, urban demarcations, public or individual demands, physical and spatial attributes, legislation, etc.). It is this research phase in which a DESIGN QUESTION is set, such as open architecture. But it could be others: such as social architecture, heritage intervention, slope occupation, urban intervention, building systems versus modular coordination; vertical architecture; environmental regeneration and so on. But not a theme or a typology, like “a” museum, “a” cultural center, “a” hotel, “a” residence, etc.

Then, the students ANALYSE the place. The PLACE (which is still mainly information) can be represented through the use of diagrams and sketches (but not forms). Diagrams are abstract and dynamic tools, prior to a speech, which summarize data such as flows, functions, events, etc. (Porto Filho, 2006). The diagrams initialize the cognitive process in the students’ minds (once they start analyzing information they also start thinking about how to spatially materialize them).

After they diagram information, the DEBATE phase starts: what does this “information package” means to each student? What is going to be done with it? Which information is important to be configured as a subsidy to generate architecture? Which one will be discarded? Here the students reveal (build and re-build) their knowledge systems along with their capacity to debate and their critical skills.

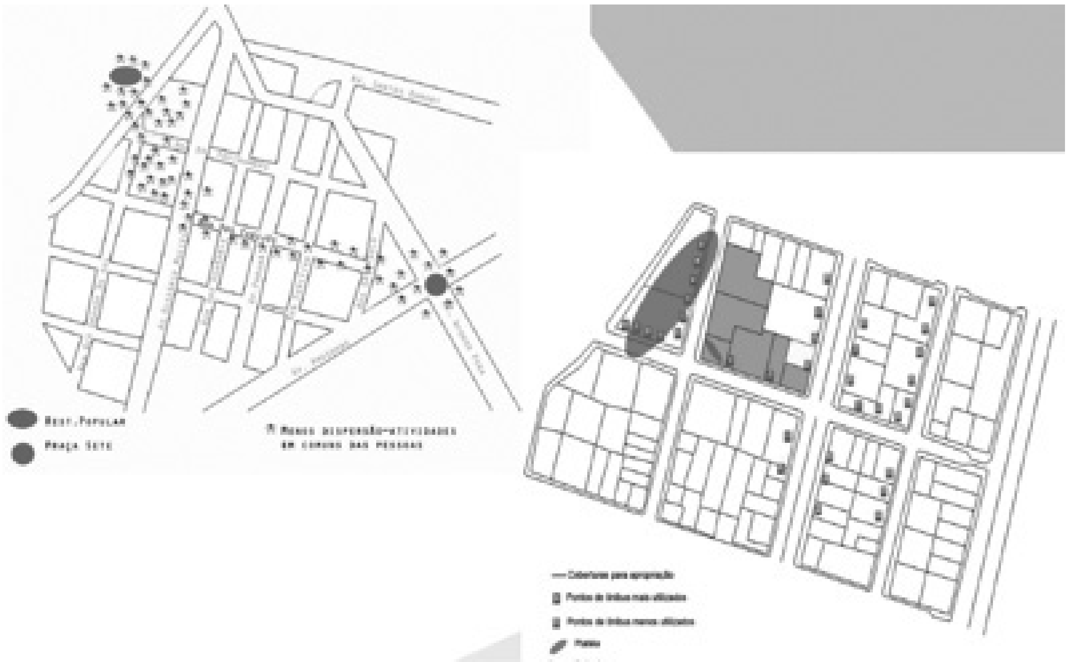

Figure 1. *The place's analysis (Students A. Ferrari, I. Almeida and L. de Nardi, Studio I, 4th semester, Professors: D. Morado, A. L. Lloyd, P. Schultz, EAUFMG)*

The DEBATE generates a DESIGN STRATEGY (some call it design concept, which is very suitable for the modernists). There is no defined form yet but design strategies' possibilities and questions to be answered: what kind of DESIGN STRATEGY would be adequate and coherent to the PLACE of the study? This means that each student will find a DESIGN STRATEGY, which is a result of his or her creativity, perception, experience, interpretation (the non-scientific knowledge) and the architectural learning – from theory to building systems, including history, technical issues, design skills, architectural works and fundaments already learnt through the experimentation of DESIGN QUESTIONS (the scientific knowledge). It is the possibility to share other capital (for example, social and cultural) rather than just the intellectual and economic ones.

Once the DESIGN STRATEGY is theoretically clear, grounded and solid, the form can be generated. These forms are not validated by the symbolic and aesthetic quality, but above all, are the result of a response to a variety of dynamic factors and contradictory urban context (Porto Filho, 2006). And the question to be answered is: what kind of form would be adequate and coherent to the defined DESIGN STRATEGY? The PROJECT (or design scheme) phase begins.

There is an incentive (not an obligation) to use processing scale models since it is understood they contribute to the design strategy's explanation. Legislation is also considered even tough changes can be critically suggested. Once again it is a continuous process generated by the knowledge systems built by the student and not transferred by the architect/professor.

Figure 2. The processing scale model (Students L. Alvim, T. Ribeiro, Studio I, 4th semester, Professors: D. Morado, A. L. Lloyd, EAUFMG)

The project proposals are usually developed by group of two or three students, based in the exchange of experience and the cooperation of each member as factors that may contribute to individual and collective learning. Each student has the opportunity of learning how to share his/her ideas, to negotiate them, to overcome obstacles, to listen, to recognize better strategies. Self-evaluation is inevitable.

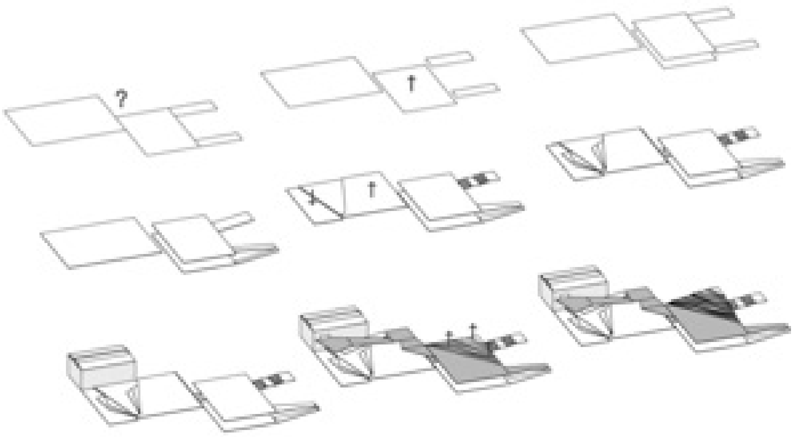

Figure 3. The design strategy (Students B. Ribeiro, N. Freitas and P. Braga, Studio I, 4th semester, Professors: D. Morado, A. L. Lloyd, P. Schultz, EAUFMG)

The studio works as a collective educative practice, meaning all the students can talk about their colleague's project. The professor, who works as a mediator, is not the only one who is supposed to analyze and criticize the project but everybody else is invited to do so as well. Such procedure promotes collective critique but also gives autonomy to the students to defend their design strategies and points of view. The design phase is essentially characterized by a back and forth process, but always guided by the design strategy already consolidated and by the new possibilities in the decision-making process of the project.

Figure 4. Open Building proposal (Students D. Andrade, F. Chagas and L. Castro, Studio I, 4th semester, Professors: D. Morado, A. L. Lloyd, P. Schultz, EAUFMG)

It is understood that the knowledge systems can be collectively amplified (again, from theoretical to technical knowledge including architectural fundaments, but mainly the non-scientific knowledge) rather than from a formal solution (plants, sections and facades) to some static program.

TEACHING OPEN ARCHITECTURE

Since it is understood that the city (people and use of spaces) changes along time, open architecture seems to be a coherent DESIGN QUESTION to be investigated. However it can't be applied apart from the PLACE; this means that architectural students must be brought closer to social, cultural, historical, economic, political and physical conditions and all the agents involved in the decision-making designing and building processes within the PLACE. They are: the dwellers and their neighbors (the city); the agents responsible for planning, designing and building (architects but also engineers and site workers); the building material industry and sellers; the private and public institutions responsible for approval, management, control and maintenance of the design and production processes; heritage council; financial institutions; real state market; publishing companies; etc.

Why is that? Architecture is not an isolated knowledge field. Architectural schools must amplify their studios' action from the micro-scale to macro-scale proposals. Through an interactive approach, professors should act together with these agents (through lectures, visits, partnerships, researches, etc.) in order to allow students to be critically involved in the PLACE'S DESIGN QUESTIONS. Not doing so, architectural schools take the risk to guide students as drawing authors of typologies or as technical specialists rather than mediators between the parties involved in the designing and building decision-making processes. If not working as mediators, professors shall not be able to work within open architecture concepts.

Open architecture can't be taught only as a technical or a design answer to the changing scenario within the cities. Buildings - and the neighborhoods they occupy - are not static artifacts; people are not static as well. So, open architecture must be seen as a possibility (or an approach) to have people effectively deciding about their everyday environment. In that sense the word "open architecture" may amplify the PLACE meaning, previously stated.

This also means that teaching open architecture can be a similar process no matter the city or the country. What will make difference is the PLACE; or in other words, the critical capacity of professors and students (future architects) to understand its social, cultural, historical, economic, political and physical conditions and the need to work with the involved agents in the decision-making designing and building processes.

LEARNING OPEN BUILDING

The affirmations here are sustained by the interviews made with some of the students who experienced OPEN ARCHITECTURE as a design question. The great majority demonstrated an overwhelming reward feeling for what the experience added to their architectural formation, capable of opening their minds to new ideas and values towards their professional acting.

The students also stated the OPEN ARCHITECTURE learning changed their design methodologies in subsequent projects since they changed their way of thinking architecture. In fact, many attested they have tried to apply the concepts of flexibility, changeability along time and user participation since then; and they all intend to keep trying. Some even affirmed that they have searched for more information about OPEN ARCHITECTURE, beyond what have been thought in the studio. Actually, they demand more theoretical information about OPEN ARCHITECTURE.

The use of diagrams was highlighted by some of the students as a valuable learning experience. They mentioned how much "easier" and "natural" it was to make design decisions once all the information collected about the PLACE was graphically visible for analysis. Some of them affirmed they would not be able to design anymore without the diagrams. They also valorized the change on the evaluating focus - the process instead of the final drawing, as a product - which in their opinion resulted in a much more fruitful learning experience: a process which goes beyond technical representation.

The divergence arises when the collective educative practice is approached. A student used the word "exposed" to express how she felt during the debate phase. Even tough, many students approved the debate, pointing it's advantages: (1) stimulates a continuous development in the design process, instead of having idle weeks or a last desperate week to deliver a drawing (rarely useful as a learning activity); (2) an increase of architectural references acknowledgment, once they could follow the other students' ideas and researches; and (3) the chance of having a balanced and a democratic discussion together with the professor, sharing doubts and questions. Still, few students missed the sketching over paper by the professor where there is no colleagues' interference.

All the students affirmed they liked their final design project in the OPEN ARCHITECTURE proposal; some even commented their participation in Open Architecture design competitions. But still, one student mentioned there is a general understanding that OPEN ARCHITECTURE is utopist. She agrees user participation and changeability through time are important concepts to be followed by architects, but she doesn't feel it is a common sense in the knowledge field of architecture. Even within an academic exercise, many students have problems to understand a real application of OPEN ARCHITECTURE.

Interestingly, many students, even those who had a good performance in the discipline, answered OPEN ARCHITECTURE concepts are still unclear to them. This may show a general difficulty and/or an insecurity to deal with them. Perhaps, it can be a remaining symptom of their uncritical background.

Generally speaking, learning OPEN ARCHITECTURE is still a challenge to the students concerning both the concepts understanding and the learning process. It seems the students have to fight for their ideas and to take risks, which sometimes is not an easy path to be followed. Even tough, as the interviews revealed, it has been extremely rewarding for them to go through the experience.

FINALLY…

The experience here is about a Flexible Studio, which receives students from the 4th, 5th and 6th semester, referring to the Studio I, II and III of the School of Architecture - Universidade …. (reference after blind review). This is meant that students from such semesters can choose which studio they will attend along their education time.

Not surprisingly, the students from the Studio I (4th semester) have presented better results if you compare them to other studios. Perhaps such students were not familiar (or contaminated) with the traditional design process; then, they were willing to work with open architecture design process.

Despite the design process described here comes from a clear and coherent understanding of a PLACE and it naturally flows in the semester, it doesn't mean it is an easy path. Eventually, the student faces urban complexity against (not experienced) autonomy, which can cause some apprehensiveness. At the same time, it is an opportunity to let the students critically think about architecture. Doubtless, the open architecture's design process increases student confidence and the results become consistent.

The Open Building approach may be far away to be part of the Brazilian building scenario, as it is related to professional and educational practices, legislation and building industry. But undoubtedly, it is one possible approach with regard to social, economic and environmental sustainability as an attempt to launch architects who will work within the market to listen to open architecture and its importance for our urban environment. Given that, the Academia is a crucial agent as part of the design and construction's modus operandi, if the students' autonomy shall come first.

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A RESEARCH OF DESIGN OF OPEN & SHARING APARTMENTS: MEET THE CHINESE USERS’ REQUIREMENT

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ABSTRACT

"Ant family" mainly refers to the long-term “drifts live” adopted by low-income college graduate in the big city, due to inability to pay high rent, they choose this way of living. In China now the rented apartments have a problem of overcrowding, unavailability of privacy, poor sanitation and homogenous space. In this paper the mentioned problems will be addressed by proposing the concept of open up design. The space is divided into a fixed area and alterable area. The alterable variable region uses of functional composite wall enclosed out of the various living units coupled with different modes of furniture combined to form alterable spatial patterns in order to adapt to different usage requirements. Fixed area includes kitchen and bathroom in public space with the open layout. Open rented apartment can be flexible and highly efficient solution to the "ant family" housing problem, while allowing low-income young people enjoy a certain quality of their living.

Keywords: Open rented apartment, fixed region, alterable region, functional composite wall, model furniture.

INTRODUCTION

"Ant family" is a recently new popular word used in chinese network mainly for long-term" drift live "in the big cities inhabited by groups of low-income college graduates. The similarities between this college graduates and ant family are: resourceful, weakness and living in groups. “Ant family” is done by highly qualified people whom their age range is 22-29 and 90% of them are 1980 generation, and mostly are engaged in the insurance marketing, electronic equipment sales, advertising sales, catering services, temporary work, with an average monthly income lower to two thousand yuan . They have no fixed residence of the housing (or co-tenants). In recent years, due to China’s rapid increase in housing prices, these no and low incoming students have no other alternative way of living but to choosing ant family where six or seven people live in a small rented. Their living conditions are very poor and there is a lack of security.. The way of improving poor living environment in “ant family” in the big and medium cities have become very important topic for Chinese architects.

LIVING STATUS AND PROBLEM

Low income college graduates rent apartments in groups because of unaffordable high rent. Because not afford the high rent, low-income college graduates rent a widespread group of partners. The joint rented apartment have a cramped space often less than 10 □ and 3-4 iron bunk beds(Figure 1), inside is small, dark, cold. There is often cross of movement in the apartments, and difficult to achieve privacy of personal space, and hence easy to sharpen their differences resulting in conflicts. All tenants share public bathrooms, wash rooms and kitchen, which are often overcrowded and poor ventilation, lighting, sanitary conditions(Figure 2).

In the apartments there is almost no basic for fire prevention measures, equipment and fire exits, existence of law and order, fire safety, personal property, and other aspects of security risks. The apartment within a multi-use gallery layout, single-space form. As we all know, young people are not homogeneous, different households have different young people's social, economic background and living preferences, the form of a fixed residence does not meet their individual needs. In addition, young tenants often change their furniture. Therefore, a single residence form can not meet the market demands and changes, there should be an open space design thinking to create a flexible "rented apartment."

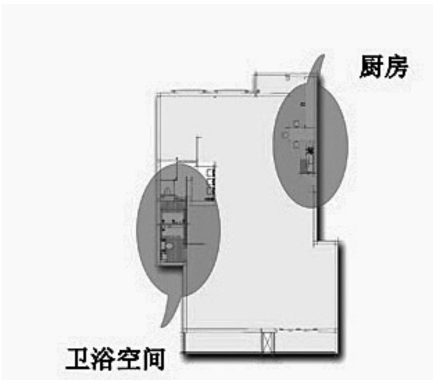
Fig 1: *Overcrowded apartment*

Fig 2*: Poor sanitation*

DESIGN STRATEGY

Open rented apartments have a fixed area and alterable area. Fixed area includes spaces such as kitchen and bathroom which constraint due to pipe lines, often set it on the edge of an apartment. On one hand, the space is conducive to natural ventilation and natural lighting, and on the other hand contributes to the achievement greater degree of freedom for alterable region. There is free combination of functional composite walls and furniture model in alterable region (Figure 3).

The whole functional composite wall is formed by a number of units connected to the wall. The shutters at the top of cell wall are set to control air flow and for the realization of indirect lighting and high-side windows, central setting controls the permeability of sight blinds, bottom setting is set to control air flow, the internal wall set the power lines, network lines. There is a support between the cell walls that has a certain vertical stability; the move does not require such strong measures to slide horizontally on the multi-variability, through a flexible combination of cell wall produce a different number of living units (Figure 4).



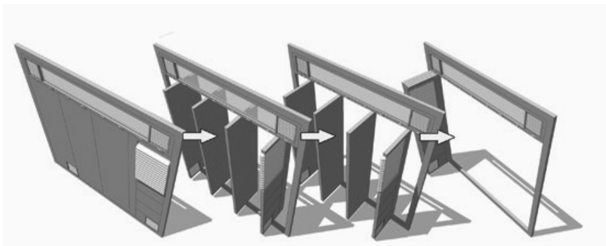


Fig 3: *Fixed Regional map*

Fig 4: *Cell walls*

At the same time, there is control of living units and public space through the opening and closing of cell walls control, hence a sense of closure and exchanges (Figure 5). Model of furniture is design according to the spatial form of living unit, in this case the triangle is used as a motive element, a flexible combination of changes in a horizontal and vertical direction, and so that every living cell has a variety of layout patterns (Figure 6). Cell wall unit in all living units coupled with different model of furniture combined to form alterable of space to accommodate different of different users.

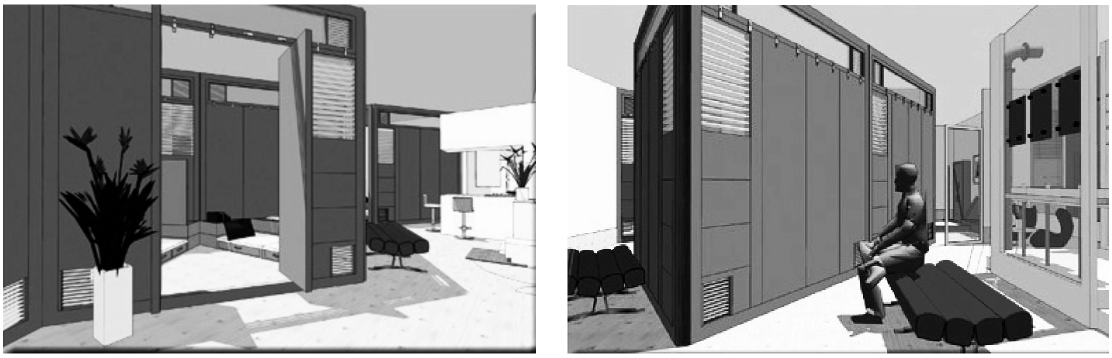


***Fig 5**: Opening and Closing of cell walls*

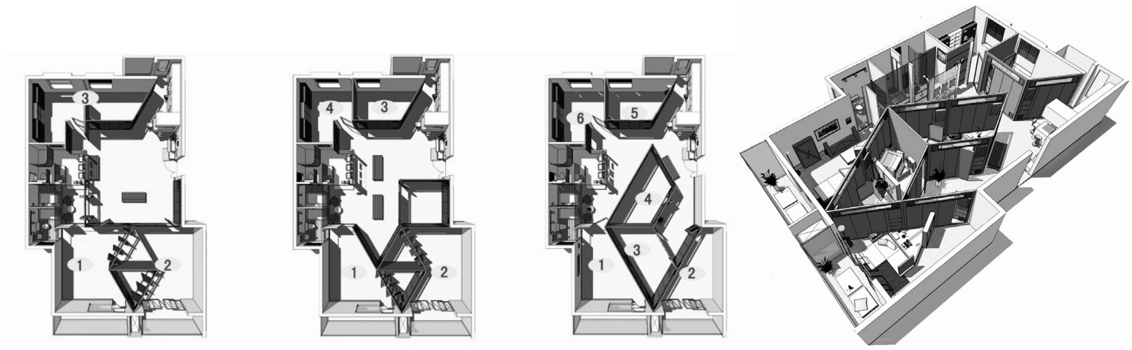


***Fig 6**: Flexible combination of cell walls*

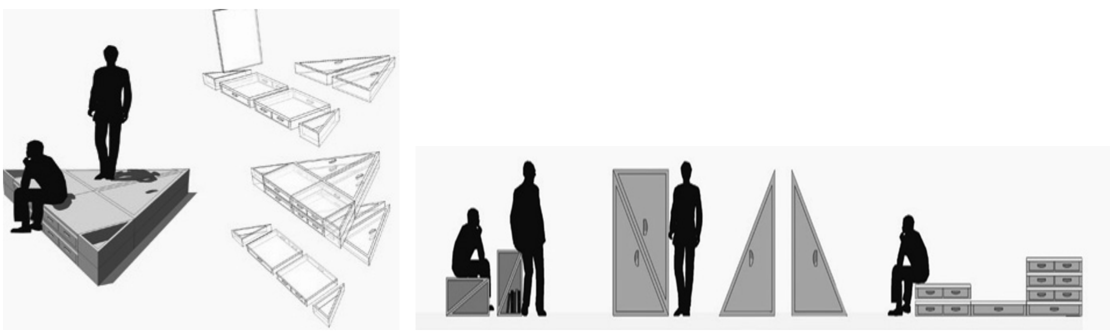


***Fig 7:** Model of furniture*

Fixed area includes kitchen and bathroom space for the public. Kitchen with open layout, dining area set up as many as possible counter dining seats, while improving the utilization of space to meet the young people in modern stylish dining approach (Figure 7). Taking into account of many people using public bathroom, features of bathing in the morning before work, public bathrooms are designed to be open-style layout to form a channel-type bathing space, which will be used by more people (Figure 8).

Lighting in apartments is design such that living units will be carried out according to the use of different separation requirements because of alterable space. So the internal functional composite walls of alterable space is set control the power cord, insert rows and network lines , but on the roof of fixed area there is a fixed lighting(Figure 9).

Fig 8: *Open Kitchen*

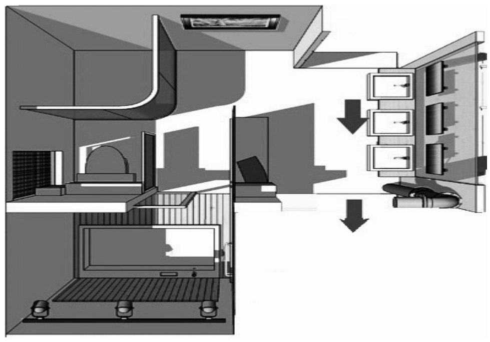


***Fig 9**: Public Bathroom*

CONCLUSION

The way of improving poor living environment of “ant family” has become a hot social concern in China. Rented open apartments bring flexible and efficient solution to the "ant family," housing problem, but also allowed to enjoy a certain quality of living for low-income young people to explore settlement patterns. With the "open architecture" concept of the continuous deepening of supporting the implementation of related policies will promote the better improvement of them.

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DIAGRAM ANALYSIS TO THE SUSTAINABLE URBAN FORM IN THE VERTICAL CITY OF HONG KONG

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ABSTRACT

Obviously the technique aspects have been the centre of research about sustainable urban development, but little has been explored related to morphology yet. This study tries to investigate the relationship between the sustainable urban development and urban morphology and then examines how to apply the morphological methods to represent the sustainable urban form in the “vertical city” of Hong Kong. The objective of this paper is introducing a research plan and a few pilot studies. This paper compares the relative diagrams of well-known sustainable buildings or urban blocks in order to find the typical characteristics of sustainable urban form represented effectively by diagrams. Under the SPeAR assessment system, this research tries to explore a simple sustainable assessment diagram system to urban form. Several high-rise urban complexes in Hong Kong with distinct functions are chosen to examine concerning the diagrams. This study is also a pilot study seeking to find new expressions related to morphological methods to describe the buildings and urban blocks.

Key words: sustainable development, urban form, vertical city, diagram analysis

INTRODUCTION: SUSTAINABLE URBAN FORM AND DIAGRAMMATIC ANALYSIS TO IT

Urban form refers to the physical layout and design of the city. It means a particular form of synthesis, an inductive procedure for indentifying the major structural (form) elements in the built environments and arranging them in a developmental sequence (Gu, 2001).

Whilst Hong Kong develops more and more vertically, the possible impacts of vertical urban form are not limited to travel behaviour; the built form also influences social conditions, economic issues, environmental quality and ecology within the city (Boarnet, 2001; Williams, Burton, & Jenks, 2000). Examining from the morphological perspective, vertical urban form going with compactness is apparently more likely to offer a more sustainable urban environment given that this form would provide a higher population density arising from either greater horizontal or vertical proximity of residents and therefore reduces total travel demand and car use(Wong, 2006)

It is raised in 2000, sustainability and urban form are closely connected in a way that fits the local context. Hong Kong's inherent compact urban form supports the current belief in the need to reduce the physical separation of activities and automobile dependence. This compactness also provides an efficient supply of social infrastructure and public service. Its high-density mixed-use urban form favours public transport, particularly for less-polluting rail systems. The community relationship is activated and the inner city is revitalized at the same time (Zaman, *et al*., 2000). Simultaneously, green spaces contribute positively to some key agendas in urban sustainability.

Many researchers believe that it is possible to define sustainable urban form through examing the certain characteristics it should posses. Sustainable urban form is the physical and spatial forms that are both cause and effect of sustainable urban development, and it is not necessarily simple or fixed patterns. (Ravetz, 2000) In *Achieving sustainable urban form*, a form is taken to be sustainable if it: enables the city to function within its natural and man-made carrying capacities; is "user-friendly" for its occupants; and promotes social equity (Williams, et al., 2000) It is also argued that urban form is only sustainable if it is acceptable to its inhabitants. Therefore, it needs to be able to adapt to changing requirements over time (Scoffham & Marat-Mendes, 2000).

Under the circumstances, the well developed theory of morphology needs to contribute to the sustainable development in practice. Since previous research about the sustainable city has been less related to the urban morphology, sustainable urban form in a vertical city is considered as one core of this research. Little consensus has been reached as to what a sustainable urban form should look like, as sustainability criteria cannot be restricted to infrastructure provision and physical environmental sustainability alone (Wong, 2006). As Peirce asserted in 1966, diagram is a useful sign for thinking, "Because it suppresses a quantity of details, and so allows the mind more easily to think of the important features". Therefore, a diagrammatic representation approach to the sustainable urban form in the vertical city would fill this vacancy and provide a direct and visual expression of how a sustainable vertical city looks. In architecture the diagram is historically understood in two ways—as an explanatory or analytical device and as a generative device(Eisenman, 1999). This paper focus on analytical diagrams, concretely, statistical diagrams and pattern diagrams. Also, this research could be viewed as a theoretically complementary part to urban morphology and urban sustainability research. While assessing the sustainable urban forms in the vertical city, the indicator systems of sustainable building need to be simplified into diagrams of morphological forms for the convenience of implementation.

As an introduction and justification of a research plan, the purpose of this paper is to introduce a research concerning diagram analysis of sustainable urban form and a few pilot studies. This research, by comparing the relative diagrams of sustainable buildings or urban complexes in Hong Kong, attempts to explore the diagrammatic characteristics of sustainable urban forms in this vertical city. Based on Arup's proven assessment tool, a simple sustainable assessment diagram system for urban form will be achieved, and be used to represent the chosen cases in Hong Kong. The proposed assessment diagrams for sustainability make it possible to locate the building projects in a simple, visual way in four dimensions of sustainability (society, environment, economy, and natural resources). The assessment diagrams show that sustainable building not only takes into account aspects related to the efficient use of natural resources but also environmental protection, economic viability and social equity issues.

This paper is an initial attempt to fulfill three aims of a larger study: (1) to explore what sustainable assessment indicators are suitable to evaluate the sustainable urban morphology; (2) to investigate what representation methods concerning diagram could be used to demonstrate the sustainable buildings and sustainable cities; and (3) to test how to apply the morphological methods to express the sustainable urban form in the vertical city of Hong Kong.

METHODOLOGY

The methodology of this research is divided into three stages that correspond to the three aims above.

- Stage 1: Explore what sustainable assessment indicators are suitable to evaluate the sustainable urban morphology.

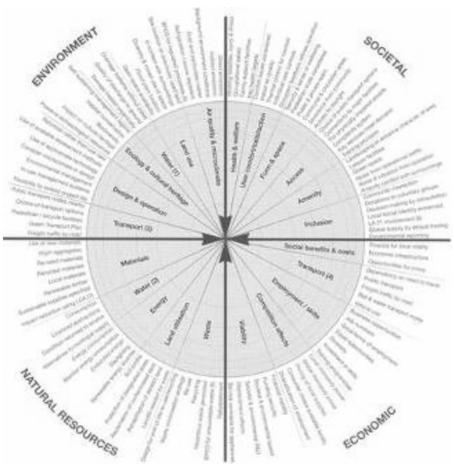


Fig. 1 *Indicators of SPeAR developed by ARUP*

The literature review of the assessment systems on sustainable urban development is the first step in this stage of the research process. The purpose is to have a broad understanding of the different assessment criteria and indicators. Arup has developed a sustainability performance evaluation tool named SPeAR(Sustainable Project Appraisal Routine) to evaluate the sustainable urban development. It broke down sustainability into four constituent parts that add natural resource part into the conventional three: social, economic and environmental (Figure 1). Each category concludes a number of indicators. These indicators seem to cover almost all the perspectives of urban sustainability effects. Therefore, the second step of this stage is to choose the indicators concerning urban morphology from this huge system.

Consequently, the literature review is carried out again to find what sustainable aspects are related to urban morphology. Urban morphology means the form of human settlements and the process of their formation and transformation. It can be realized on different scales and levels, from a city and regional scale to a neighbourhood and district scale and finally expressed at the building and site scale. As Figure 2 shows, the sustainability has time and spatial dimensions, even if these are somewhat vaguely defined (Bell & Morse, 2005). In other words, sustainability concerning urban form is not only related to natural resources or the satisfaction of spaces, it is also connected to the changes of physical urban patterns in the long term. Whitehand (2001) observed that any inherited physical form, referred to as morphogenetic, have an unrelenting and deep-rooted influence on future developments. Arguably, the urban growth process and resultant physical forms in each phase, would involve measures of adaptation and redevelopment(Wong, 2006). This research focuses on how urban morphology influences urban sustainability from the time dimension. In such a case, the urban morphology that maximizes the lifecycle of the physical form in every phase and minimizes the consumption of natural resources is likely the most sustainable.

Given the limitations in time and resources, this study could not provide an integrated analysis of all sustainable aspects. It chooses the indicators especially related to urban form. Each main dimension of sustainability is described in four features (Appendix: Table 1) for which there are reference numbers. The reference numbers are evaluated according to a simple point system. After a division of scoring, the indicators are transformed to a diagram like Figure 3 (DASSUF), which summarizes the selected sustainable features regarding urban form. The features are chosen from the temporal dimension, that is to say, these features could influence the duration of a particular urban form and the sustainability of the urban form is a direct response to these selected features.

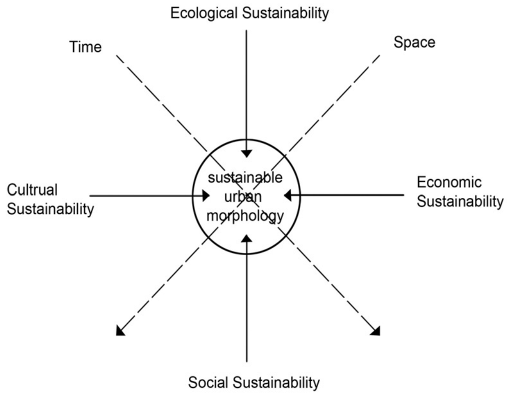


Fig. 2 *Time and Space Dimensions of Sustainable Urban Development*

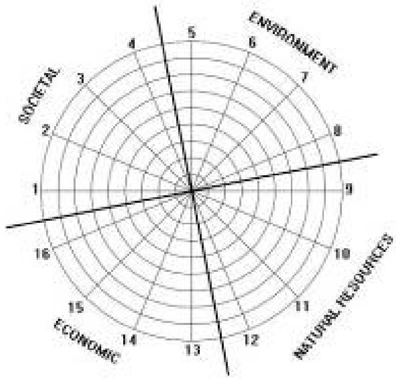
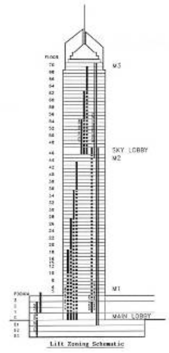
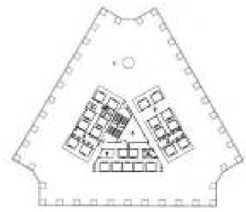
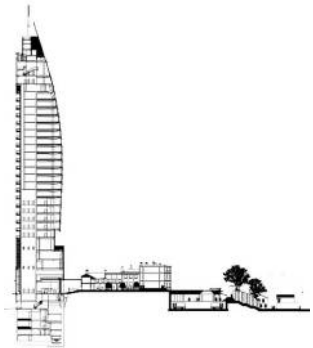
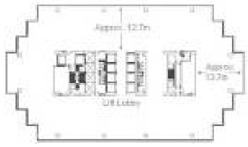
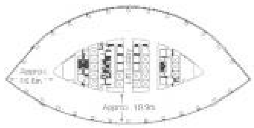
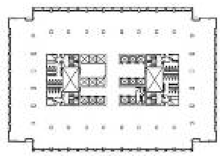


Fig. 3 *Diagrammatic Assessment System for Sustainable Urban Form*

- **Stage 2: Investigate what representation methods concerning diagram could be used to demonstrate the sustainable buildings and sustainable cities.**

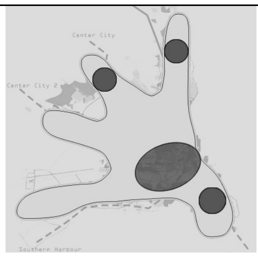
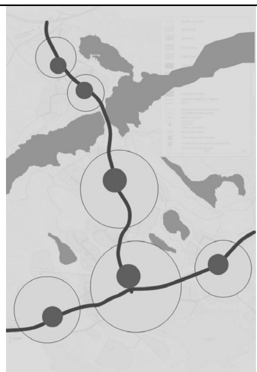
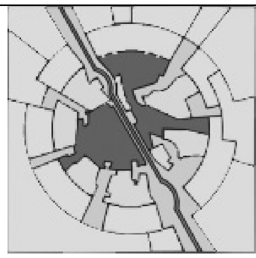
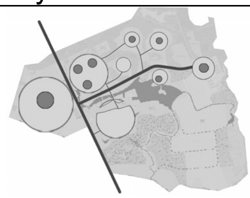
While the city becomes more vertical, we find that it is not enough to rely only on the horizontal maps during the analysis of a vertical city because it is misleading and creates misunderstandings. In this case, section maps offer another perspective to provide a complete comprehension of the vertical city regarding urban morphology. A normal master plan of cities could not provide a clear image of the structure and development track of a city, especially why it is a sustainable city. The comparative analysis method is the chief methodology in this stage. For sustainable buildings, how they are sustainable what makes them different from other buildings are the major concerns. Tables and pictures that show these fruits have been widely used. However, to read the data in tables is not simple or convenience for everyone and diagrams seem to be more obvious and clear in this case. Because of the time limitations, only four HK-BEAM certificated high-rise buildings in Hong Kong are chosen in this stage (Table 1). Their sections and typical floor plans will be compared individually with that of an unsustainable building nearby and the common diagrammatic characteristics of sustainable buildings are summarized, especially focusing on the sectional and vertical perspective. After that, four cases of sustainable cities or sustainable urban development concerning the urban form are selected from around the world to compare the patterns and proportion of different function distributions (Table 2). Finally, it will provide a good impression of how the combination of different functions lay out in the sustainable city.

Table 1 Relative Diagrams of Selected HK-BEAM Certificated Buildings

Name of building	Main function	Section	Typical floor plan
Central Plaza	Multi-tenant office complex		
One Peking	Office and entertainment and commercial		
Two Pacific Place	Office and hotel and retail		 Phase 1  Phase 2
Prince's building	Office and shopping mall		 Typical Floor Plan

(Summarized from: http://www.hk-beam.org.hk/general/home.php)

Table 2 *Sustainable Cities and Urban Developments around the World*

City	Copenhagen	Vuores	Warsaw	Tainan New Eco-city
Urban structure				

(Summarized from: http://sustainablecities.dk/)

- **Stage 3: Test how to apply the morphological methods to express the sustainable urban form in the vertical city of Hong Kong.**

Based on the diagrammatic representation method of SPeAR, the assessment indicators achieved in Stage 2 will be transferred to a similar diagram. By cooperating with the common diagrammatic characteristics of sustainable buildings and urban developments, a new system is discovered that uses various diagrams to represent the sustainable urban form. Then, the corresponding diagrams of chosen vertical urban complexes in Stage 1 are drawn. After a series of comparisons to the new system, the most sustainable urban complexes amongst the selected cases are found.. Also, the diagrams give us a visual impression of how the sustainable urban form looks in the vertical city of Hong Kong.

FINDINGS: THE DIAGRAMMATIC CHARACTERISTICS OF SUSTAINABLE URBAN FORM IN THE ´VERTICAL CITY´ OF HONG KONG

The sections, elevations, and floor plans of selected certified buildings under HK-BEAM are listed in Table 3. After a comparison to other unsustainable buildings, it is obvious that there are a lot of diagrammatic characteristics of sustainability (DCS) in the sustainable buildings or cities. The characteristics are numbered in sequence to be used as the standards of sustainable urban form.

(1) The characteristics of sectional form:

(A) like most tall buildings, they extend underground while they grow to the sky; interestingly, the depth corresponds to the height of building to some extent.

(B) In addition, skirt constructions exist in the bottom of most buildings to provide support that could revitalize the complex by attracting more activities.

(C) They emphasize the space connection in the vertical direction and most vertical connection spaces are used for circulation.

(D) Moreover, it is amazing to find that open and communal spaces are inserted indoors to offer more places for the public because of the intense land use outdoors and on the ground. At the same time, sky lobbies are common as well, which supply more communication space to users and create a social sustainability to some extent.

(2) The characteristic of floor plans:

(E) First, the aspect ratios of typical floor plans are close to 1:1; therefore, the shapes of the floor plan of sustainable buildings are nearly circular or square.

(F) Second, exterior wall and circular array columns act as constructions and the interior is flexible so users could divide the space for their own needs.

(G) Third, on each individual floor, the circulation space is put in outer areas and the rooms are in the central regions. This form usually contributes to good ventilation.

(3) After comparing the sustainable cities and urban developments in Table 4, the characteristics of functional distribution in sustainable cities are the following:

(H) On one hand, green space takes up a large area and the large areas in different districts are connected by small greenways; in this case, the green spaces are continuous.

(I) On the other hand, the functional distribution is no longer a simple lay out or combination of plots and the shapes of function districts become more complex and irregular; they are interspersed with each other. Then, mix-use becomes more and more common.

APPLICATION-DIAGRAMMATIC SUSTAINABLE ANALYSIS TO THE URBAN FORM IN THE VERTICAL CITY OF HONG KONG

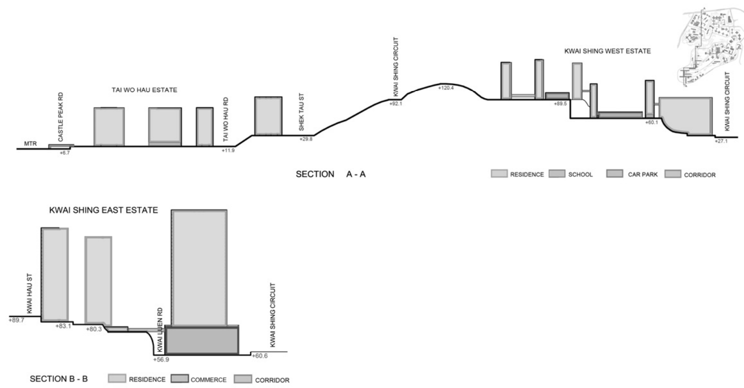
Three vertical urban complexes with distinct functions are investigated (Table 3). Each complex was developed in different periods of the late 20th century. This research tries to assess the three urban complexes by the DCS and standards developed in previous stages.

Table 3 *Basic information about selected urban complexes*

Name of urban complex	Sheung Kwai Chung residential estate	Shatin New Town	Langham Place shopping center
Construction period	1980s	1970s	2004
Main functions	Public Housing Area	New Town Area	Office Building & Hotel & Shopping Mall
Land coverage(ha)	60.2	28.1	7.9
Floor area(m^2)	2106991	1429947	167225
Plot ratio	3.5	5.08	2.11
Developer	Hong Kong Housing Authority	SUHJY[1] and Hong Kong Government	Great Eagle Group and URA[2]

The characters of sectional land use maps of selected urban complexes are compared to each standard (DCS) in Part 3 one by one to explore whether urban complex is in agreement with which standards. The DCS comparison results are listed in Table 6 if matched. Also, based on the data collected by the field survey and the archives, the cases are evaluated by the selected indicators in Table 1 (Appendix). Each indicator in this table is divided into several ranking grades and the full score is given followed by the name of indicator. For example, take "Housing types" to explain how to score. If the vertical city evaluated has only one type of housing, it gets one point; if it has 2-3 types of housing, it gets 2 points; if it fits the third condition, it gets 3 points. Similarly, as Table 5 shows, each indicator gets a score and the results are represented by the DASSUF (Fig.3). Since the assessment indicators are relevant to the form, the data are collected mostly by field investigation and examination of the sectional maps. After these steps it can be determined whether the vertical urban complexes are sustainable from the diagrammatic perspective.

Table 4 *Diagrammatic Characteristics of Sustainability*

Name of urban complex	Sectional land use map	DCS comparison result
Sheung Kwai Chung residential estate		B,E,G

[1] Sun Hung Kai Properties Limited
[2] Urban Renewal Authority, Hong Kong

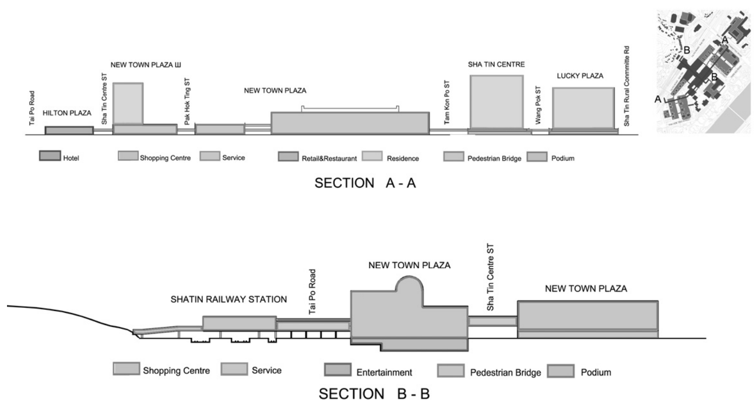
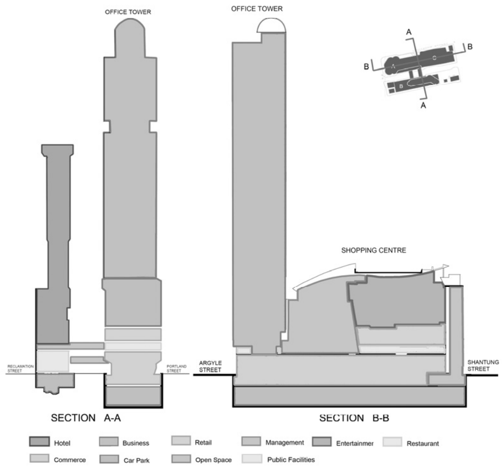
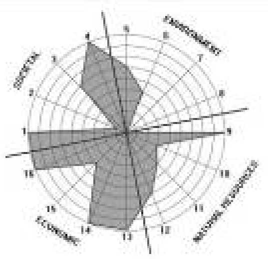
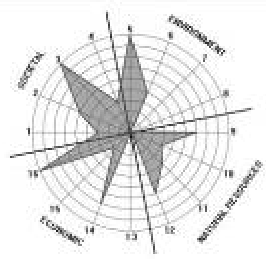
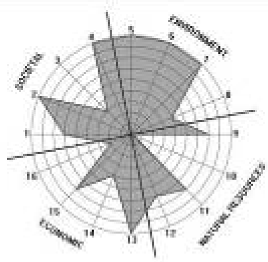
Shatin New Town		A,B,C,D,E,G
Langham Place shopping center		A,B,C,D,E,G,I

Table 5 List of DASSUF Assessment Results

Name of urban complex	Sheung Kwai Chung Residential Estate	Shatin New Town	Langham Place shopping center
Assessment result			

On the basis of the results of the comparison revealed in Tables 6 and 7, it is obvious and visual that Langham Place is the most sustainable urban complex among the three cases. In the four dimensions of sustainability, the environmental aspect is the best. Furthermore, Sheung Kwai Chung Residential Estate acts better in economic viability while Shatin New Town acts better in social equity.

CONCLUSION

This paper does not provide an overview of diagrammatic analysis results of the sustainable urban form in the vertical city of Hong Kong, but instead it identifies those aspects of the diagrammatic analysis of urban form. Therefore, it presents experimental methods related to a diagram that could particularly evaluate the sustainability of an urban form in the vertical city, and provide several pilot studies in Hong Kong. While diagrammatic representation of sustainable urban form could provide a visualized elaboration to a sustainable urban form, this research is a pilot study to help architects and researchers to understand sustainable urban form and how the sustainable urban form appears.

This research has demonstrated that the normal drawings of sustainable buildings or cities can not clearly interpret the sustainable urban form in the context of the vertical city anymore. As a complement, the morphological methods and other diagrammatic approaches illustrate the sustainable vertical cities from a formal perspective. It is evident from the pilot studies through present day that the sustainable cities cannot depend only on the sustainable techniques and materials in a traditional sense; they also have some connection with the urban forms. A standard sustainable urban form in the vertical city of Hong Kong might be concluded in the future as a reference or guidance in the sustainable city's design. In this way, architects and urban planners could project quickly a "sustainable city" only because they have a direct expression of what a sustainable city looks like, even if they don't know the details.

However, due to the time limitations, this research is only at an initial stage. This study needs to focus more on both diagram representation approaches and sustainable planning strategies in the future. In order to more precisely identify the characteristics of sustainable urban form in the vertical city, it also should choose more sustainable and unsustainable buildings in Hong Kong to compare and summarize. Furthermore, this research will conduct an analysis of the selected cases and finally put forward a systematic diagram assessment method of the sustainable urban form in the context of the vertical city of Hong Kong.

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APPENDIX

Table 1 Selected Sustainable Indicators Concerning Urban Form

Social Equity	14	1. Green Space No Green Space; Small Scale Green Space; Large Scale Green Space	3
		2. Access to Public Transport >400/ ≤ 500m; >300/ ≤ 400m; >200/ ≤300m; >100/ ≤ 200m; ≤100m	5
		3. Housing types Mono type; 2-3 types; 4 types or more	3
		4. Communal/ Circulation Areas Only Circulation Areas; Independent Communal and Circulation Areas; Continuous Communal and Circulation Areas	3
Environmental Protection	14	5. Diversity & Mixed Use Mono-function; 2-4 functions mixed use; 5 functions or more mixed use	3
		6. Open Space No Open Space; Semi-open Space; Public Open Space Outdoor; Public Open Space Indoor	4
		7. Habitat Conservation No Conservation of Old Habitat; A Bit of Conservation of Old Habitat; Large Scale Conservation of Old Habitat; New Construction Design is Based on Conservation	4
		8. Flexibility No Flexibility; Part of Flexibility; Full Flexibility	3
Efficient Use of Natural Resources	14	9. Reduction of Materials Use Mostly Ornamental Materials; Simple Ornamental Materials; Simple Materials & with Functions; No Ornamental Materials & all with Functions	4
		10. Materials Re-use No Materials Re-use;10-20% Materials Re-use; 20% or more Materials Re-use	3
		11. Energy Sources Gray Energy Source; No Natural Energy Source Use; Only One Natural Energy Source Use; More than One Natural Energy Source Use	4
		12. Daylighting No Natural Daylighting; Part Natural Daylighting; Full Natural Daylighting	3

Economic Viability	14	13. Regeneration No Regeneration; District Regeneration	2
		14. Cost of Usable Floor Space (HKD/m^2) ≥100,000; ≥70,000/<100,000; ≥40,000/<70,000; <40,000	4
		15. Journey Time More than 2 minutes from Ground to Top; 1-2 minutes from Ground to Top; 30 seconds-1 minute from Ground to Top; Within 30 seconds from Ground to Top	4
		16. Ratio of Usable Floor Space vs. Total Floor Space <0.4; ≥0.4/<0.5; ≥0.5/<0.6; ≥0.6	4

O&SB2010 "Open and Sustainable Building" – Chica, Elguezabal, Meno & Amundarain (Eds.)

DEVELOPMENTS TOWARD A RESIDENTIAL FIT-OUT INDUSTRY

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ABSTRACT

This paper outlines the background for and constraints facing the emergence of a new industry equivalent to the building industry, focused not on buildings as such but on residential interior fit-out – what users can control "behind their front door." Residential application of the distinction between base building (support) and fit-out (infill), although sharing the same principles as the well-established office building and shopping mall sectors, is particularly important because it affects a very large market whose potential is not yet exploited but is arguably nascent, and can harness the untapped potentials of industrial manufacturing in support of customized residential living.

It is well understood that industrial manufacturing processes – now becoming "product service systems" in the consumer sector – are most effective and dynamic where individual users are directly served, as seen in the automotive and electronics/communications sectors. Construction of base buildings understood as "infrastructures for living" is capable of stimulating the evolution of a fit-out industry that will itself accelerate innovation and distribution of new domestic fit-out services and systems.

In general, the creation of a genuine fit-out industry is not a technical or industrial design problem. Material subsystems and components like partitioning, bathroom and kitchen equipment, as well as "plug-and-play" piping and wiring are available or are being invented. While smart products are needed, the problem is essentially a business issue. By shifting into the provision of benefits rather than simply manufacturing products, some leading companies may find a competitive advantage in a sector of the building industry now poised for an innovation leap. In this perspective, the trend toward base building architecture allows the building industry to effectively come to terms with new and creative modes of industrial production.

Key Words: Open Building, Fit-out Industry, Product Service Systems.

INTRODUCTION

Personalization in housing is not new. Families have always personalized their dwelling places, independent of wealth, climate or culture. It is only in prisons or in military barracks that this is impossible. In rented flats, people bring in furniture, cabinets and appliances, paint the walls and put flowers on their balconies. In owned flats, families upgrade kitchens and bathrooms and rearrange spaces with new equipment even before the old equipment is obsolete.

Considered in the aggregate, this is a massive economic reality. In a development or building of identical dwelling units, a visit to the same place in 10 – 20 years will reveal customization and personalization – no two dwellings will be the same for long. The evidence for this is ubiquitous, in all countries. In the United States alone, more money is spent each year by families at home project "do-it-yourself" centers and in hiring contractors to upgrade and modify houses, apartments and condominium units than is spent on new housing construction. While cyclical, the fact remains that the potential market for infill is massive.

Thousands upon thousands of companies offer products and services in response to the demand for personalization. Most of these companies are constantly improving their products and services to maintain a competitive advantage. The national show organized by the National Association of Home Builders is a remarkable display of this phenomenon in the US. The equivalent showcases occur everywhere if not at the same scale.

Since personalization is ubiquitous, and the worldwide building industry is deeply committed to it, investing heavily to develop new products, tools, and methods, what, then, might be the next steps in for an industry already deeply involved in personalization and customization?

BALANCE

Because personalization never occurs in a social / technical vacuum, there are important constraints that must be spelled out. Most importantly, there is always the reality of "the other" - the other family next door, upstairs or downstairs exercising the same initiative. And there is the larger social system of individuals, i.e. the "community."

To be specific, my electrical appliance attaches to an outlet and cable in a wall, which eventually connects to a cable in the building and then to a cable in the street. Similarly, my WC connects to a drain line in my wall, which connects to the building's drain line, which connects to the city sewage system. And a wall or floor not under my control may divide the space I occupy from the space of another family. The levels of control thus crossed, and the territorial boundaries thus made by physical systems under the control of various parties, causes potentially complex and disruptive conditions of entanglement unless well sorted out.

Because of these physical / technical / territorial issues, consumer electronics and even the automobile - all seeing extraordinary advances in mass-customization - are poor models for the building industry. All of these devices are known not by their place in the larger fabric of the built environment but exactly by their fundamental detachment from any place.

Further advances in personalization and customization for the individual in respect to the built environment – and housing in particular - cannot ignore the inevitable territorial and technical dialectic between the individual and the group. Since neither a detached house or a unit in a multifamily building can exist in contemporary society without action by both the individual and the community, it is futile to expect further evolution of mass-customization and personalization in support of physical environment improvement processes without recognizing both forces.

In what follows, trends in the building products and services sectors are discussed, indicating a new understanding of how to release the tensions so often found between the individual and the group in the realization of personal preferences in housing. The release of such tensions will inevitably release new energy to solve the problems that have here-to-fore hampered the full application of mass-customization and personalization to the built field.

TRENDS

To survive in the competitive global market place, manufacturers and suppliers have to develop new ways to sell their products. One trend is to package core products, developing a combination of products and services, which makes the sale more attractive to customers. Consumers no longer look only for physical products, but rather focus on the benefit enabled through a value-adding service. Thus, by shifting into the provision of benefits rather than simply manufacturing products, companies might become more competitive.

According to Morelli (2002), companies are facing the challenge to align their production systems with emergent complex demand patterns. The same author also argues that there must be an understanding of costumers' needs to enable the provision of knowledge-intensive systemic solutions, or product service systems (PSS). PSS can be defined as a service-led competitive strategy, which addresses the issues of environmental sustainability, and is the basis to differentiate from competitors who simply offer lower priced products (Baines et al. 2007). According to the same authors, by considering product's life cycle, companies increase value in use for consumers by taking the risks, responsibilities, and costs traditionally associated with ownership, while still retaining asset ownership that can enhance utilization, reliability, design, and protection.

The importance of considering all stages of products' life cycle, as well as the connections with other products and services, has led to the emergence of the concept of "through-life management" (Koskela et al., 2008). Through-life management should encompass designing and producing artifacts, producing services through those artifacts, and planning for deconstruction (or disposal) of those artifacts. According to the same authors, the central idea of introducing through-life management is to create an understanding of all those stages as one unit of analysis and as one integral object of management.

PRODUCT BUNDLING

Homebuilders watching such business trends will undoubtedly notice a development called "product bundling" or "kitting", a version of PPS. This means that product manufacturers and service providers are "adding value" and gaining profit in the supply channels by preparing certain packages of building parts off-site, for easy on-site installation. Sometimes this is called "kitting", for example when an electrical contractor pre-wires all the boxes and terminations in his shop, packs all the cable whips and associated parts needed for the entire wiring installation in boxes, and brings them to the site for installation. In these instances, no "new" products are needed, only a new way of organizing the work.

The term product bundling can have several meanings. One is characterized by the legal battle involving Microsoft, charged with monopolistic practices by its "bundling" several discrete pieces of software into a unified package the parts of which cannot be purchased separately. The business literature concentrates on this definition.

In the context of the building industry, bundling refers to bringing together a number of discrete products (made or purchased) into a coordinated (integrated) package by a single company. Normally, this process occurs at a distance from the site of final installation, signifying that value is added both off-site (in preparing the bundle or kit) and on-site (in installing it).

Product bundling is similar to prefabrication, which means assembling elements – ordered by the user – in an off-site location, to be installed as a whole when it reaches the construction site it was prepared for. But there is a difference. Product bundling or kitting focuses on the delivery of packages of generally small parts **READY TO ASSEMBLE**, connoting the idea of boxes of parts small enough to get in a pick-up truck and through the front door or window of the house.

This is not particularly new. Examples of "product bundles" include a kitchen from IKEA or even a plastic - wrapped toilet bowl valve-replacement kit. Often, these products are not made entirely by the company doing the bundling (although they can be), but may be products brought together from a variety of manufacturers or suppliers. The "bundler" is an intermediate service company.

It is characteristic of a "product bundle" that it arrives at the site ready for assembly, rather than pre-assembled. This means that further value must be added at the site, but that the on-site assembly work is facilitated by the bundling together of just the right parts "designed for assembly" and sometimes also the tools for the job. The on-site work is a form of construction.

Kinds of Bundles

There are two kinds of "product bundles". One is **"project independent".** This kind of bundled product is made "off-site", but in this case, the product is not made specifically for the project but for ANY project – that is, it is made at the initiative of the producer, for a particular market segment. This kind of product is often called "manufactured." Examples of this are a Velux roof window kit; a lighting fixture with all the cables, hangers, fasteners, etc in the box; a passage door hardware kit with a variety of strikes and other parts to fit a variety of door installation conditions; a faucet/ drain/ overflow kit; and so on.

The other kind of product bundle is **"project dependent."** This kind of bundled product is also made at a distance from the building site and is prepared to facilitate on-site assembly with increased speed and quality with reduced dependence on site labor. This is the kind of production that is initiated for the project at hand. Again, the bundle is "ready-to-assemble" when it reaches the site it is intended for. Such "project bound" bundles can and usually do use manufactured parts made for the market, and brought together (cut, bent, shaped) for the particular installation. Examples include a sunroom extension from a local window/patio enclosure company; a set of kitchen cabinets the selection of which is specific to the job at hand including the countertop; and so on.

The key distinction is the locus of initiative. In the former case the producer takes the initiative and risk. In the latter case, the user takes initiative and assumes the risk.

HISTORY OF WHOLE BUILDING KITS

The housing industry in the US has experienced a number of efforts during the past 50 years at "WHOLE HOUSE" kitting. Some have failed because they were out of touch with the market and because they tried to introduce too many product substitutions out of the ordinary.

Sears Catalog Houses

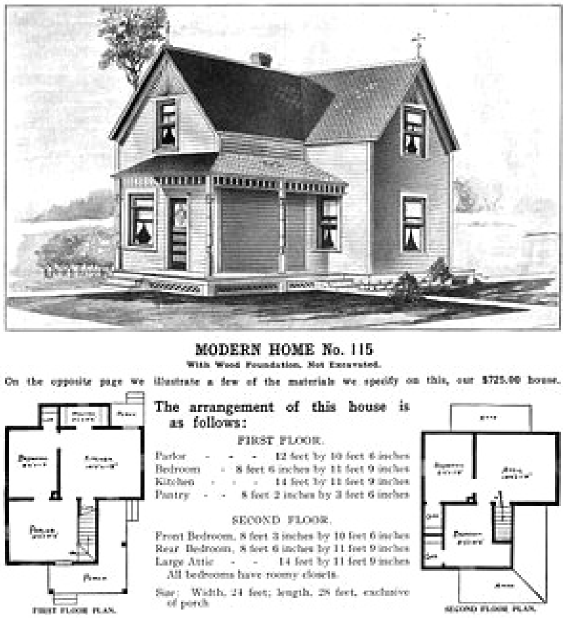

***Figure 1**: One of the Sears Catalog Houses*

"**Sears Catalog Homes"** (sold as **Sears Modern Homes**) were ready-to-assemble houses sold through mail order by Sears Roebuck and Company, an American retailer. Over 70,000 of these were sold in North America between 1908 and 1940. Shipped via railroad boxcars, these kits included all the materials needed to build a house. Sears offered the latest technology available to house buyers including central heating, indoor plumbing, and electricity. As demand increased, Sears expanded the product line to feature houses that varied in expense to meet the budgets of various buyers. Sears began offering financing plans in the 1920s. However, the company experienced steadily rising payment defaults throughout the Great Depression, resulting in increasing strain for the catalog house program. Over the program's 32-year history, 447 different house models were offered. The mortgage portion of the program was discontinued in 1934; the entire program ceased altogether in 1940." (Wikipedia)

Lustron House

Another case is the Lustron House, only several thousands of which were built after massive private and public sector investments in the late '40's and early '50's.

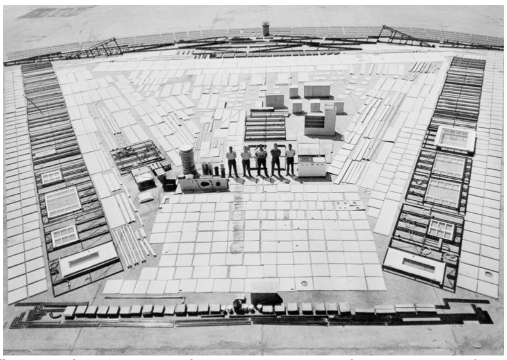

***Figure 2**: A Lustron house "kit" spread out on an airport runway to demonstrate the extensive contents of a Lustron House kit of parts. (ca 1950)*

In 1947, the Lustron Corporation received a U.S. government $12.5-million Reconstruction Finance Corporation loan to manufacture “mass-produced prefabricated” homes (a contradiction in terms – author’s note) featuring enamel-coated steel panels. The Lustron Corporation set out to construct 15,000 homes in 1947 and 30,000 in 1948. From its plant in Columbus, Ohio the corporation eventually constructed around 3,000 Lustron homes between 1948 and 1950. The Lustron Corporation declared bankruptcy in 1950.” (Wikipedia)

Techbuilt

***Figure 3**: Techbuilt panels arriving by truck*

Designed by architect Carl Koch, the Techbuilt house was – in the 1950’s and 60’s - a “prefabricated” house using ordinary wood framing in 4’-0” panel modules for the exterior walls and roof, and a post and beam interior structure with panelized floor elements. Each house was designed for the specific customer on a 4ft-planning grid, but the house package was not produced until the drawings were done and a purchase contract signed. The entire house package was delivered by truck, including the operable windows and pre-hung exterior doors already installed in their wall panels, kitchen cabinets, heating equipment, radiant heating elements, and the roofing shingles. Exterior siding (consumer choice), fixed glass, electric service and plumbing were obtained locally. A local contractor assembled all parts. A Techbuilt advisor stayed on-site only until the shell was erected and enclosed.

***Figure 4**: View of the erection of interior post and beam elements*

DEVELOPMENTS IN INTERIOR INFILL SYSTEMS

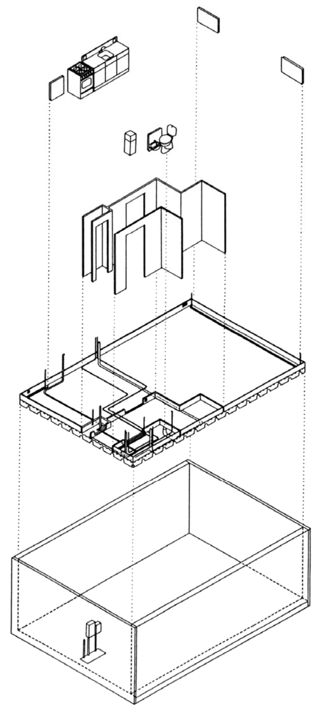

Figure 5: *The Matura concept of lower and upper systems*

Matura

Between 1990-95, Infill Systems BV in the Netherlands introduced an integrated interior fit-out product for the European market called Matura®. It was based on a decade of research at the Delft University of Technology and was designed for new construction and the renovation of older buildings. It offered fully customized residential interiors "just-in-time". Two new products were developed to organize the assembly of "off-the-shelf" products used commonly in the European market. With newly developed software that provided seamless IT management from design through installation – with pricing, fabrication, packaging and installation information and drawings – the two new products make a proprietary system that had patents in seven countries including Japan, the US and Canada.

It was one of the most advanced "product bundling' or "kitting" products for the multi-family (apartment or condominium) residential market. It focused only on the interior. The base building and main service / utility access (shown at the bottom of Figure 5) in which these packages are installed is the responsibility of someone else. The Matura "lower system" is shown in the diagram as the more technical layer containing the horizontal pipes, ducts and cables. The "upper level" contains the more consumer-oriented products such as cabinets, fixtures, finishes, lighting, and so on. That initiative produced a number of completed dwellings but eventually went out of business.

Matura 2

Now, the developers of Matura are introducing a new set of products, one of which, CABLESTUD, is in the market in Europe introduced by GYPROC.

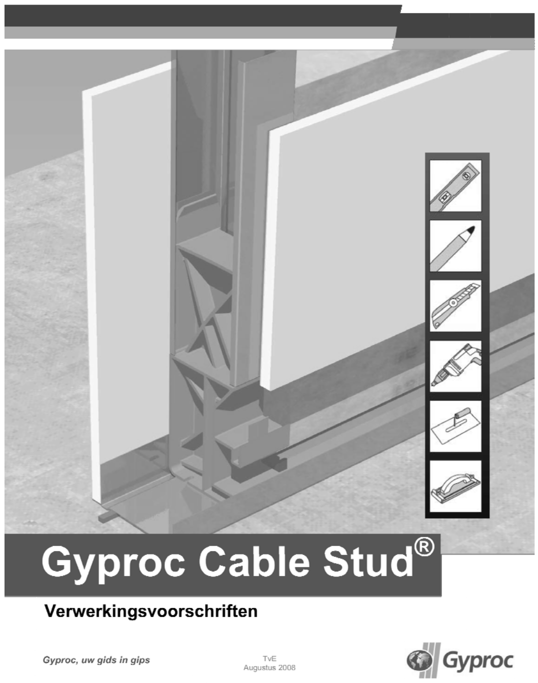

***Figure 6**: Cable Stud*

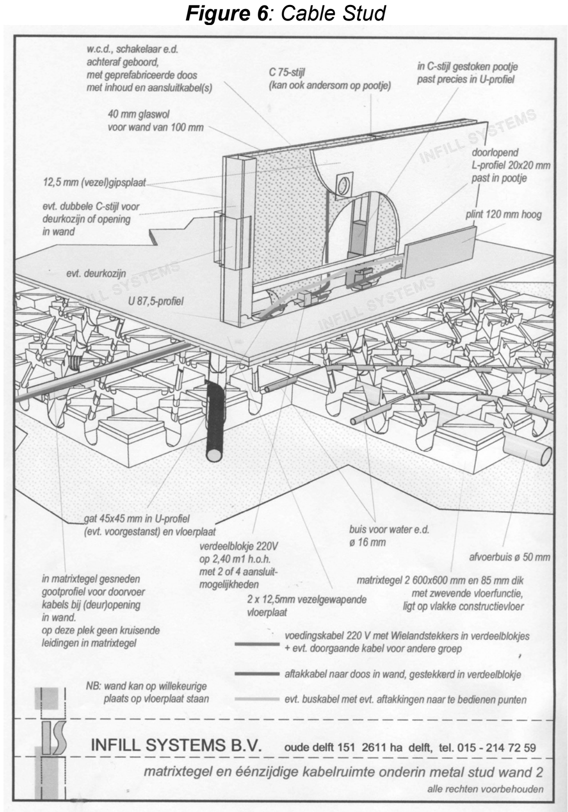

***Figure7:** Matura 2 matrix tile for horizontal pipe routing*

Whereas in the early Matura Infill System the partition and the matrix tile were technically interdependent, the new thinking keeps them separate, as the drawing at the right shows. (Infill Systems BV)

Next Infill

Originating in Japan as a product innovation initiative of Sekisui Heim, in response to the emerging demand for efficient and consumer-oriented renovation of obsolete but still useful large housing blocks, Next Infill was a product bundle including a thin raised floor under which pumped drainage and water supply piping would be placed. It also included a partitioning system within which electrical and data cabling would be placed, and dropped ceilings to accommodate other cabling, light fixtures, air conditioning pipes and the variable beams of many of the concrete buildings needing renewal. Later, the concept was taken outside of Sekisui Heim and now operates as an independent company successfully selling product bundles in the Japanese market.
(http://www.next-infill.com/index.html)

Figure 8*: Next Infill Partitions*

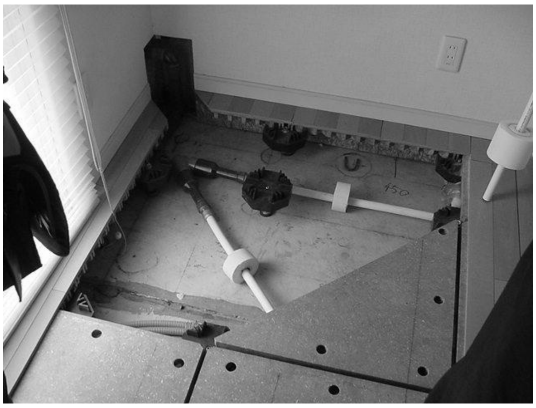

Figure 9*: Next Infill raised floor with piping*

Currently, the number of newly built private housing units for sale is decreasing for the last five years in metropolitan areas of Japan. The newly built housing market is decreasing, while the stock of second hand houses is increasing. In this context, the business practice of "buy, refurbish and sell" is growing rapidly. "Intellex" is one of those companies. They've already sold 8,000 units over the last few years, with 1,000 -1,500 units sold each year. Their share of the stock renovation market is 5.2% in metropolitan areas. They call their commodity "Renovex Mansion". The period from "buy" to "sell" is under 120 days including 20 days of design and 30 days of work. They always remove all existing infill parts (including plumbing and wiring) and "fill in" new infill. They call this way of refurbishing "Full Skeleton Reform." They have their own design firm and have developed their original design –build system. Their business practice is completely different from that of apartment building developers, because their work sites are scattered across vast metropolitan areas and each site has only one unit under renovation at one time. Their system is similar to house builders.

The "Next Infill" system is a supplier to Intellex. Two systems are delivered. One is the wooden (under layer) frame system without surface panels, applied to walls, ceilings and floors. The second system is the equipment system of plumbing and wiring. He calls this the "infra" of the infill.

Another distinguishing movement of the stock renovation market is "full body renovation of one building". "Revita" is the leading company. They are one of the subsidiary companies of Tokyo Electric Power Company. They buy company-owned (apartment) house for employees that are not so old but which the company wishes to sell for economical reasons. They renovate and refurbish the entire common area and associated piping and electrical equipment. Then they sell each unit to the people who want to dwell there, with each unit having its old, existing infill. Then the inhabitants (to be) order the renovation of their units to a builder of their choice, according to "Revita's" coordination guidelines. Revita is paid a coordination fee. "Intellex" and "Revita" are two typical business styles of the Japanese infill Industry today (Notes from Shinichi Chikazumi).

CONCLUSION

With the passage of new laws in Japan encouraging 200-year housing; with the trend in Warsaw, Poland toward open building as the “Warsaw Standard”; with the initiative of the Sato Development Company in Finland; and with the continued “adaptive reuse” of obsolete office and warehouse buildings world-wide into housing, it is only a matter of time before new companies discover the pent-up demand for “product service systems” and enter the market with residential fit-out. A well-developed consumer market is, however, a prerequisite, supported by sensible financial and regulatory reforms.

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FLEXIBLE BUILDING SKINS: AN HISTORICAL PERSPECTIVE OF REPLACEABLE PANELS ENCLOSURES

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ABSTRACT

In the later years, the tendency towards the optimization of the building process, looking for an open and sustainable architecture, flexibility concept has become essential. Open Building means the competence of the architecture to transform and adapt, when new requirements arise.

Within this flexibility concept, Enclosure plays an essential role, as it is not only the visible face of the building, which gives its character. Enclosure is partially in charge of the achievement of optimal environmental conditions of the liveable spaces. When environmental conditions required to a building evolve and change, cladding must be suitable to adapt to those new circumstances.

The struggle to reach adaptable and flexible buildings is not something new. This concept has been developed through many built examples since the early 20th century.

The aim of this paper is doing a reflection, from an historical perspective, on the evolution of architectural flexible skins, analyzing some pioneer case studies and reflecting the development of a concept that remains along the years, adapting and taking advantage of the possibilities that industrial technology allowed.

Keywords: skin, flexibility, open-building, enclosure, changeable, cladding, adaptability.

OPEN BUILDING AND FLEXIBLE SKINS

Flexible means "able to change or be changed easily according to the situation". Thus, a *flexible skin* must allow to be modified by means of easy and fast operations as occurs with enclosures formed by replaceable elements.

New situations often imply new uses or different configurations of the interior space. As every use require different relationship with the outside environment, to achieve optimal conditions of lighting, ventilation and visual communication, *flexible skins* play an essential role in the whole concept of *flexibility* in Architecture.

The paper will focus on six non-residential case studies, designed by some of the most influent architects of recent times, and based on a chronological sequence, ranging from 1930's to the end of the century. All of them are icons of the modern industrialized architecture and pursue the same goal: a flexible skin.

In order to be able to do a critical analysis of each case study enclosure, all the examples will be analyzed in 5 stages: *previous conditions* to the enclosure design, *support conditions* of the cladding elements, enclosure *element types*, *constructive features* of the elements, *fixing and jointing* systems for the cladding assembly and, finally, *placing and replacing* procedures.
This critical analysis will allow compare the selected case studies and, finally, set the evolution that might have happened thought those years, and also the aspects of the systems suitable to be improved in the future.

1 - MAISON DU PEOPLE OFFICE FAÇADE. Jean Prouvé

Clichy, France. 1935-1939

a. Previous conditions of the enclosure design

By the year 1935, the Municipality of Clichy made a courageous decision: to construct a building in an entirely *new spirit*. For Jean Prouvé this was an opportunity to make a demonstration of how the advantages of the industrial production applied to Architecture, would allow to combine several functions in the same component.

b. Enclosure support

The main frame consists in a post and beam system of steel I-section profiles, and concrete slabs. The enclosure elements are self supporting, thus each panel can be fixed directly to the steel channels bolted to the upper structure, as a curtain-wall façade.

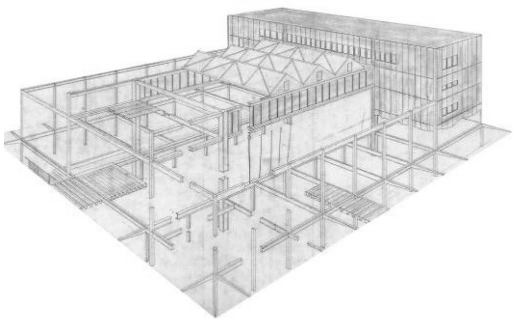

***fig.1**: constructive perspective.*

c. Enclosure element types

The skin is composed by the assembly of *sandwich* panels, 1.00m wide and 3.00 or 3.50m high, depending on the floor-to-floor distance.
There are two types of panels: solid and partially glazed. (*fig.2*)

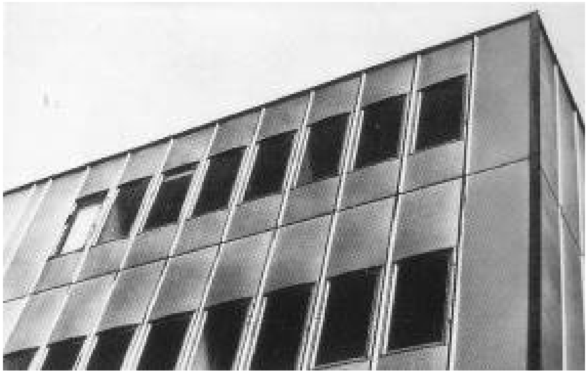

***fig.2**: Office block cladding.*

d. Constructive features

The panels are *sandwich-type*, composed by outer and inner layers of cooper-steel alloy, internally coated with 5mm of Mica asbestos and slag wool. Its average depth is 60mm. Both outer and inner layers of the panel are bellied by the inclusion of internal springs that press the metal sheets avoiding border tensions when the panel expands or contracts due to the temperature changes.

The outer sheet is also V-folded in their vertical borders to stiffen the panels and thus resist the wind pressure without additional frame. (*fig.3*)

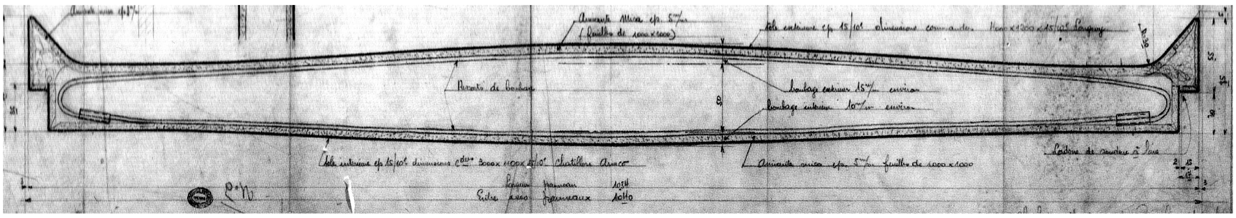

***fig.3**: detail showing V-folded edges and internal springs.*

e. Fixing and jointing

As said in *b*, panels are hung from steel angles bolted to the upper floor frame, by two *hooks* included in the upper border of the panels. These *hooks* allow the regulation of the panel position and alignment. The base of the panel is fixed to the lower panel by a tongue-and-groove lapping, which avoids panel from swinging.

Horizontal joints sealing is solved by the inclusion of asphalt strips between tongue-and-groove, which gets pressed both panels when upper panel is assembled. No mechanical fixings or adhesives are applied to the asphalt strip, so it can expand and shrink. Vertical joints are also designed following the pressure principle. Asphalt gaskets are set once side panels have been fixed and levelled. The pressure is achieved by means of an steel channel and springs.

f. Placing and replacing

As said in *e*, the panels can be easily fixed and jointed and, furthermore, they can be placed by only two people and a simple pulley. The fixing procedure implies that panels cannot be easily replaced, as the lower joint is tongue-and-groove type. (*fig.3*)

fig.4*: On-Site assembly process*

g. Criticisms

- Thermal insulation achieved by the panels would not be acceptable nowadays. However, as the insulation layer is rather thin, there are almost no thermal bridges, nor in the panel and neither in the vertical or horizontal joints.
- Although this façade still does not allow a full flexibility, the optimization of the industrial process, achieving the standardization of both panels and joints, it could be considered the starting point of flexibility in architectural skins.

2 - "PANEL" CURTAIN-WALL PATENT. Jean Prouvé

Used in various buildings. 1956-1970.

a. Previous conditions of the enclosure design

The aim of Prouvé to achieve rationality, quality, working conditions, and even economy, together with new existing developments in manufacturing technologies, such as metals moulding and stretching procedures, or the advances in insulation materials, led him to improve the system used in the Maison du Peuple.

b. Enclosure support

Prouvé followed the same concept used in Maison du Peuple.

c. Enclosure element types

The skin, as in Maison du Peuple, is composed by the assembly of sandwich panels. But in this case, the measures of the panels are variable, limited by maximum surface of 9 sq.m. Width vary from 1.20 to 3.30m, in multiples of 30cm., with heights of 2.41 and 2.70m. Panels can be solid, or glazed with multiple variations *(fig.5).*

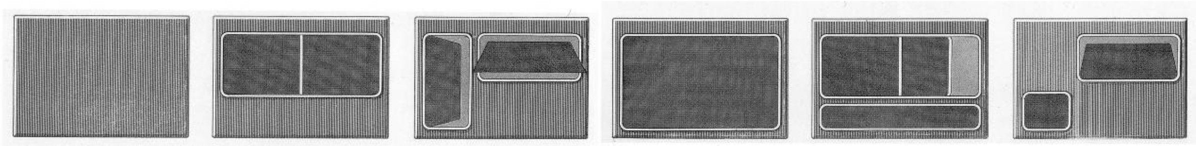

***fig.5**: different types of panel.*

d. Constructive features

The panels are *sandwich-type*, with an outer metal sheet and multiple kind of inner sheet, fully filled with injected polyurethane foam insulation. Its average depth is 50mm. Panels are reinforced with a steel frame that provides the rebates for the watertight seals. The external sheet is fixed to this frame.

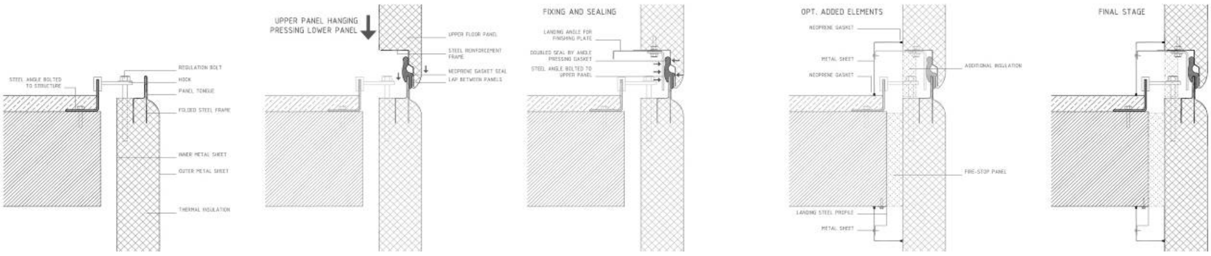

***fig.6**: panel assembly process, vertical section detail.*

e. Fixing and jointing

As in Maison du Peuple, panels are hung from an steel angle fixed to the upper floor structure, also by means of 2 or 3 *hooks* (depending on the panel width) attached to the panels, which allow its easy levelling.

Lower retention evolves: upper panel laps onto lower, placing a neoprene gasket between them. The three elements are pressed together by the inclusion of an steel angle bolted to the upper panel. This operation allows both the retention of the upper panel and the sealing of the horizontal joint. The shape of the neoprene gasket allows a *double-sealed* joint. *(figs. 6&7)*

The sealing process in the vertical joints follows the same concept as in Maison du Peuple, using a neoprene strip instead of asphalt.

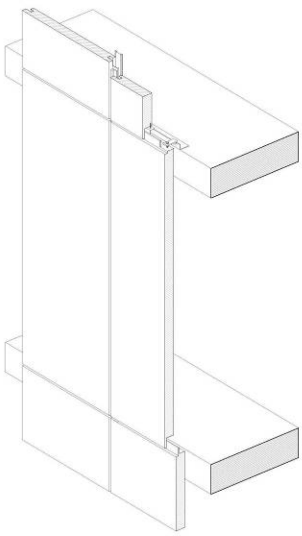

***fig.7**: panel assembly process, perspective*

f. Placing and replacing

As in Maison du People, the panels are hung as a picture by means of an steel angle fixed to the structure. The assembly of the panels requires three people working on-site: the first in the upper floor, raising the panels and levelling them once hung; the second on the main floor, placing the panels and the third outside, supplying panels and controlling the levelling process. *(fig.8).* Thanks to the evolution of the system, panels can be replaced without demounting adjacent panels, although the upper panel would remain released during the operation.

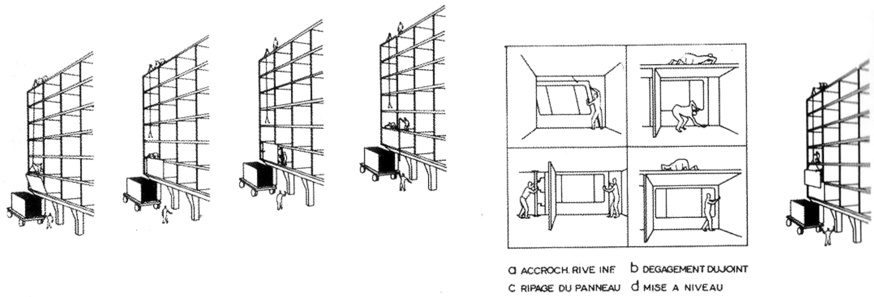

***fig.8**: panel placing process.*

g. Criticisms

- This patent becomes an important improvement of *case 1* façade system: panels can be replaced, and the thermal insulation obtained could probably be acceptable even today.
- On the other hand, thermal bridges exist in the vertical joint and, above all, in the horizontal one. Certainly Prouvé was concerned about it and the system allows the further inclusion of additional insulation in the joints. But that implies less flexibility as the insulation must be detached for panels' replacement.
- The system would also needs additional elements to round off the interior finish of the façade vertical joints.

3 - HERMAN MILLER FACTORY ENCLOSURE. Nicholas Grimshaw

Bath, R.U. 1970

a. Previous conditions of the enclosure design

In this case, the client wished to obtain a building with a great potential for change, like an organism that can adapt to suit different demands. This condition was the reason of the design of a new façade system, using G.R.P. panels which provided the building a very flexible and adaptable skin.

b. Enclosure support

The façade is supported by vertical steel RHS mullions (125x35mm ap.) spanning the six meters distance between floor and roof structure, set every vertical joint (each 1,20m)

c. Enclosure element types

The skin is composed by the assembly of *sandwich* panels, 1,20m wide and 3,00m high; plus special curved panels for corners and junction with the roof.

All kind of panels could be interchangeable: solid and glazed panels, louvered panels and doors could be replaced between them to avoid the skin change.

d. Constructive features

Each panel is composed by two sandwich *subpanels* of G.R.P. and injected thermal insulation. These panels are joined in a 6mm flange around the edges, providing and air cavity between them. *(figs. 9&10)*

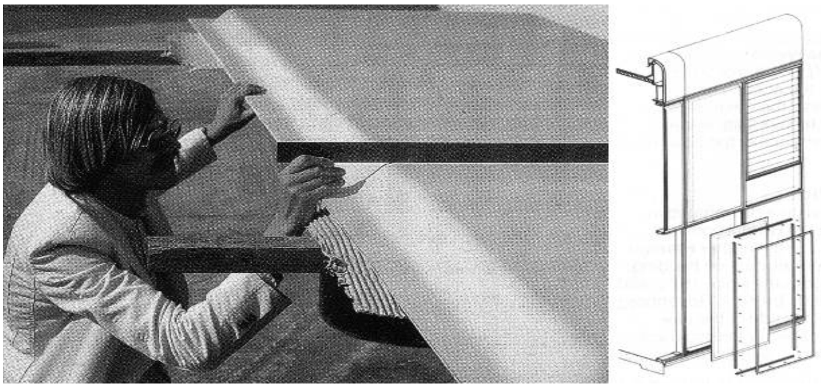

fig.9*: N. Grimshaw supervising panels; assembly process*

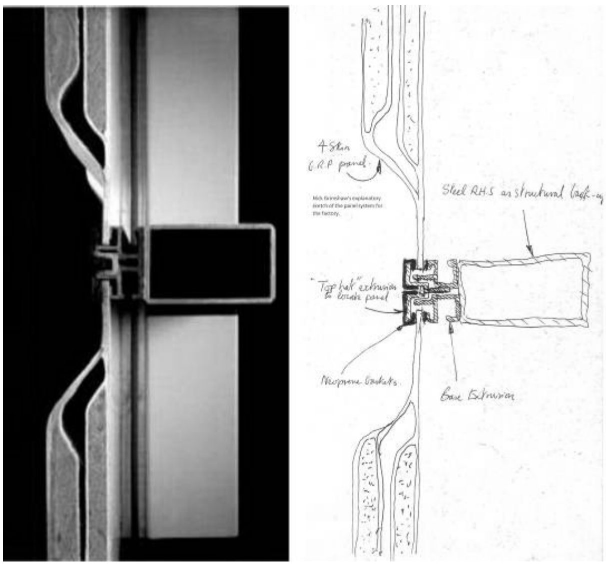

fig.10*: joint between panels. Prototype and sketch*

e. Fixing and jointing

The 6mm edge fits into a standard system of aluminium framing grid and neoprene pressure gaskets, attached to the steel mullions.

This procedure provides the double sealing between panels, in both horizontal and vertical joints, and fixes panels simultaneously on both sides.

f. Placing and replacing

As said previously, standardized aluminium framing grid is fixed to steel mullions. Panels are positioned onto the frame and attached by bolting aluminium profiles that press together panels and neoprene gaskets to the frame. Finally, outer neoprene gaskets are folded and pressed into the existing rebate in the outer aluminium profile.

Replacement is very easy, by just two people executing the inverse procedure. *(fig.11)*

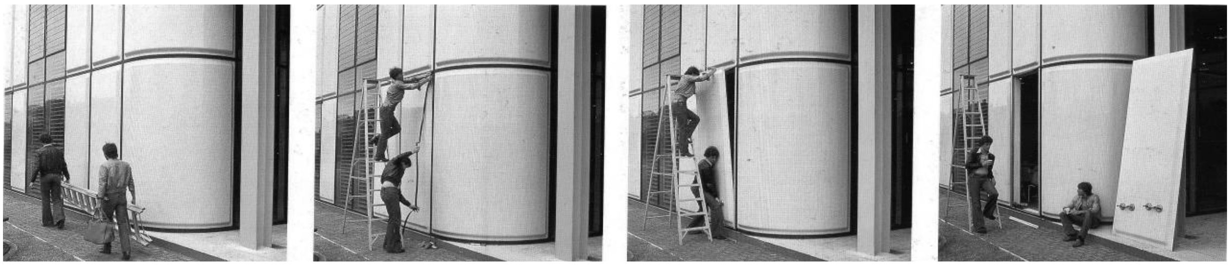

fig.11*: cladding replacement.*

g. Criticisms

- This work means a significant advance in building enclosure flexibility: the standardized aluminium frame allows the absolute interchange ability amongst all types of panels. It even would allow the inclusion in the future of any element with a 6mm flange in the edge.
- Achieving this goal implies the existence of significant thermal bridges, both in panels and framing. The panel case is due, in great part, to the economic restraints which did not allow the use of more efficient metal panels, problem that could be solved in the future by the replacement of the panels with more efficient ones.

4 - SAINSBURY CENTRE FOR THE VISUAL ARTS ENCLOSURE. Norman Foster

East Anglia, Norwich, U.K. 1974-1978.

a. Previous conditions of the enclosure design

The building has to shelter two main activities: art gallery and University services. This derived in a scheme composed by a great central space with a double skin enclosing it. This enclosure consists in two skins separated by a 2.4 wide void used to accommodate services and utilities. Due to the changing needs of this auxiliary uses, the façade should be easy to adapt.

b. Enclosure support

The 2.4m wide void also integrates the main structure: a lattice portal frame, with a triangular section of 1.80m wide and 2.40m deep. The gap between portals is also 1.80m.

This allowed that an aluminium frame grid of 1.80x1.20m, was directly bolted to the landing plates in the main portal frame. The enclosure panels leaned on that grid. *(fig.12)*

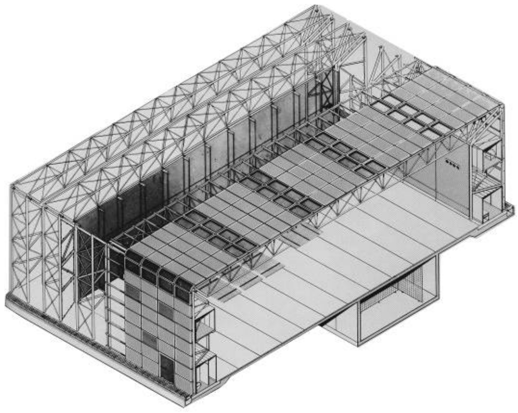

***fig.12**: construction process showing cladding sequence.*

c. Enclosure element types

Three types of panels were used to build the enclosure: solid glazed and grilled. *(fig.13)*

All the panels are the same size, 1.80m wide and 1.20m high. That means total interchange ability of the enclosure if needed. Special curved panels are used in the roof and façade junction.

d. Constructive features

The sandwich panels are composed by two layers of highly malleable stretched aluminium, with 100mm of phenolic foam between as insulation. This was made using techniques usually applied to automobile and aircraft industries.

Outer layer is folded, covering the whole edge. The inner layer is also slightly folded, overlapping with the outer. Both layers are riveted together for fixing.

e. Fixing and jointing

As explained in *b*, the aluminium grid is bolted to the structure. Each panel is fixed to this grid only by six bolts. *(fig.13)*

The gasketing system consists in a web of extruded neoprene gaskets, vulcanized in the field. Gaskets are pressed into existing rebates in the aluminium grid, and then pressed by the panels, so a double seal is achieved.

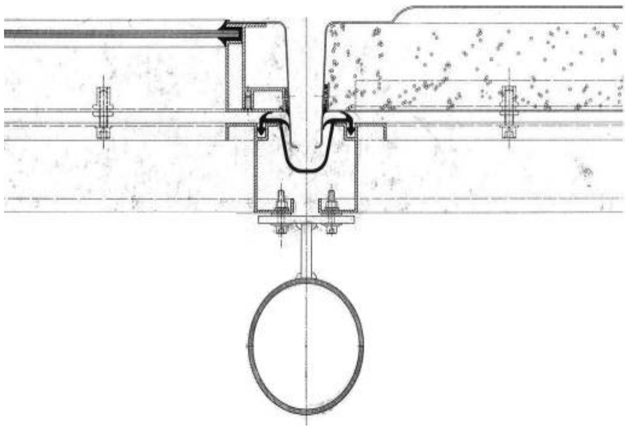

fig.13:*panel junction detail*

f. Placing and replacing

As the panel is fixed only by six bolts, and its size is only 1.80x1.20m, place or replace it will take only five minutes and could be done only by one workman *(fig.14).* Due the neoprene gaskets are placed below the panels, there is no need of manipulate any other item.

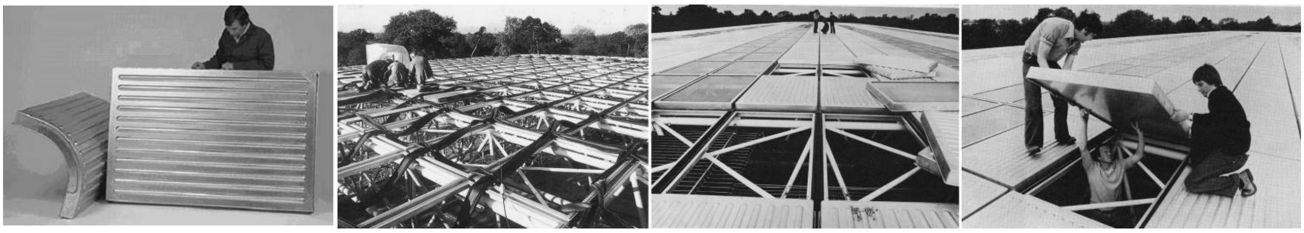

fig.14: *panel assembly process.*

g. Criticisms

- Apart from the goals mentioned in *f*, Foster´s system goes further in the achieving of flexibility. In this case, the changing needs in natural lighting, lead to extend the flexibility concept to the roof; so the same system is used to enclose it, acting the neoprene gaskets as gutters.
- As a weak point, it is important to say that a significant thermal bridge exists in the gap between panels.

5 - HERMAN MILLER DISTRIBUTION CENTRE. Nicholas Grimshaw.

Chipenham, U.K. 1982

a. Previous conditions of the enclosure design

Once again, Herman Miller asked for a budget and flexible industrial building, which could be suitable to change for the future requirements.

b. Enclosure support

The main frame comprises UC steel columns in the whole perimeter, every 3.60m distance. Horizontal steel angles are fixed to those columns at a height of 2.40 and 4.80m, as the roof frame is placed at a height of 6.00m. Façade profiles are bolted to the mentioned steel angles.

c. Enclosure element types

As in the Bath factory, there are four types of panels: solid, glazed, louvered and doors. All panels are the same dimension, 1.20x2.40m, plus special curved panels for corners and junction with the roof. Once again the interchange ability is absolute.
In this case, panels are not sandwich-type. Cladding is formed by a *versatile elements kit*, in two layers: outer and inner, including insulation, plus an aluminium frame to fix the elements.

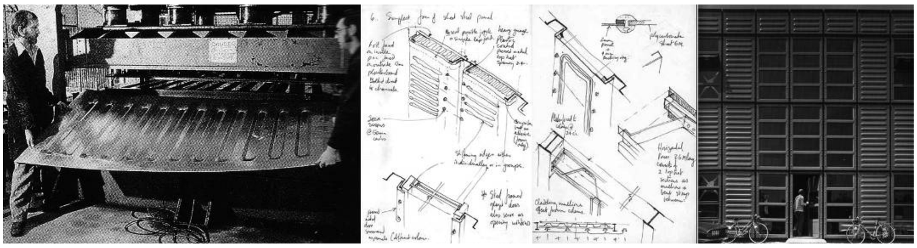

fig.15:*panel manufacturing, sketches and façade.*

d. Constructive features

The fully-functional unit, as explained in *c*, consists in a 2 layer panel. Outer sheet is made of coated aluminium, with folded edges, made by Syntha Pulvin. The inner sheet is a drilled steel panel, folded in the edges and containing a 50mm Rockwool panel. *(fig.15)*

Each layer is bolted to a double aluminium frame of 2 *Unistrut* welded together, opened in and outwards, with a gap of 80mm between them.

e. Fixing and jointing

External panels are directly bolted to the *Unistrut* channels in their vertical edges. Previously, an extruded neoprene gasket is placed between channels and aluminium panels, providing the required double sealing. In the outer horizontal joint, upper panel laps over lower and a stiffener T-shape aluminium profile is fixed together with the panels.

Internal panels are fixed by angle steel cramps, welded on the folded edges and bolted to the *Unistrut* channels. In the gap between the channels, to avoid thermal bridges, an additional insulated steel panel, 80mm wide, is pressure fixed. *(fig.16)*

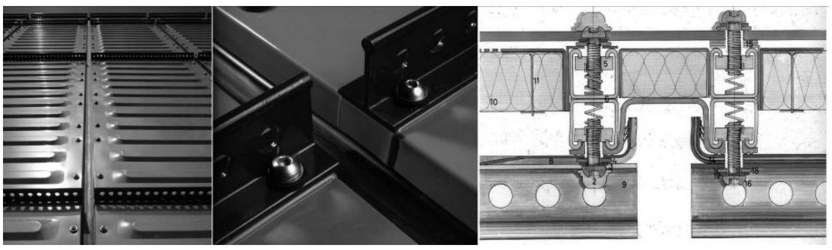

fig.16: *panel jointing, images and horizontal section detail.*

f. Placing and replacing

The placing process is explained together with the fixing and jointing process in the *e* paragraph. Replacing the skin elements, though quite simple, requires here two operations, inner and outer sheets have to be demounted separately.
However, both operations can be done simultaneously.

g. Criticisms

- From the viewpoint of the façade performance, this case is probably the most efficient, as thermal bridges are almost totally avoided, with the exception of the *Unistrut* channels.
- On the other hand, this enclosure consists in two different layers with different assembly processes, which implies that more workmen are needed. However, this allows replacing only outer or inner layers if necessary.

6 - IGUS FACTORY. Nicholas Grimshaw.

Cologne, Germany. 1990-2001.

a. Previous conditions of the enclosure design

The client wanted a building which would provide maximum flexibility to accommodate future changes. The building's design was conceived to give the capacity to change the factory layouts rapidly and frequently, with the aim to allow the frequent changes the business needs.

b. Enclosure support

The façade is fixed to a secondary structure of mullions, which are composed by the façade frame *Unistrut* channels (three profiles welded together) and a CHS steel profile, joined together by a castellated plate. This mullions span from floor level to roof frame. *(fig.17)*

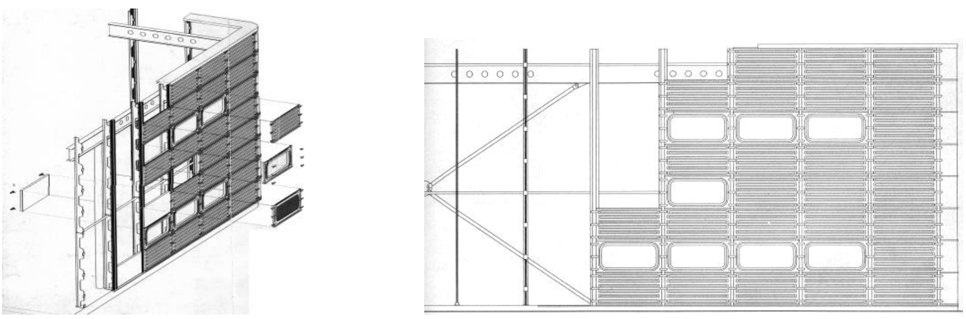

fig.17*: assembly process. Perspective and elevation.*

c. Enclosure element types

The cladding, in this case, is also formed by two different layers: inner and outer. Panels can be solid, include double glazed windows, louvre and different kind of doors. Panels are 2.25m wide and 1.05m high. Special curved panels are used in the corners.

d. Constructive features

The fully-functional unit consists in a 2 layer panel. Outer sheet is a pressed aluminium panel, folded in the edges. The inner layer is also an aluminium sheet with 100mm thermal insulation.

Both panels are clamp fixed to the composite mullions, with double function: cladding frame and secondary support structure.

e. Fixing and jointing

Both, inner and outer, panels are fixed to the aluminium channels frame by means of pairs of aluminium clamps in vertical edges. These clamps are bolted to the *Unistrut* channels, pressing together the two layers and the sealing neoprene gasket. *(fig.18)*
As mentioned, double sealing is achieved by the inclusion of a U-shaped neoprene profile between layers, by pressure when cladding is fixed.

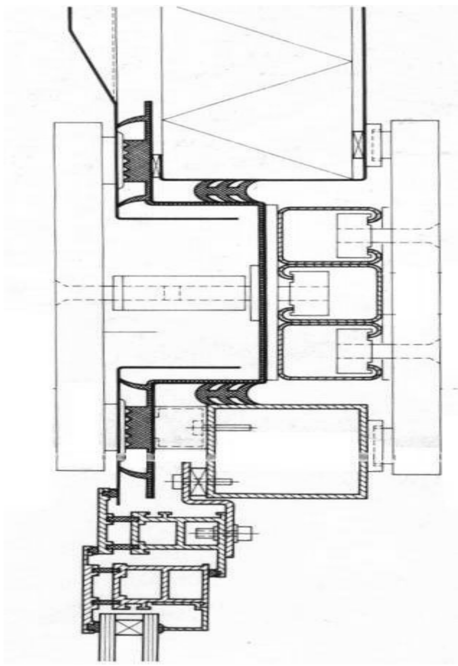

***fig.18**: vertical junction detail.*

f. Placing and replacing

As in Herman Miller in Chipenham, external and internal panels must be placed and replaced separately but, in this case, panels can be easily removed by loosening the clamps and turning them. *(fig.19)*

***fig.19**: inside view of panel fixing cramps.*

g. Criticisms

- This building means an important contribution to building flexibility, but not only in the cladding, but also the whole building is completely portable.
- Certainly there is an evolution in the secondary frame, as the junction of the mullions and the cladding frame channels optimizes the number of elements, but the panel system is really similar and thermal bridges are more relevant, even more if considering the smaller size of the panels which implies much more joints length.

LESSONS LEARNT

In all the studied cases (except *CS2*) the innovation process begins with the first approach, from a strict demand of the client for a flexible and adaptable building, not only in the enclosure, but also in the structure, inner distribution or even piping or electrical supply. CS2 goes even further: the aim of Prouvé to offer a flexible enclosure system, able to be adapted to a wide range of building types.

In spite of the different conditions of each case study, all of them share the same intention: trying to exploit to the maximum the existing industrial technology to give their buildings the best comfort conditions and flexibility, giving their clients the best value for money.

The basic principles to render this intention are constant in all the study cases:
- The attempt of using non-mechanical reversible fixings, trying to do the assembly process by means such as hanging or pressing by cramps, springs and clips.
- Reduce to the maximum the number of fixing points.
- Provide the necessary joint sealing through elastic elements pressed together to the elements. - Use the minimum amount of auxiliary elements in fixing and sealing processes.

Comparing the 6 cases, an evolution to *Open-building* can be observed: each case makes a step further to create fully-functional enclosure units composed of compatible components. That means the goal of achieving both internal and external flexibility of the enclosure (CS5&CS6).

The common aspect to be solved in the future is the continuity of the thermal insulation in the joints, without the extra addition of thermal insulation elements.

Despite the previous considerations, if there is an important lesson obtained with this investigation, is the need to innovate always starting from the existing knowledge.

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+ or – HOUSE, HOME AS A PROCESS

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ABSTRACT

Casa + o – (+ or – house) is a line of work and research in which we are trying to formulate housing production strategies in order to offer the users the chance to take part in the design and transformation process of their houses, as well as to enable an optimisation of economic resources through time by building in phases. To achieve this aim typologies are proposed to generate spatial flexibility and management models which make the user a participant in his own building project are offered.

Casa + o – was created in response to the current housing situation, associated fundamentally with investors and speculators that propose obsolete models for city planning and housing, which less and less people identify with, at less and less affordable prices.

Casa + o – is being developed through concrete experiences and specific projects, trying to make the planning and implementation process for these ideas become part of a critical reflection. We think it is important to propose construction systems and typologies that answer to modern ways of habitation. But we understand that we also need to rethink housing management models to provide greater resource flexibility, offer different purchase options and allow phases for expansion. In this way, we hope to facilitate access to housing to the population in accordance with the specific situation of each individual or group.
In this paper we focus on 3 case studies that we have done in the last 5 years.

Keywords: Adaptability; user participation; house growth; public housing

INTRODUCTION

Never during the years of our studies nor after have we heard architects and professors talk about the user other than as the person who gets in the way of you achieving your masterpiece, who chooses a very ugly floor that destroys the coherency of your project. Until one year ago we had never heard of John Habraken and open-building.

This is not an academic research paper. The aim of this paper is to share the work that we have done over the last 5 years trying to incorporate the user in the processes of collective housing. We want to share our efforts, doubts, and conclusions, to show the short path we have walked, where it has lead us, and where we would like to go next. We hope to meet more people who are dealing with similar issues, so that we could exchange ideas and benefit from each other's experiences.

This paper represents an ongoing learning process, and we are very excited to see more and more people working under similar principles: Bringing the user back to architecture, opening the processes of decision making to the user. We believe that through this process both architect and user can learn from each other and that together they could build a better environment.

We propose to understand architecture as an open software: a joint work of user and architect, a work that is never fully finished, and that grows and changes through time. We believe that it is important to create more powerful and open networks for the spreading of different notions and applications of the idea of user participation and we aim to take part in their creation.

HOUSING CONDITIONS IN ANDALUSIA

The housing situation in Andalusia when we began to work can be summarized by giving the following details: From 1998 to 2005 the price per square meter increased by 15% on average per year (an increase 120% in that period). By contrast, the Gross disposable income of family units grew by an annual average of just over 3% in that period. Currently, the housing price declines, while remaining at a high level and the exorbitant increase in supply has caused a large empty housing stock. Moreover, there is a higher rate of growth of family units, as these are becoming smaller. Therefore, while birth rate stagnates or even declines, the demand for housing increases.

Housing has become a place to invest in instead of a place to live in; it has become a priority for investments causing a price increase. This has greatly hampered access to housing for the population that really needs houses "to live in". The housing market has become highly conservative, promoting obsolete housing models with which fewer and fewer people identify. The high prices have led paradoxically to a high demand which in turn has led architectural quality generally to a very low level (if everything is easy to sale, why take risks proposing something different?).

A large percentage of brand new homes are modified before they are actually inhabited: partitions and finishes are demolished, fittings are moved, and so on… just to be rebuilt to the user’s preferences, increasing the final price, and resulting in a lack of sustainability.

HOUSING AS A PROCESS

The current dominant model in Spain has been to understand housing as a **commodity object**, which implies that the house is built at a particular moment in time, and subsequently used in the state in which it is completed. Any further processing involves costly legal and construction processes, which limit the adaptation of housing to the real needs of the user as well as the evolution of these needs through time.

Given this model we prefer to understand **housing as a process**, a process that has to be opened to increase user participation. From this point of view the house is transformed over time according to the necessities of life and the economic potential of the users. A house is not finished at any given moment, and may adopt different configurations over time. These different configurations may lead to adding, replacing or removing items as well as acquiring (or not) certain services, which implies adaptation to the changing needs of a single user over time, or to those of different users throughout the lifetime of the home. This concept has taken us to the principles of open building.

CASE STUDY 1: 8 APARTMENTS in Alcalá de Guadaira

The first experience of “+ or – house” was Alcalá 01, an eight-unit apartment building near Seville where users could participate in the design and finishing process of their homes: they could choose the degree of finishing of their house, defining what they wish or what they can afford. They could personalize it depending on their needs and financial situation. This experience was also an attempt to reduce housing prices using the architectural tools available to us, all the while being aware of the limited field of action available to an architect in changing purchasing prices in today´s market.

Main elements of the project

The building is located in a neighbourhood on the outskirts of the town; an area where the price of land is relatively low, which translated into a more affordable end price. Nevertheless, this is an area close to the center of Alcala (the old city) and with excellent transportation possibilities to Seville.

The project aims to use different reference points from the area, making them its own and reinterpreting them. It uses ceramic elements as a material for uniting and contrasting the traditional and the contemporary. Ceramic lattice is placed facing the south light filtering the vistas between neighbours and reinforcing inside-outside permeability.

Figure 2: *South view and a view from a terrace with lattices.*

In this complex most of the homes are small, in order to make them more affordable. Even so, outdoor spaces, patios and terraces play a key role multiplying habitable space and allowing transparency which visually widens the house's horizon. With this approach, these outdoor spaces have the advantage that the price per built square meter is substantially lower than that of the interior spaces. Even though each apartment is different, two basic types of apartments are proposed: apartments measuring approximately 45 m2, and duplex homes with a surface area between 70 and 80 m2.

The construction system

The building's structure has been resolved with metal beams and pillars supporting a joint sheet floor. The enclosure is 29 cm-thick thermo-clay, outside some windows ceramic lattice makes it possible to enjoy outdoor light and ventilation while reducing views between neighbours. The floor is finished by polishing the concrete poured on the joint sheet. The user has the option of directly leaving the polished concrete as the floor for his or her home or placing any other type of flooring on top. In the same way, the joint sheets can be left as they are, can be painted over, or can be covered by a false ceiling.

The design process

The apartments went on sale on a webpage www.casamasomenos.net, where the user could gain detailed knowledge of each of the apartments and the different levels of finishes on offer (+ or -). In each case we suggested a series of options to the user: starting from the standard option each user could add (option +) or remove elements (option -), thus increasing or reducing the final price.

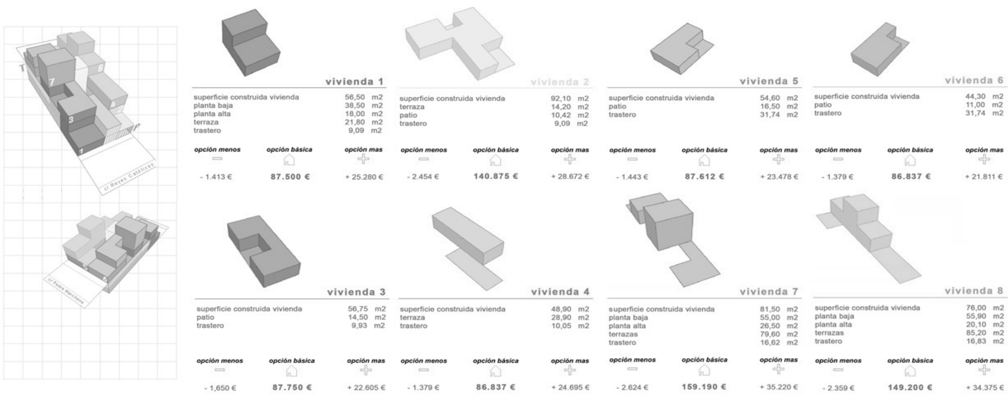

Figure 4: *web index with the price possibilities of the different houses*

Figure 6: *Different adaptations and transformations from different users .*

RESULTS

The basic option was the most popular among users. The finishes in this possibility were sufficiently rough to allow everyone a margin for transformation and improvement according to their money and needs.

Our experiences from the project for an apartment building in Alcalá de Guadaira have taught us of the necessity of formulating new mediums for creating a more direct connection and exchange of ideas between architects and users.

Because the normative system of building today requires an investor who is usually also the contractor, all relations between user and architect become indirect and mediated, thus preventing a positive interchange of ideas between them. We tried to bypass this system by creating a website through which users could have a direct access to the project and choose for themselves different options of design. However, we discovered that the majority of potential users did not use this platform and instead approached the contractor/ real estate agent for purchasing and for modifying their purchase requests.

This experience has led us to pursue the option of working with purchasing groups of private citizens, an option that allows for a maximum connection between architect and users.

CASE STUDY 2: SOCIAL HOUSING COMPETITION in La Florida.

After the case study 1 we wanted to go further opening more possibilities to the user. We decided to explore the possibilities available in the field of public housing because at the time it was very difficult to propose alternative models of housing in the private market.

The housing administration of Andalusia proposed a research competition about the future of public housing in Andalusia; the aim was to rethink the current regulations in this sector that are considered obsolete. Our idea was to propose a house type that could be extended and adapted to the needs of users. We proposed a “volume” house, of about 40 m2 of floor space and 5 meters hight. The house would be delivered with minimal finishes that would make it inhabitable from the beginning. From this point the user can modify the house, not only its finishes or equipment, but also increase the usable area from 40 m2 to a maximum opening of 80 m2 by adding mezzanines.

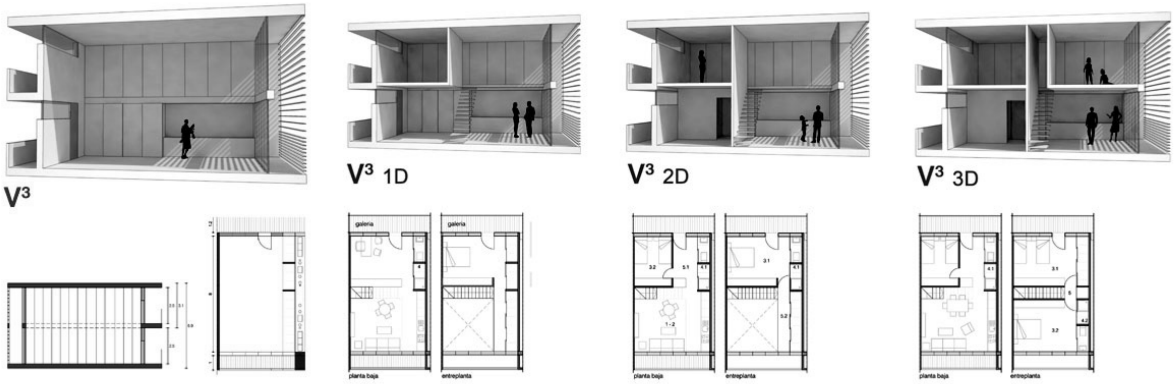

Figure 7: *Possibilities of internal growth and evolution through time .*

All interior modifications would therefore not affect the building envelope, always ensuring the integrity of the building and the keeping of optimal thermal insulation. It was a sort of “architectural bricolage”, leaving the user the possibility to build himself mezzanines and partitions, were he to need more room. All the facilities were concentrated in a technique band, which was modulated to allow the use of prefabricated elements. This “volume” house could be combined with other types sharing the same structure.

This project was chosen as a finalist in the competition, but did not win.

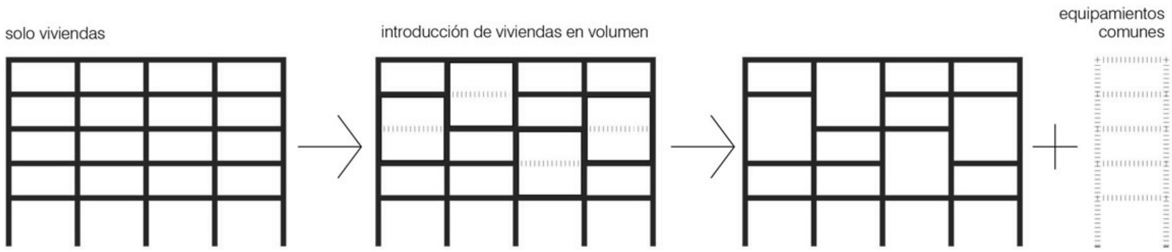

Figure 8: *Due to the use of the "volume" types the entire building surface is not constructed in the beginning, and because of that, more money can be invested in common spaces, allowing people to invest more money in their home when needed*

CASE STUDY 3: SOCIAL HOUSING COMPETITION in Velez Rubio

In this proposal, we tried to further develop the ideas of the earlier case study. The house is defined as the aggregation of modules of 24 m2, an intermediate size between a living room and a bedroom as defined by the rules of social housing. This space of undetermined use is connected to a technical service area of 5 m2(bathroom or kitchen). The modules are placed one on top of the other, thus forming a space 5.25 meters in height.

This module organization allows a differentiation of environments with minimal use of partitions, and an optimization of usable floor area by reducing corridor space. Moreover, the double height enables the extension of the living area by building a mezzanine floor which allows the adaptation of the house to the economic and physical needs of the user.

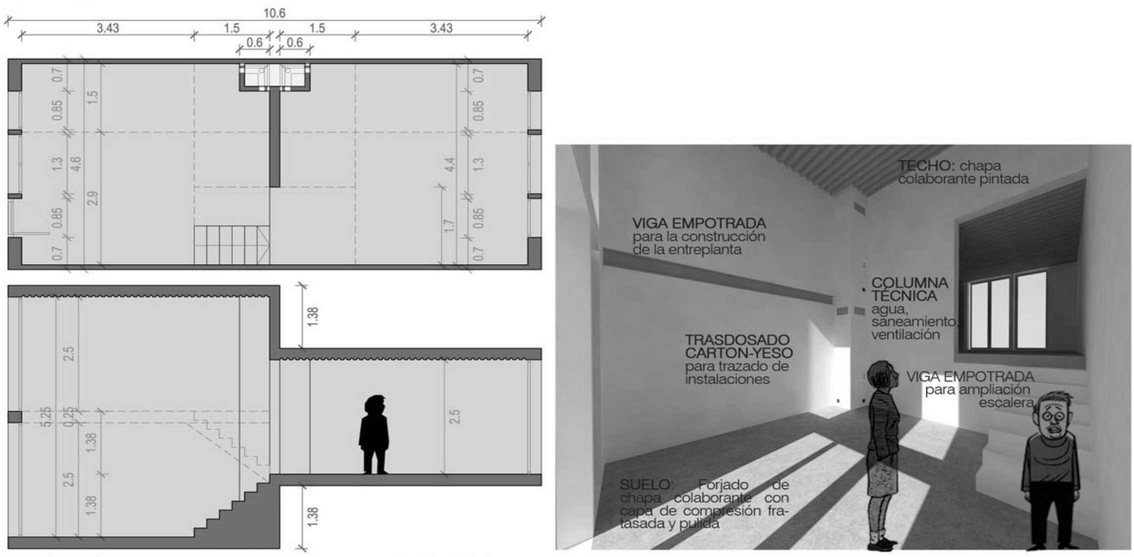

Figure 10: *Floor plan and Section of the house type.*

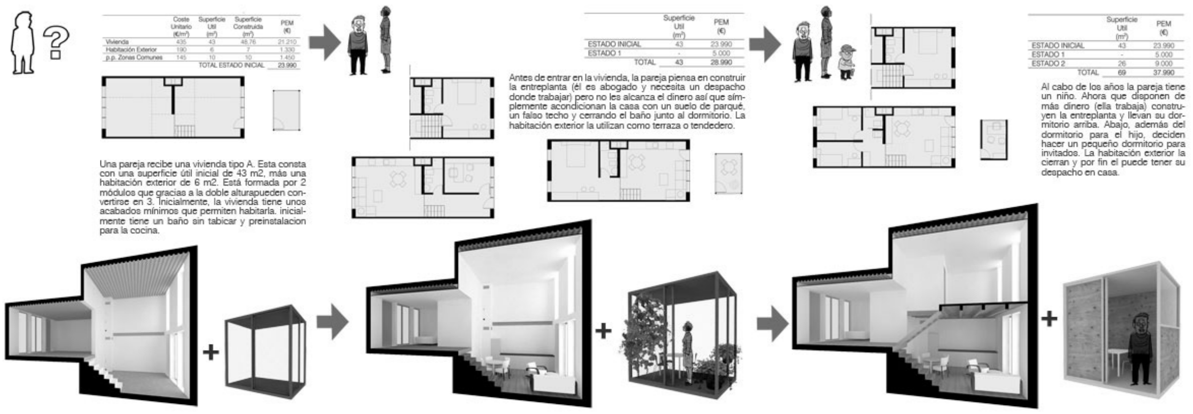

Figure 11: *prototype* development in time.

We devised an imaginary scenario of an evolution of one module apartment:

1. A user receives a house. This includes a usable area of 43 m2, plus an outer room of 6 m2. It also includes the possibility of building 21 m2 more inside as a mezzanine. Initially, the house has a roughly- finished floor that could be covered according to the taste of the user.

2. Before living in the house, the couple planned to build the mezzanine (she is a lawyer and needs an office) but did not have enough money so they just added a parquet floor and a false ceiling. The outer room was used as a terrace and a utility room.

3. Over the years the couple had a child. Now they had more money, built the mezzanine and moved their bedroom upstairs. Below, in addition to the bedroom for the child, they decided to make a small guest bedroom. the outside room is closed so that finally she can have her office at home.

The building initially didn’t utilise the entire surface, allowing the house to be consolidated over time by the building of mezzanine floors and by the occupation of the outer rooms. This allowed the distribution of the cost of housing over time, and had two consequences: The initial cost of housing is lower, and the investments are tailored to the user´s needs and possibilities.

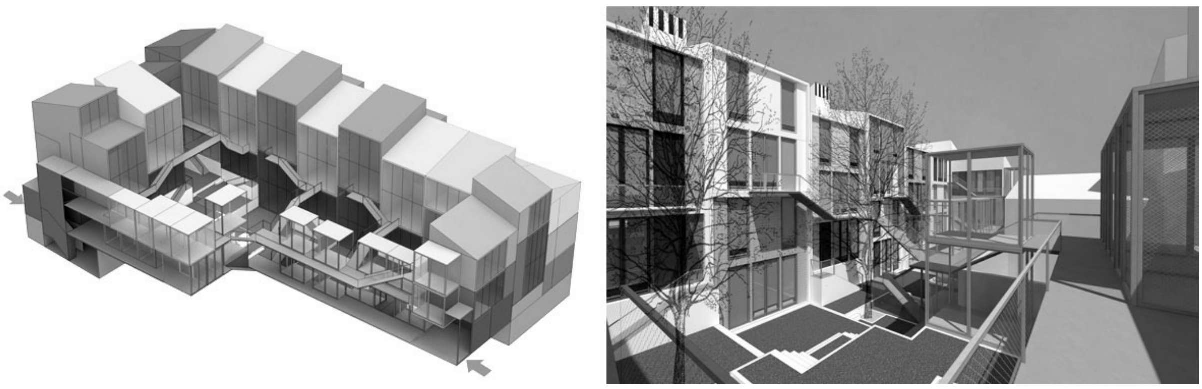

Figure 12: *General view with the common spaces and the outside rooms.*

This proposal was not chosen, but recently, due to the publication of the project in an architectural magazine, we have received a call from the metropolitan housing consortium of Seville contracting us to do a viability study of this prototype so that it could be used as a public housing model for young people. We're currently working on that.

CONCLUSIONS

Our experience has led us to realize the importance of creating an online platform that could function both as manual and archive, gathering together different ideas and experiences regarding the concept of user participation and thus allowing for a more lively exchange of ideas, as well as for the dissemination of this concept throughout a more extended and diverse group of potential users/ architects. We are now in the process of developing this project with the support of a research grant from the Housing and Land Regulation Department of the Regional Government (Junta de Andalusia).

As well as an online platform we are looking into the possibility of creating a printed manual gathering different concepts and principles of open building within the context of public housing. This manual would be distributed to functionaries and people participating in building comities in the public administration of Andalusia. We hope that a manual like that might help in introducing the administration to new options for affordable public housing, options that take into consideration the needs of different users, as well as the necessity for a home that can change through time with the changing needs of its user.

These suggestions and more are for us open questions awaiting open answers…

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INDOOR FLEXIBILITY BY INDUSTRIALIZED METHODS: A WAY TO IMPROVE USE OF DWELLINGS

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ABSTRACT

This paper will examine flexibility and its relation to an Open Building Industrialization.
Flexibility means adaptability to the different ways of using buildings, easily and within short time.
Flexibility is suitable for both space planning, inside the building, or, the exterior envelope, the skin.
Inside Flexibility increases the options for using dwellings, as rooms can be resized and adapted easily to the different conditions dwellers live, indoor space is maximized without demolishing any of the dwelling.
Flexibility for office, commercial buildings, or factories has been always mandatory.
Flexibility improves the way space and functions are employed in different circumstances, taking into account the number and the needs of the dwellers; their age and requirements.
Flexibility and its value has been known during all 20$^{th.}$ Century, although it has not reached dwellings.
Tools for flexibility have not evolved as industry has, but we can evolve those tools providing light industry with products and instructions in a sort of Do It Yourself procedures.
Nowadays indoor flexibility could provide comfort and quality of life rather than only aesthetics or saving space solutions. Architecture must be useful for human needs, not only for economical proposals.

Keywords: Flexibility, dwelling, open building industrialization, acoustic, progressive habitation.

OBJETIVE OF RESEARCH: INDOOR FLEXIBILITY, A CHARACTERISTIC TO BE ACHIEVED AT SOCIAL DWELLING

Flexible, is becoming a common adjective when describing qualities and progress of dwelling.

Flexible, as happens with industrialized or ecological, is been used mainly as an adjective for commercial purposes; just because these qualities can make look better a product to be sold.

In order to avoid indoor flexibility as a commercial purpose, with no true value, we should know what it is, why it is worthy, when main examples happened, why it is not often used for social dwelling, and how we can make indoor flexibility as a useful characteristic of dwellings without repeating those common mistakes indoor flexibility has shown.

With all that information we can face to industrialize a low cost indoor flexibility as an evolution for social dwelling.

WHAT IS A FLEXIBLE DWELLING? OUTSIDE - INSIDE FLEXIBILITY

Flexible is the ability to adapt to the different conditions and needs.

Flexibility is seeing in advance what are the possible evolution and improving of the building, keeping them open for the incoming future, while maintaining comfort and quality of life; all over the different stages that users and dwellings will pass together.

Flexibility allows dwellings to adapt themselves easily to users needs.

Outside Flexibility (flexibility at envelopes)

Conditions Outside the building depend on weather (natural issue) or pollutants (artificial issue).

Weather, as natural issue, involves day & night, summer & winter, rain & sun, snow & storm. Pollutants can be from different nature: toxic, light, noise; even we humans are pollutants.

Outside flexibility needs innovative bioclimatic envelopes ready to adapt themselves to the different conditions, so they can match efficiency i.e. summer and winter; day and night conditions. Those envelopes will need to be improved during the life of the building.

Outside flexibility it is not a longer matter at this text.

Inside Flexibility (indoor flexibility, floor planning flexibility)

Inside flexibility is the ability of changing and improving spaces easily to the different needs and conditions. Conditions inside dwelling depends on human beings, our needs and desires.

Indoor flexibility, as architecture, should provide comfort and quality of life. Inside flexibility adapts dwelling to allow and enrich human being needs as it maximizes floor planning.

Inside flexibility does not mean the indeterminacy of empty rooms; as it is seen frequently when flexibility is just only for commercial purpose.

WHY INSIDE FLEXIBILITY MUST BE TAKEN INTO ACCOUNT?

Dwellings are supposed to be made to accomplish the needs of the users, human beings.

We, human beings, are social beings with economical, medical or other limitations.

Social being involves friendship and family. And living together, alone or however.

Spanish home market is rather static: property and renting relationship is approximately 5:1. A family uses the same dwelling for a long period of time: 15, 25 years or even more than one live. Emancipation, marriage, birth, childhood, divorce, emancipation, ageing, sickness, death, etc. Those can be used as the main words that describe the enormous variability of a standard family.

The traditional concept of dwellings based on corridors, rooms and doors can not face the evolution of homes that, by the other side, flexibility allows; in order to satisfy users' needs.

ARE FLEXIBILITY OR INDUSTRIALIZATION NEW WORDS AT ARCHITECTURE?

Nevertheless, flexibility and industrialization were together at the early XX century.

R. Buckminster Fuller, proposes at 1927 both Dimaxion house, and its industrialized 12 floor dwelling building: 45 tons of steel, glass and aluminium alloy to be Zeppelin transported.

Le Corbusier "*la habitation en série*": A structural grid where multiple floor plans can fit.

Gio Ponti teaches some great inside flexibility examples ("uniambient home for 4 people", DOMUS magazine, 1956. "la casa adatta" Eurodomus 3, Milán 1969).

John Habraken's work at S.A.R., during the 60´s and 70´s, shows again and compiles how important porticated and industrialized systems are for dwellings and flexibility.

Joe Colombo's short life was full of interesting works for improving dwellings trough industrial possibilities like : "Eurodomus 3" Milan 1969 and "Total Furnishing Unit" MOMA N.Y. 1972.

More Recently: Abalos y Herreros ("habitatje y ciutat" contest 1990 Barcelona), Alan Wexler (Crate House, New York 1991), Aranguren y Gallegos (Bentaberri home contest, Donostia, 1993), Josep Bohigas ("Espai Elastic" at CONSTRUMAT Barcelona 2007).

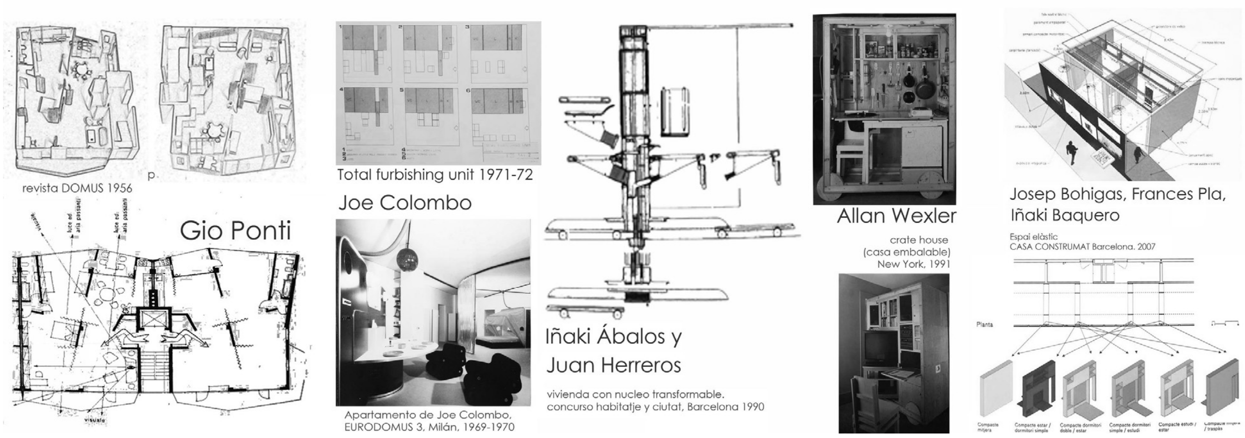

Figure 1: *State of art of indoor flexibility. Left to right: 1956, 69-70-71, 90, 91, 2007.*

WHAT ARE PEOPLE´S REQUIREMENTS FOR DWELLINGS?
COMFORT AND QUALITY OF LIFE (C. & Q.L)

We need quality of life at our homes. We, as users and inhabitants of dwellings, need a place to develop ourselves at multiple situations: rest, clean ourselves, feed, joy, increase our culture, raise a family, work, study, communicate and feel like a useful human being.

C.& Q.L. do not depend on having the best technology gadgets; although it can help.

C.& Q.L. can be fitted at five easy and primary requirements: private life, roomy indoor, customize, and a low cost to maintain the dwelling; mother earth and human respect is assumed.

Private life: sense privacy.

Homes must provide privacy, not only from the outside but, from neighbours and flatmates.

A lack of privacy disables comfort and quality of life.

Noise is the origin of most of dwellers complaints.

Acoustic and visual isolation allows privacy, which is one of the most important needs of human behaviour. Privacy allows us to use the home for work, leisure, study or whatsoever.

Roomy indoor: spacious, organized and ready for multi-purpose resizeable rooms.

Human needs tools. They are very useful things for our life, like clothes, cleaning kits, electronic appliances, kitchen or hardware stuff, etc. An organized storage makes tools ready to use, if not, any search for tools includes wasting time. Wardrobes are useful.

Inside flexibility organizes and evolves space and tools to accomplish easily the needs of users.

Accepted standards which measures human activities, like Neufert bauentwurfslehre, can only be used as minimum measures.

Low cost of maintenance: energy consumption, repairing and transforming the dwelling.

More than 60% of energy consumption is used in thermal comfort.

Although transforming the dwelling is rarely applied, fixing or repairing it locally will happen more often. All these can be very expensive if dwelling is not designed and built for.

Sustainability is a relationship between produced and consumed energy and materia.

Customize.

Human being needs to feel useful and different one from each other.

Customize needs compatibility between products from an open and smart industrialization.

Dwellings, as computers, can be made ready to face plug in solutions. Customizing is also adapting to new incoming technologies.

ACHIEVING FLEXIBILITY: SETTING THE BUILDING SHOULD NOT CONDEMN FLEXIBILITY.

Building can be made with set or unset parts depending whether they can or cannot change position during the life of the building.

A wrong chosen relationship between both of them can condemn options for indoor flexibility.

Set parts cannot change position: structure, drainage, venting, shared systems.

Set parts are immutable, they are always at the same position during the life of the building because the are usually shared between different users.

Structure, stairs, elevators, drainage and venting are the most important set parts of the building.

Set parts provide conditions for modifying floor planning. Set parts decide whether a building is flexible or not. Set parts can condemn flexibility.

Indoor flexibility for the XXI century ask set parts to allow multiple choices, in order to attach the unset parts when changing position.

A structure that allows evolution: Anchorage decision.

Structure must prevail different stages of the building according to the evolution of the envelopes, the installation systems, or indoor evolution.

Structure is defined by the anchorage system that is used. Anchorages decide how quick, easy, resistant and thought for the future the structure is. Anchorages decide how the building is made.

During the life of a building, structure, envelopes, systems, the building itself, will be under inspection, it could be evolved or repaired too. It can also be dismounted and rebuilt at another site. A correct decision for the anchorage system will prepare us for the future; at a low cost.

Flexibility associates with big spans, but floor vibrations can be uncomfortably felt by dwellers.

Plumbing, venting, and other shared systems must become multiple choice plug-in.

Installations are needed to supply water, heat, electricity, communications, etc. They are needed for venting. They are necessary to drain out used and wasted water, they can be very noisy and must run vertical across the building. Among entire life of the building.

We must think about using multiple choice, changeable, plug-in solutions for needed systems.

We can find at Europe many industrialized solutions made in some valuable technical polymers.

Service wall panels, which are useful, should be designed again according to nowadays principles of flexibility i.e. an easy access to allow multiple choice along the life of the building.

Unset parts can be moved: partitions, equipment, furniture, individual systems.

Unset parts can change position whenever the dweller decide to pay for it, i.e.: ceilings, indoor partitions, furniture, individual systems, even non structural envelopes should be taken as unset.

Attachment of unset parts should be prepared in advance, flexibility concerned, so dwelling will be prepared to admit easily any option user decide.

Flexibility asks unset parts to be versatile, easy to change, we ask them to be plug and play.

INDOOR FLEXIBILITY'S
TWO METHODS FOR EVOLVING THE DWELLING

First of all, flexible is thinking dwelling for being improvable since the first moment.

Dwellings can be improved, through inside flexibility, by 2 related methods: modifying the dimensions of indoor spaces, or improving systems and equipment to face more uses.

Modifying the dimensions of interior spaces (rooms)

Nowadays at traditional dwellings, function is adequate to the room; rooms are adequate to laws and economical possibilities. By the opposite, flexibility adequates room to its function.

A bigger room means that another one must be made smaller or joined together in order to have a big indoor space. That big indoor space can be useful for many things.

A human being can not use two rooms at the same time, but a family can. Due to the multiplicity of activities a logical planning, according to users' needs, must be taken into consideration.

According to the human being needs, the equipment that gives function to that space should be plug & play and easy to store when unused or when redistributing indoor space.

As we will see next, there are some tool types like i.e. panel walls or big sliding doors, that can face modifying dimensions of indoor spaces in a few time and with no cost.

Improving installations, systems and equipment. Adapting to new technologies.

This means evolving and improving water or heat net, electric, communication or other systems.

One of the main problems when evolving a building is to adequate and improve those systems to face the requirements of new times or a new floor planning. Those systems are made static and hard to evolve; even when we know they will need to be repaired during the life of the building.

Compatibility and multiplicity is needed to improve access and evolution of systems and nets.

INDUSTRIALIZED TOOL TYPES THAT CAN BE USED TO ACHIEVE INDOOR FLEXIBILITY BY MODYFING THE DIMENSIONS OF INTERIOR SPACES.

There are 4 tool types to allow flexibility at floor planning, according to a 1976 classification made by Joaquín Grau Enguix: Capsules or boxes, screens, wall panels and wardrobes.

Designing a flexible and industrialized building concerns knowing the possibilities of the tools which can be acquired and of those which can be designed and industrialized for first time.

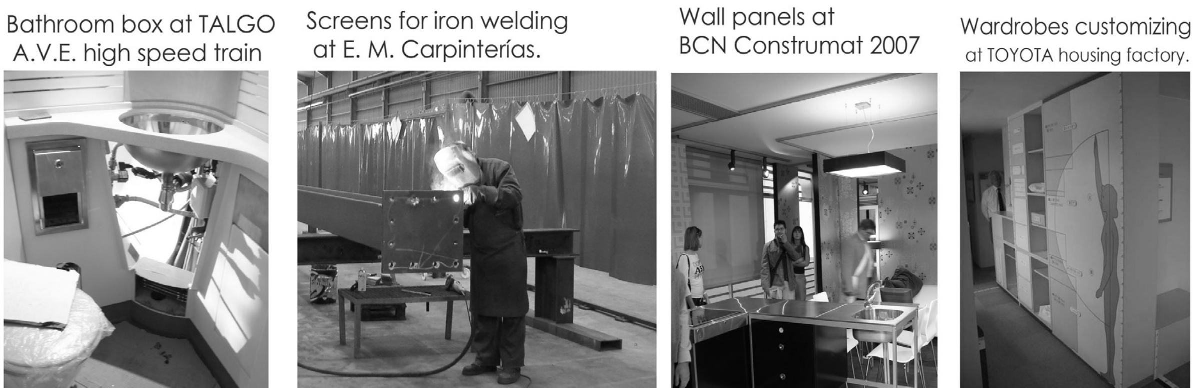

Figure 2: *Tools for flexibility. Boxes, screens, wall panels, wardrobes.*

Capsules or boxes.

Capsules are 3D medium size components which can include technical systems. They are fixed at dwelling to form i.e. kitchens, bathrooms or any other option designed for being repeated.

Nowadays this tool is not often used at dwelling, although big capsules as full bathroom boxes are commonly used at hotels due to its economical repetition and the great value of factory built quality, luxury equipment and quick installation. These boxes should be designed for comfort.

Screens.

Screens are 2D easy movable components that can help if only visual privacy is needed.

A great and affordable aesthetic performance should be completed with other requirements.

Wall panels.

Wall panels are 2D movable components that can close and divide, visual and acoustically, spaces into rooms. They can perform a great aesthetic value due to the election of outside layers.

They are hanged from a substructure deployed at a technical ceiling. So we must add the cost of the ceiling to the high cost of the panels themselves.

Wall panel most expensive parts are magnetic connection within panels and the mechanisms which press and seal panels against floor and ceiling.

Wardrobes.

Wardrobes can store clothes, hardware or tools for living; Wardrobes are essential to a home.

Joe Colombo's machines for living demonstrate what can be done within boxes and wardrobes.

Allan Wexler's 1991 remembered “arts&crafts wood resources” and “do it yourself” procedures with a smart an easy storage solution.

Most of big sale furniture stores provide multiple easy to apply storage solutions.

MAIN FAILURES WHILE TRYING TO INTRODUCE INSIDE FLEXIBILITY.

Flexibility and its value has been known during all 20$^{th.}$ Century; but it has not reached dwellings. Dwellers have seen flexibility as a way to reduce the cost of building, instead of a set of tools that can make life easier. They think they would receive empty small dwellings, without rooms or walls, without acoustic requirements to be achieved. No comfort, nor quality of life; but the same expensive prices.

The main failures of flexibility are: Space planning for the minimum, the high cost of industrialized tools for flexibility and, last but not least, acoustic transmission.

Space planning for the minimum:

Minimum space planning comes from economical limitation.

Municipal laws, according to human activities standardization, were pulled to protect users against too small rooms. But these laws are thought for static dwellings, based on separated and different rooms, not for indoor flexible and multiple choice planning.

Measured standards for human activities are constantly increasing.

Spanish social dwelling standards take care about number of rooms and surface; not comfort.

High cost of the industrialized solutions for flexibility.

This makes the choice of flexibility only for those who can afford it, although flexibility is much more suitable for people of lower income, as flexibility maximizes floor planning.

When industrialized solutions are not achievable Do It Yourself (D.I.Y.) procedures happens.

D.I.Y. procedures uses both industrial products within arts and crafts concepts. It diminish the cost because as an arts and craft it has not need to pay patents nor industrial rights. But it does not take into consideration the hours to implement the proposals; because you don't pay yourself.

Acoustic transmission, a common problem.

Flexibility examples seem unable to answer people needs due to the unsolved problem of acoustic transmission; there are not being used proper sound barriers nor gaskets for gaps.

Sound barriers must be made with multiple layers of different composition, heavy and light weight, in order to interact with different wave lengths, improving sound absorbency and isolation, and minimizing redundancy phenomena.

The gaps within moving parts of a building (i.e. doors, or moving walls) or within sound barriers must be sealed to avoid air transmitted sound. It is not all about hermetic spaces or rooms, but to reduce the movement within air particles.

Although the non soundproof gaps is a common problem in flexibility, there are multiple options for sealing gaps which allow movement. Most of them deal with the compression of the moving parts against the surfaces they move around. There are gaskets with GreenGuard certification.

INDOOR FLEXIBILITY AND INDUSTRIALIZATON.

Industrialization needs to produce repeated series to match investment and to reach low cost. Customizing is often made through finishes; a slight surface variation.

Industrialized tools for flexibility, like wall panels, are nowadays expensive, although they have not evolved as expected; except for aesthetic value.

The most expensive they are, the less they are sold. So there are less benefits, and less money to invest in new designs or new production concepts that would help to decrease the price of those tools for indoor flexibility. This seems a circle that we, architects and industrial designers, can break in order to provide a low cost but full versatile indoor flexibility.

New industrial designs needs hand made models, like those made by Do IT Yourself procedures, to test the viability of the new designs. D.I.Y. procedures can be a start for new industrialization.

Light industry should be ready to industrialize and customize a smart, open and multiple choice industrialization, beneath “ 0 stock ”, or Lean production environment.

PROGRESSIVE INHABITATION, A GREAT FEATURE FOR XXI CENTURY SOCIAL DWELLING.

Life means change. Homes, where life happens must change too.

A progressive home, is never dead as it can change to adapt easily to the different conditions.

Progressive inhabitation means that a home can progress according to the evolution of its inhabitants, as those users can increase or decrease on number, age, needs or money income.

In order to decrease the cost of that home, a progressive home starts with the minimum necessary, including the multiple choice for future systems, equipment, spaces or rooms.

Users improve their homes whenever they need, they can, or want to.

The most important characteristic of progressive inhabitation is that all possible evolution of the home is thought to be easily achieved. The evolution can be made through different options that exist at stock, or as light industrial options to be produced specifically. Lean production must be considered, as when well applied, is the most effective industrial production environment.

All those options must be compatible, ready to be customized plug and play, etc., avoiding monopolies or a reluctant and no interesting choice for the user that would cause a monotonous life.

Furniture and building industry should be concerned of the possibilities of dwelling indoor equipment and systems.

CONCLUSION

There are many examples of industrialized components since the XX century; almost any kind of building activity has been industrialized in order to obtain profit.

There are many examples of indoor flexibility that can guide us to design flexible dwellings.

There are many tools for flexibility too, but because of they are not evolving as desire, we, architects, industrial designers, engineers, and any others can match industrial products and processes, new technologies and easy applying techniques for evolving tools for flexibility.

Many industrial designs include Do It Yourself procedures. They will be the first step in order to evolve industrialized indoor flexibility components or tools.

We will need to provide local industry with instructions and materials in order to face a proper execution of desired indoor flexibility tools.

We must design tools for flexibility again in order to achieve better comfort and quality of life standards, according to sustainability and low V.O.C. emission, low energy consumption, or other green concepts with the final objective of reducing the cost of those solutions.

Lean industrial production must be taken into account to acquire variability, compatibility and low cost. New materials and related processes should be used to reduce production costs.

Many industrial products, thought for other purposes, can be used to progress indoor flexibility.

We must be flexible to adapt to new technologies which can progress comfort and quality of life.

Industry should lead for an OPEN and SMART INDUSTRIALIZATION.

Users should be provided with the tools for a MULTIPLE CHOICE FLEXIBILITY.

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INTERFACE DESIGN FOR OPEN SYSTEMS BUILDING

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ABSTRACT

Open Building and IFD (Industrial Flexible Demountable) building are philosophies that aim to create high quality buildings with increased flexibility and better environmental characteristics. However, a successful adoption of IFD principles has not yet occurred because of concerns for the types of connections that are needed between building components. Therefore, this paper describes PhD research at the University of Twente that has the objective of designing a typology of flexible interfaces for IFD building that can be widely applied in the construction industry and aims to standardize connections, at the various levels of technical composition of a building, to create compatibility between building products from different suppliers. Such a typology of interfaces will increase the re-use and recycling of building parts, resulting in the increased sustainability of the building process. Furthermore, it will help accelerate the industrialization of the housing industry and mass customization of housing. A preliminary case study, in which a sustainable, flexible bathroom is designed, illustrates the various types of interfaces that can be applied, based on existing research.

Keywords: Interface Design, Open Systems Building, IFD Building, Interface Typologies, Sustainable Building.

INTRODUCTION

The philosophy of Open Building suggests that a building is composed of different environmental levels, each with a certain lifespan. Ideally, independency between these levels is required, which achieves that building levels can be adapted separately, resulting in more freedom to *change*. Options to realize the ambitions of Open Building have been researched extensively (Brouwer & Cuperus, 1992; Cuperus, 1998; Kendall & Teicher, 2000; Cuperus, 2003; Habraken, 2003; Kendall, 2004; Durmisevic, 2006). In the Netherlands, the IFD (Industrial Flexible Demountable) concept has been introduced as a technique to create buildings with a higher quality, more flexibility and with better environmental characteristics. IFD is as an application of the Open Building philosophy (van Gassel, 2003; Scheublin, 2005; Durmisevic, 2006).

However, notwithstanding its clear advantages, the successful adoption of IFD principles has still not occurred. One of the main problems is the type of connections that are needed between building components. Therefore, this paper describes proposed PhD research at the University of Twente that aims to design a typology of flexible interfaces that can be widely applied in the construction industry and aims at the standardization of connections, at the various levels of technical composition of a building, to create compatibility between building products from different suppliers. This is achieved by applying methods from the field of Industrial Design Engineering. A compatible set of interface configurations will boost the industrialization of the housing industry and mass customization of housing.

First, the proposed research method for the four year PhD research will be described. Second, as an illustration of the proposed research, the design of a sustainable, flexible bathroom is taken as a preliminary case study, and discussed in this paper,

THEORY

Open Building aims to involve users in the building process and to create buildings that have increased flexibility. Habraken, the founder of Open Building, states that Open Building has two perspectives: social and technical. Firstly, the social perspective aims to respond to user preferences by offering flexibility of a building. Such flexibility makes it possible for (parts of) the building to adapt. Secondly, the technical perspective aims to divide a construction into several systems and sub-systems that can be “changed or removed with a minimum of interface problems” (Habraken, 2003) . However, applying Open Building principles in practice is challenging. Kendall explains that on the one hand it is essential to design a built environment that supports *stability*, which is important for long term community interests, but on the other hand, *change* is necessary to meet the individual preferences of users. This prompts the question of how we can plan and implement, as Kendall describes it, a “regenerative built environment” (Kendall, 2004).

If the capability to *change* is needed, a high number of options (or variants) need to be established in the house building industry. It is challenging to achieve this in a cost-effective manner in the building process. However, research indicates that applying *platform-based development* in the housing industry could achieve this (Halman *et al.*, 2008). Applying platform-based development increases flexibility in product design and increases the efficiency of product development (Halman *et al.*, 2003). However, applying a platform-based approach in the housing industry is difficult, as other studies indicate (Hofman *et al.*, 2006; Veenstra *et al.*, 2006). The proposed research in this paper aims to apply a platform-based design approach to design a typology of demountable connections for IFD building.

IFD building

A building method that aims to achieve flexibility as a key aspect in the construction industry is that of IFD building: Industrial, Flexible and Demountable building. It is a method based on the principles of Open Building and is increasingly applied in the Netherlands but also in the United States and Japan. The three aspects of IFD building are (van Gassel, 2003):

- *Industrial:* most of the construction takes place under factory conditions, compared to the conventional way of building that mostly takes place at the building site.
- *Demountable*: the connections that are made between the components of the building can be demounted, which make reuse, configuration and replacement possible.
- *Flexible*: the building is designed with the facility to make changes at the various levels of technical composition of a building.

One of the OBOM initiatives - "The Building Node Research Project" (Cuperus, 1998) - mentioned that the industry has to aim to agree on *a set of connection conditions for building parts*. The aim was to come up with building components that can be designed by different companies, while maintaining a certain type of standard, resulting in the mutual compatibility of components. To develop such a system, it is important to separate the functions of systems and subsystems so dependencies between components will be decreased (Brouwer & Cuperus, 1992). This is important for achieving flexibility. Figure 1 (left) shows the various levels of a building. The right diagram shows the hierarchy of the functional and technical decomposition of a building into independent systems and subsystems. The displayed composition is the ideal situation of a building in which every building function corresponds to an independent part of a building (Durmisevic, 2006).

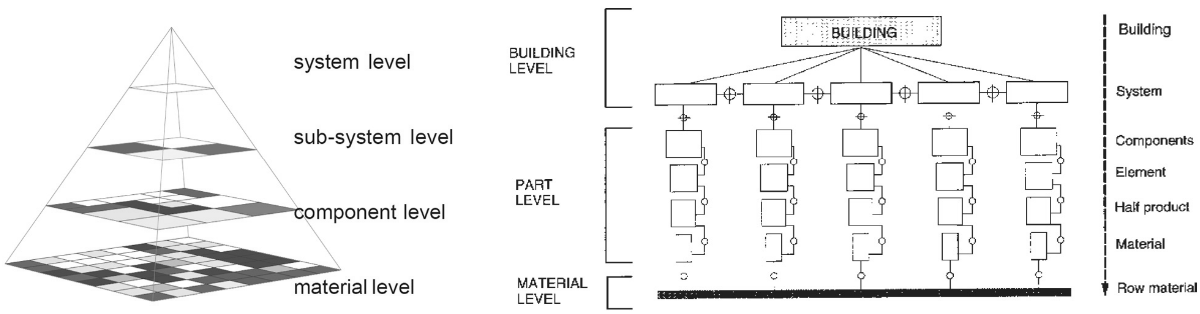

Figure 1: *The composition of different levels in a building (left) and the ideal situation in which every system is independent (right) (Durmisevic, 2006)*

Extensive research in the field of Open Building was performed by members of the OBOM group (van Randen, 1976; Brouwer & Cuperus, 1992; Cuperus, 1998; Durmisevic, 2006). Their research all stresses that a building must have the ability to adapt in response to changing circumstances. However, to realize flexibility, the connections between building components (called *interfaces*) also have to be adaptable. In research on flexible connections, Durmisevic defines two key criteria that determine the performance of a building configuration with respect to disassembly at connections: independency and the exchangeability of building components. The level of independency is determined by the functional decomposition of a building, while the level of exchangeability is determined by technical and physical decomposition (Durmisevic, 2006). Also, research has been conducted on the actual connections (or joints) between building components: Olie created a so-called "typology of joints" that supports sustainable development in building (Olie, 1996).

However, a uniform set of connections that can be applied by different manufacturers in the construction industry and aims at IFD building, is not yet available.

METHOD

The objective of the proposed PhD research as presented in this paper is to develop a typology of interfaces for the building industry that can be applied in IFD building which improves mass customization and industrialization of the building industry. In this context, an interface is defined as a common boundary or interconnection between systems. In the case of a building, the interconnections will be the joints that hold together the different parts (or building blocks) of the structure and which separate the different functions of the building. A typology is defined as a systematic classification of types that have common characteristics. Therefore, a typology of interfaces can be considered as a set of joints. From the research objective, the following research questions are derived:

1) *Theory:* What are existing interfaces in the construction industry?
    i. To what extent are these interfaces applicable for IFD building?
    ii. How can these interfaces be best arranged in a typology, taking IFD building as a criterion?
2) *Design:* How can interface typologies and interface configurations be designed for IFD building that are broadly applicable in the construction industry and aim to achieve mass customisation and industrialisation of building processes?
3) *Application:* How can the designed interfaces be applied and tested in the building industry?
4) *Reflect:* i. What are the improvements, limitations and applications of the designed interfaces? *(Conclusions)*
    ii. How can the limitations for further implementation be minimized, by improving the design? *(Recommendations)*

The three questions will be answered by dividing the research project into four phases, each with its own focus. Figure 2 shows the project schematically.

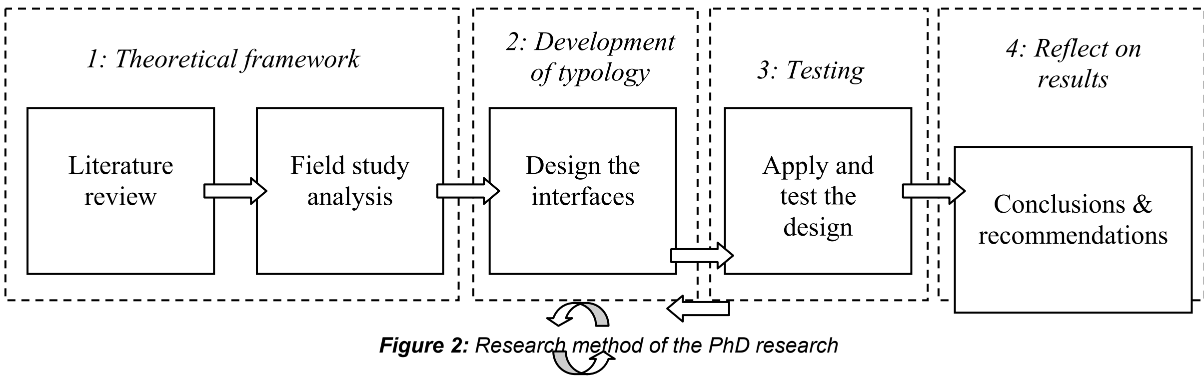

Figure 2: *Research method of the PhD research*

In the first phase, a theoretical framework will be built by reviewing the literature and conducting a field study analysis. The literature review is concerned with the research fields of Open Building, IFD building, joints, Industrial Design methods and Product Platforms. The field study analysis will be conducted by interviewing experts: both academics in the previously mentioned research fields, as well as construction companies that already apply the principles of Open Building and IFD building. The interviews in the field study analysis will complement the literature review, together creating a thorough theoretical framework.

Using the theoretical framework, in the second phase, different interface typologies and configurations will be designed. The deliverable of this phase is the design of a compatible set of interfaces at various levels of technical decomposition that can be widely applied in construction industry and conforms to IFD building principles. The design process is iterative and includes feedback from several construction companies throughout the process, hereby optimizing the design. This design will be presented as a detailed 3D CAD model, ready to be manufactured as a prototype.

In the third phase of the research, the design of the set of interfaces will be manufactured as a set of prototypes and tested at a test building site at the University of Twente. The application of the prototype will function as a test case, providing data about the functioning of the design. Again, companies will participate in this phase and give feedback. The result will be a working prototype which will lead to a set of conclusions and recommendations for the design in the fourth and final phase of the research.

Research will be conducted in close collaboration with several construction companies in the region of Twente, the Netherlands. The participating companies are members of a working group called IDF (Industrial Sustainable Flexible building) which focuses on IFD building. The participating companies are: 4D Architects, Winkels Techniek, de Woonplaats, Raab Karcher, Plegt Vos, van Dijk Groep, Hodes Bouwsystemen, de Groot Vroomshoop and Twinta. These companies are mostly construction companies, but also include housing associations, suppliers, installation companies and architectural firms. The research results will be applied in several of the participating companies.

To kick off the PhD project, a small pilot project was conducted, functioning as a preliminary case study for the research. In this project, a sustainable and flexible bathroom was designed as an illustration and clarification of the proposed research.

PRELIMINARY CASE STUDY

A case study was performed for the local district water board “Waterschap Regge en Dinkel” (WRD) in Twente, in the Netherlands. The requirement was to design an adaptable (and therefore flexible) bathroom that would also be sustainable by saving both water and energy. The project was executed in collaboration with two Masters Students in Architectural Building Component Design & Engineering at the University of Twente.

In the literature, several models are available that decompose a building into different levels. An example is the model developed by Duffy that defines a building through four different levels in terms of the so-called four S’s: *Shell, Services, Scenery and Set* (Duffy & Myerson, 1998). This model is shown on the left in Figure 3. Another systematization of building levels is the model developed by Brand which distinguishes six levels: *Site, Structure, Skin, Services, Space Plan and Stuff* (Brand, 1995). This model is shown at the right of Figure 3.

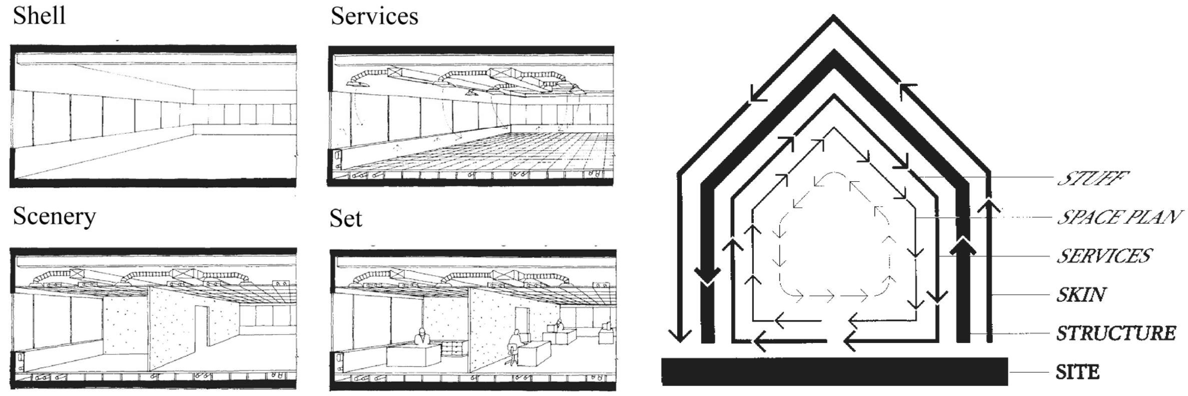

Figure 3: *Duffy's model (Duffy & Myerson, 1998) at the left and Brand's model (Brand, 1995) at the right*

Both Duffy's and Brand's models indicate that different levels of a building have different life spans. In conventional building, levels often overlap in functionality. If flexibility is to be achieved, it is necessary to design every level apart from one another. By doing this, conflicts of interfering level properties do not arise. Such separation of functionalities per level is applied in the design of the bathroom in the preliminary case study.

To help indicate the levels of the bathroom, the models of both Duffy and Brand were combined. This resulted in the following set of levels:

- *Shell:* this is the building in which the bathroom will be located; it is defined as the walls and floors of the building.
- *Structure:* this is the structure that holds together the bathroom; in this case the aluminium frames placed against the wall and the blocks on which the floor will be laid.
- *Services:* these are the technical components, such as piping, electrical wiring and ventilation ducts.
- *Scenery:* these are the covering of the walls and the floor with tiles.
- *Stuff:* these are the appliances such as the toilet, shower and sink.

Interfaces

The different levels of the building are connected with each other by means of *interfaces*. If flexibility is to be achieved, the interfaces have to be demountable. The research published by Durmisevic proposed a classification of seven different connections, ordered from fixed to flexible. Figure 4 shows the different principles behind these seven connections (Durmisevic, 2006). These will be used to illustrate the possible interfaces in this case study.

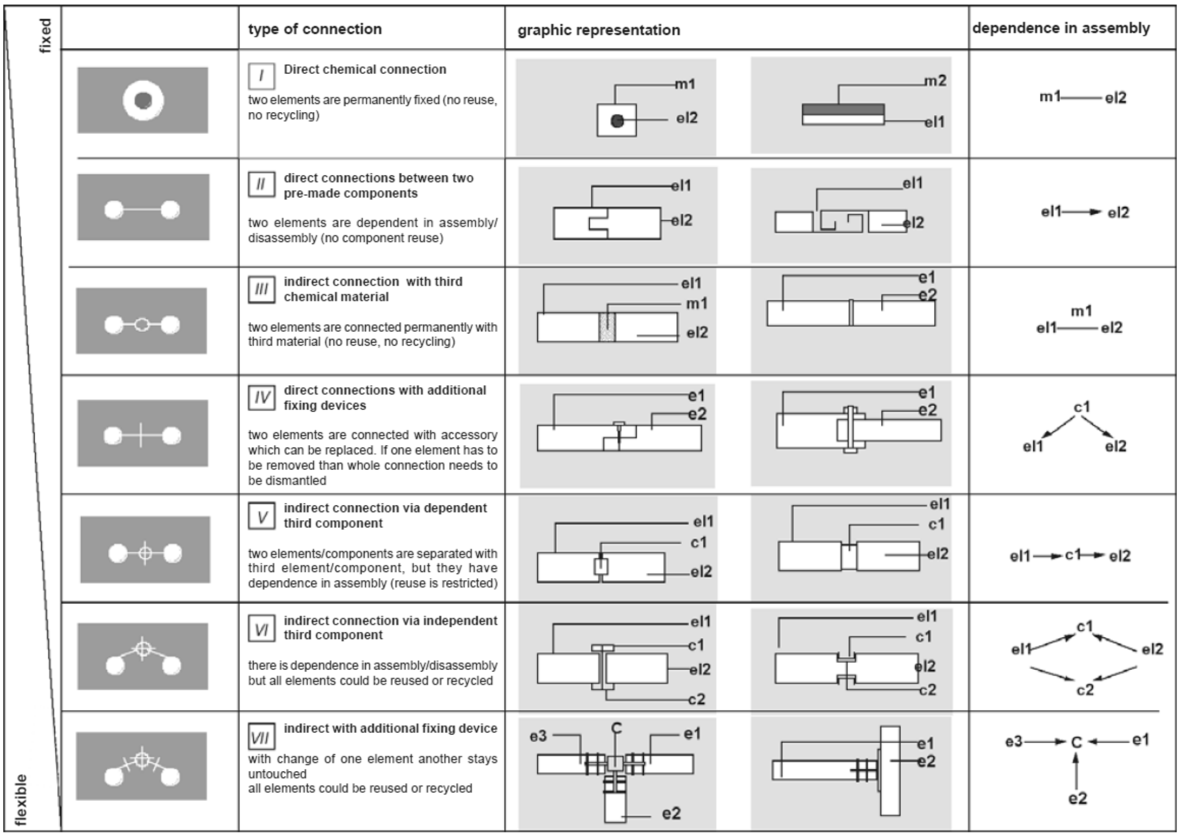

Figure 4: *Seven principles of connections, ranged from fixed to flexible (Durmisevic, 2006)*

Design

The new bathroom design consists of different levels, with each level providing an individual function. This offers a flexible design because changes can be made per level. Figure 5 shows the design and illustrates the different levels, following the combined models of Duffy and Brand. The interfaces between the levels of the design are demountable, thereby offering flexibility. In Figure 5, the *shell (1 & 2)* of the bathroom consists of the walls and floor of the building in which the bathroom will be realized. The *structure* of the bathroom consists of aluminium frames *(3)* and small blocks for the floor *(4)* that form a pattern. The *services,* such as piping and electrical wiring *(5),* are mounted within the aluminium frames, as well as the tubing for the floor heating *(6)*. The *scenery* of the bathroom consists of wall tiles *(7)* and floor tiles *(8 & 9)*. Finally, *stuff (10)* represents the bathroom appliances such as the toilet, shower and sink.

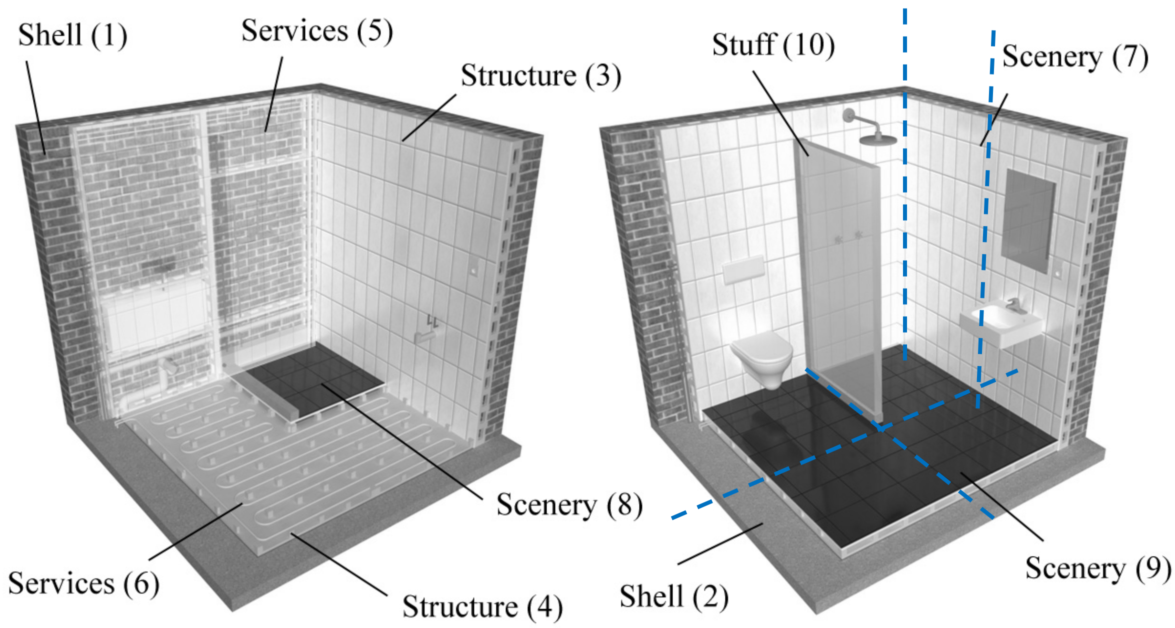

Figure 5: *The design of the sustainable and flexible bathroom of the pilot project (images by Guus Rammeloo)*

Modules & interfaces

The basis for the design is a combination of modules. This is shown in Figure 6. At the left, an exploded view of a wall module developed by an architectural firm in Amsterdam (4D Architects, 2009) and at the right a floor module that was designed during the pilot project (at the right), are shown. Again, the levels indicated in the figure. Both modules have fixed dimensions and can be seen as building blocks out of which a bathroom can be built. In the bathroom, four wall modules and four floor modules were used (see the dotted lines in Figure 5). Every wall module has space for one appliance (indicated by the level *stuff*). For every bathroom appliance, a wall module is available. By using demountable piping and applying a common height for *services*, it is possible to create a bathroom by placing several modules next to each other. In Figure 6 (at the right) it is shown how a floor module is composed. In this particular module, space is used for the drainage (the brown pipe) at the side of the module. Also, the blocks are shown that form the *structure* on which the floor tiles (*scenery*) lie. These floor tiles are prefabricated plates and can be demounted from the structure of the module. This demountability provides the opportunity to access the services later on, but without damaging the module.

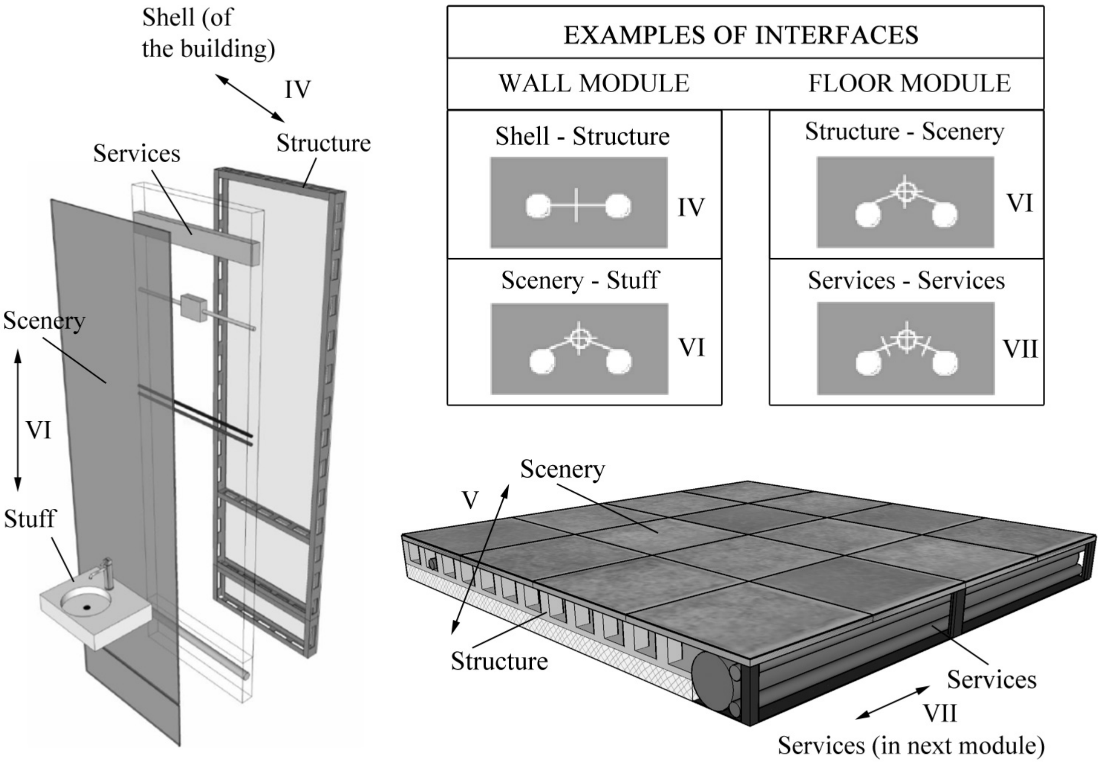

Figure 6: *The wall module at the left (4D Architects, 2009)and floor module (at the right) of the bathroom and examples of interfaces between levels of the modules (upper-right)*

The table at the top-right in Figure 6 shows several configurations of how different levels of the modules can be connected. Two examples are given for the wall module, as well as for the floor module. These examples indicate where the interfaces occur and how they can be applied. The illustrated interfaces are examples, but can also consist of other types of connections. They illustrate the importance of interfaces. The following examples of configurations are given:

- The *Shell* – *Structure* interface in the wall module consists of connection type IV from Figure 4. This is a direct connection with an additional fixing device such as a nut – bolt connection. Such a connection is sufficient because this interface will rarely be changed.
- The *Scenery* – *Stuff* interface in the wall module consists of a VI connection which is an indirect connection by using an independent third component such as a clamp or click connection. This offers the facility to detach/replace an appliance easily.
- The *Structure* – *Scenery* interface in the floor module is a VI connection which makes the floor tiles detachable from the structure. This facilitates access to the services.
- The *Services* – *Services* interface of the floor module is a VII connection; this is an indirect connection with an additional fixing device such as a "coupling part" for the piping. It offers changing elements so they can be re-used or recycled.

Water and energy saving

Although the main focus of the pilot project was to improve the adaptability of the bathroom, sustainability aspects regarding water and energy saving also played an important role. Reducing the amount of water was a key objective for the local water district of Waterschap

Regge en Dinkel. The sketch to the left of Figure 7 shows the design of a new product; a transparent shower wall that functions as a water-saving reservoir. At the right of Figure 7, the working of the product is shown: water coming out of the shower (1), which normally goes to waste down the drain, is filtered (2) and then saved in the shower wall reservoir (3). Next, the collected water can be re-used for flushing the toilet (4). Furthermore, the shower wall aims to make people more aware of their water use because they can see through the glass wall how much water has been used. This increase in awareness is expected to encourage people to save water. Water is also stored in the floor underneath the shower, which further increases the water storage capacity.

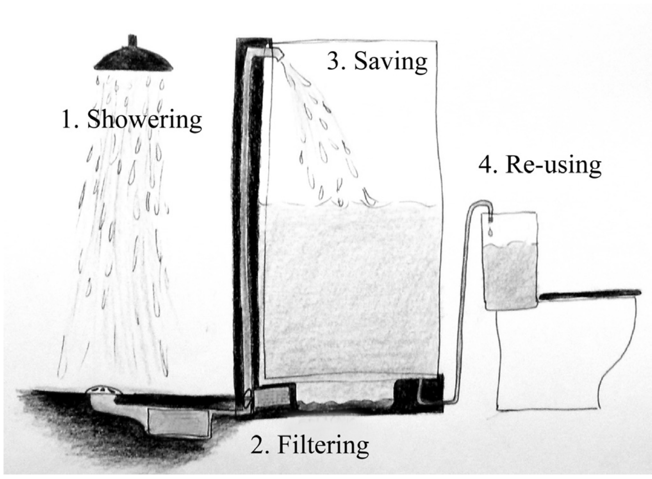

Figure 7: *The shower wall functions as a water saving reservoir (sketches by Eline Kolk)*

As well as saving water, the reduction in the required energy plays a role in the bathroom's design. This is acquired by applying a low-temperature floor heating system (as represented by the tubing in the floor in Figure 5). Furthermore, both water reservoirs in the shower wall and the floor will be filled with warm water from the shower. The residual heat in the water will then be transferred to the colder air in the bathroom, which leads to a further reduction in the energy required. Therefore, both water reservoirs function as a passive heating system.

CONCLUSION

The proposed PhD research described in this paper aims to design a typology of interfaces for the building industry that can be applied for IFD building and that will increase mass customization and industrialization of the building industry. If such a typology will be the result in the future, this will comply with Open and Sustainable Building by offering *stability* on one hand (the building consists of properly designed, strong connections) as well as *change* (the interfaces are flexible, so users can make alterations to the building). Furthermore, such a typology will increase the re-use and recycling of building parts, resulting in increased sustainability of the building process. The preliminary case study, in which a flexible and sustainable bathroom was designed, shows the importance of the interfaces between the various levels of the design of a structure. Also, it indicates how flexibility offers the potential to customize individual levels apart from each other; leading to improved opportunities for *mass customization*. In addition, the various levels can be manufactured and assembled in the factory, which makes the design *industrial*. Finally, the bathroom consists of systems and sub-systems that can be changed or removed with a minimum of interface difficulties due to the use of *demountable* connections. Undoubtedly, these properties will become increasingly important in the future of the construction industry.

FUTURE WORK

This paper has presented an overview of a PhD research project that will be executed over a four-year time span. Future work consists of conducting the research plan shown in Figure 1. Following the pilot project, future work is expected by cooperating with companies that showed an interest in the design of the bathroom. Improving the bathroom's design by specifying the flexible interface connections will be a first step. Next, the design can be tested in an experimental project.

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We would like to thank Eline Kolk and Guus Rammeloo, students in Architectural Building Components Design & Engineering at the University of Twente, for their collaboration in designing the sustainable, flexible bathroom. Also we would like to thank the workplace IDF, Pioneering and Innovatie Platform Twente which make this research possible.

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WHAT IS THE MEANING OF ADAPTABILITY IN THE BUILDING INDUSTRY?

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ABSTRACT

In an age of sustainability focussed on the short term of carbon reduction, it is important that we maintain an understanding of the broader characteristics which make places sustainable over the longevity of time. Adaptability as a design characteristic embodies spatial, structural, and service strategies which allow the physical artefact a level of malleability in response to changing operational parameters over time. This paper starts by reviewing definitions of adaptability in the literature and sets forth a holistic definition, coalescing essential characteristics through a critical analysis. The following two sections contextualize the conversation about adaptability through two distinct approaches for achieving it along with its current perception. Subsequently, the paper subdivides adaptability into a set of strategies which provide a comprehensive resolution for describing the different types of changes a building may be forced to endure. The last segment then examines the relationship between the Open Building movement and our findings regarding adaptability. We conclude with some provocations towards the open building movement and industry shifting towards a more sustainable and time-based approach to design.

Keywords: adaptability, strategies, sustainability, open building, time

INTRODUCTION

In an age of sustainability focussed on the short term of carbon reduction, it is important that we maintain an understanding of the broader characteristics which make places sustainable over the longevity of time. As society has progressed through economic prosperity and technological innovations our personal understanding of time has grown increasingly shorter. The disparate realities of these two perspectives on time are at the crux of shifting mindsets towards the design of a more sustainable built environment. Time as a design contingency relies on placing architecture in context, making it susceptible to its temporal reality and biggest fear - change. Designers tend to ignore these temporal aspects focusing on an aesthetic fixation and functional performance, freezing out time in pursuit of a static idealized object of perfection. A reaction to this way of operating is the encouragement of a more dynamic and long-term understanding of the built environment. How then, does one design for time?

Adaptability as a design characteristic embodies spatial, structural, and service strategies which allow the physical artefact a level of malleability in response to changing operational parameters over time. This strategic shift reflects buildings, not as finished work removed from time, but as imperfect objects whose forms are in constant flux continuously evolving to fit functional, technological, and aesthetic metamorphosises in society. The capacity for buildings to respond to these changes are highly determined through design decisions early on resulting in the building's design structure – what it is, how it is constituted (Baldwin et al. 2000). Achieving adaptability then demands a shift away from the current emphasis on form and function in response to immediate priorities, towards a 'context' and 'time-based' view of design.

This paper puts forth adaptability as a design principle which brings to the forefront this critical dimension - time. As Croxton (2003) points out, "If a building doesn't support change and reuse, you have only an illusion of sustainability." This paper starts by reviewing definitions of adaptability in the literature and sets forth a holistic definition, coalescing essential characteristics through a critical analysis. The following two sections look to contextualize the conversation about adaptability through two distinct approaches for achieving it along with its current perception. Subsequently, the paper subdivides adaptability into a set of strategies which provide a comprehensive resolution for describing the different types of changes a building may be forced to endure throughout its life.

Unsurprisingly, our exploration of adaptability includes ideas and findings intertwined with aspects of the Open Building paradigm. The last segment of this paper then examines the relationship between the Open Building movement and our findings regarding adaptability. We conclude with some provocations towards the open building movement and industry shifting towards a more sustainable and time-based approach to design.

DEFINING ADAPTABILITY

Looking backwards, the etymology of the word adapt can be traced to early 14th century Latin, aptus, meaning "suited, fitted" to adaptare meaning "to join", through Middle French as adapter, to its English roots in 1610 to mean "to fit something for some purpose" (Harper 2001). Current definitions have changed subtlety, "to make suitable to requirements or conditions; adjust or modify fittingly" (Random House 2010). Adaptability then is concerned with the capacity to be adjusted to suit new situations.

One could assume that is simple and straight forward enough, but through literature and conversation one finds dozens of interpretations of what adaptability means embodying the very plasticity it looks to describe. Depending upon its application and context, even within the built environment, one finds a wide range of subjective permutations. Within the architectural literature, for example, a high-level characterization can be made. Adaptability can mean:

Accessibility - to describe making spaces accessible for all concerning stages of life and various special physical conditions (Lifetime Homes 2009).

Open Plan - to symbolize a universal floor plan or open office which allows a company the capacity to subdivide a space based on its needs (Gelis 2000).

Building Responsiveness - to describe an interactive building via real-time changes through the use of kinetic systems in response to environmental changes through variable mobility, location, and/or geometry (Bullivant 2005, Hoberman et al 2009).

Performance-based buildings - to describe the performance aspects of a building related to functionality and maintaining fit purpose over time concerning issues of planning, programme, and people (Slaughter 2001, Blakstad 2001).

Although the above characterizations are not mutually exclusive, this work is concerned with the fourth area, and focused on clarifying a definition for adaptability within this broad realm without specific stakeholders or solutions in mind. In order to generate an informed definition we identified overarching characteristics gathered from the literature. The first is the capacity for change. Every definition in some way mentions change: "change the size or use of spaces" (DCSF 2008), "change its capacity, function, or performance" (Douglas 2006), "less frequent, more dramatic changes" (Leaman et al. 2004), "subsequent alteration" (OECD, 1976), or "modified, relocated" (Canadian Standards, 2006). A second overarching characteristic is the ability for the building to remain "fit" for purpose or "reduced in mismatches" between the building and its users (Friedman, A. 2002, Blakstad, 2001, Ridder et al 2008, etc.). A third leitmotif is value; "maximizing its productive use" (Graham 2001), "to fit both the context of a system's use and its stakeholders' desires" (Engel et al. 2008), and "at minimum cost" (Blue Mountains City Council, 2005). The last characteristic is time. Time is presented in two ways throughout the definitions. First to indicate the speed of change ; "quick transformations" (Juneja 2007), "respond readily" (Kronengburg 2007); and secondly, to indicate through life changes; "future changes" (Gorgolewski 2005), "in the long term" (DCSF 2008), or "extension of use" (Hasemian 2005).

Our current definition of adaptability is a synthesis of these four underlying characteristics, namely 'the capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life'. The intent of this definition is to provide a clear and robust view on adaptability in regards to buildings.

Adaptability Approaches

Our project research burgeoned on a simple premise that adaptability could take place before the building was occupied through the preconfiguration of initial design choices by way of industrialized building systems or after the building is occupied through the reconfiguration of the building for subsequent changes in use (Gibb et al 2007, Beadle et al 2008). The distinction was given to represent the two different approaches by the primary collaborators in the research project GSK and their Newways system (preconfiguration) (Fuster et al 2009), and 3D Reid's Multispace approach (reconfiguration) (Davidson et al 2006). Pre-configuration dealt with speed and quality of project delivery through the standardization of building components focused on the initial use (a kit-of-parts approach). In contrast, re-configuration represented the spatial geometry and interior furnishings focused on the prolonged use or re-use of the building ameliorating whole life cost. This particular distinction is not always helpful since both strategies are inclusive to initial design decisions and if successful both will accommodate or ease some form of change after initial occupation.

However, there is another distinction which can be more helpful and lies in the distinctively different design approaches. Newways represents a systems approach, a hard approach; where Multispace embodies a set of strategies to design, a soft approach. The distinction in this sense is clear. Newways is a technically determinant system looking to (re)invent the way buildings are delivered and assembled through product innovation offering a specific solution (i.e. kit of parts). Control of that said adaptability remains in the hands of the designer. Multispace, not tied to any specific solution or project delivery, offers a set of rules or specifications as guidance for the designer's decision making to enable the building to accommodate an appropriate range of uses through a broader understanding of the requirements various functions demand. This indeterminate approach embodies a social process between designer and user over time and demands a greater response from its users due to the greater ambiguity of the space. Such a distinction between approaches is not new (Schneider 2007), but is important because most guidance on adaptability tends to mix the two approaches without a conscious understanding of the difference or simply focuses at one extreme.

Perception of Adaptability

Through our pursuit into understanding adaptability, the most common perception has brought with it an expensive and negative connotation. For many people, it has been branded as costly, an 'extra', rarely used, and involves state-of-the-art gadgetry which only works half the time. This is all in an effort to safe-guard the end user against unpredictable changes in organizational structure, functional use, spatial arrangements, technological advances, and so on. This perceived view has been driven by technical attempts at future proofing buildings through the application of specific solutions (i.e. movable partitions, drop ceilings, raised floors); while other buildings, which have stood the test of time have been coined accidental adaptability or just simply good design (e.g. Georgian terrace houses, Dutch canal houses, industrial warehouses, etc.).

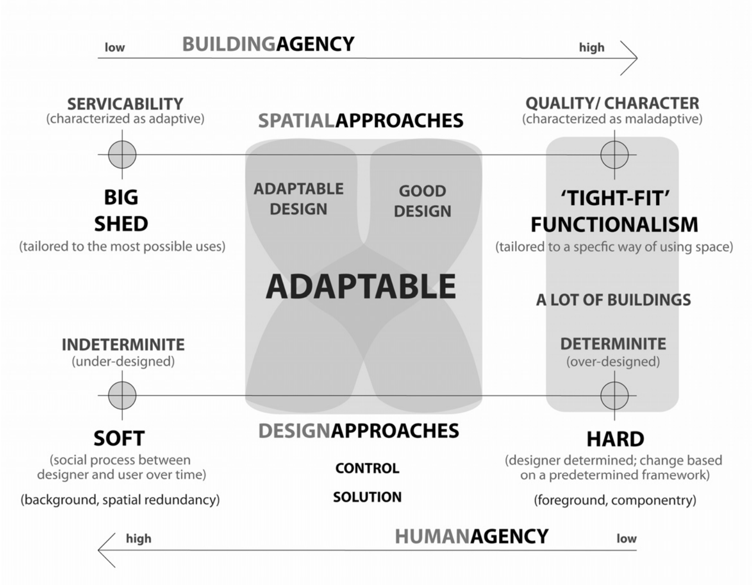

Figure 1. *Summary of approaches towards adaptable design*

The latter argument is that adaptability is not distinctly a result of technical detailing or special componentry which allow multiple configurations to take place. Meaningful adaptability can take place through an understanding of the fundamentals (i.e. getting the basics right). Understanding the subtle spatial and physical differences between various uses; grappling with the social, economical, political, legal, technical and environmental forces at play by designing architecture within a holistic context making it conscious of time and change. An architecture that is susceptible to a real set of operational parameters; a type of 'weak' architecture which needs continual work to stay balanced. In his essay on Weak Architecture, Kengo Kuma (2005) acknowledges the strength and uncanny longevity of 'weak' architecture because it demands constant attention from both designer and user; while 'strong' buildings, often left alone, only give an illusion of durability.

The scepticism looms large over the concept of adaptability. We are convinced that achieving adaptable buildings lies in a broadening of perceptions through a more balanced and integrated approach. This response lies in a re-conceptualization of time that goes beyond matters of durability to a more nuanced view of a building as a socialized product constantly in the making, a view that chimes with what Till (2009) describes as 'thick time'. Here architecture can no longer be thought of as a noun, but as a verb - always on the move - responding to a milieu of change.

In this sense, successful adaptability may not always need to come from the capacity of the building itself, but from the user or owner's capacity to adapt and/ or any other numerous variable which supports the dynamic interplay between building and context. Figure 1 above summarizes our current understanding towards adaptable design.

DESIGN STRATEGIES

Early in the project six strategies to achieve adaptability were identified as a series of 'ables' to describe the physical capacity of the building to be adaptable - the building is available, extendable, flexible, refitable, moveable, and recyclable. As part of the iterative thought process some of the keywords shifted slightly to incorporate slightly different connotations (extendable to scalable, recyclable to reusable). After reviewing the literature, a plethora of design strategies were found; however, the result presented a mixture of terminology and correlating definitions leaving no clear way of easily deciphering the semantically tangled strategies. In an effort to confirm and compare our strategies with the literature, an exercise was conducted to position these approaches and meanings against our strategies (Figure 2). This analysis led to the elimination of two of the strategies (available and reusable) as they were deemed outside the scope of adaptability. Available was concerned with the speed of design and construction by shortening the delivery of a building (through a standard set of components) largely in regards to the commercial benefits of early occupation, although such a kit might lend itself to subsequent modification for new uses or sites. Reusable focused on the building's capacity for its components to be recycled after the building's life; while the capacity to deconstruct a building is of particular relevance to refitable as a characteristic it was determined to be outside the framework in regards to prolonging the life of the building itself.

In addition to finding these two strategies outside our scope, the large cluster of definitions surrounding our interpretation of flexible led to the splitting its meaning into two specific strategies. Our initial definition of flexible covered a spectrum of possibilities from how the space was defined physically to how the space was being used functionally. In this regard, flexible was split into versatile to represent the physical change of space (i.e. spatial layout), and convertible to signify change of use. The dissolving of flexible as a strategy along with the more specific meanings of versatile and convertible resulted in one last addition of adjustable to correspond to equipment and/ or furnishing changes which respond to changes in task or user.

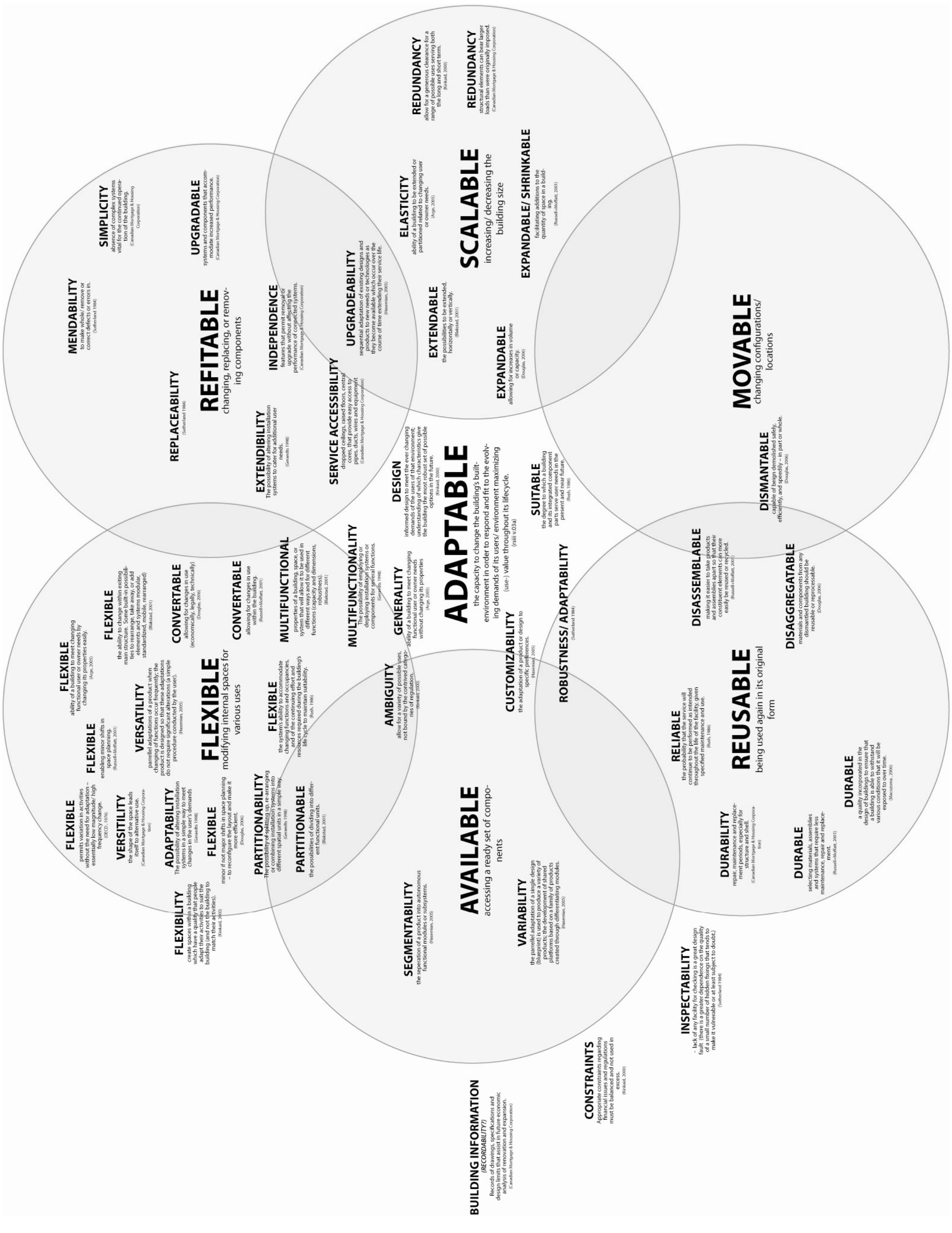

Figure 2. *Mapping of literature against AF strategies*

The above exercise resolved the desire to map our strategies against literature and assure a level of comprehensiveness. However, it still left the strategies themselves as descriptors floating rather ambiguously. With that in mind, each strategy was given a one to one correlation to a specific type of change, which provided a clear and concise definition. Furthermore we have positioned each strategy in relationship to a decision level (i.e. stakeholder), a built-environment scale, a time scale or cycle length, and Stewart Brand’s physical layers (Brand, 1994). Figure 3 provides a summary.

able	type of change	decision-level	B-E scale	Time (cycle speed)	Brand's layers					
					Stuff	Space	Services	Skin	Structure	Site
adjustable	change of task	user	components	daily/ monthly	O					
versatile (flexible)	change of space	user	components	daily/ monthly	O	O				
refitable	change of performance	user/ owner	components	7 years		O	O	O		
convertible	change of function	user/ owner	building	15 years		O	O	O		
scalable	change of size	owner	building	15 years		O	O	O	O	
movable	change of location	owner	building	30 years					O	O

Figure 3. *Summary of Strategies in relationship to other dimensions*

OPEN BUILDING & ADAPTABILITY

Open Building’s (OB) roots developed as a reaction to the housing boom post WWII in the 1960s with the desire to empower the user (e.g. Bosma et al 2000, Cuperus 2001, Kendall et al 2004). As a design philosophy, it equates levels of individuals’ control with environmental levels both in design and use in an effort to evince a realistic understanding of how ‘things work’ - understanding limits and roles (i.e. a separation of responsibilities/ ‘power’ amongst a strong collaborative/ multi-stakeholder effort). As a resulting physical object, it bolsters the capacity for change to take place through an ease of tension between building components, particularly at the distinctive levels of short-life/ infill and long-life/ base building. This mindful separation supports a conscious effort by the designer(s) to think about the durability (or foreseeable life) of the materials and systems and their relationships to other components.

The approach, while not neglecting the social and wider context, has had most success being implemented from a top down approach focused on the technical detailing of the building. Several examples supported by the Japanese government have led the way to promote the dissemination of the philosophy through a technical interpretation (Fukao 1987, Eguchi et al 2010). Despite tremendous efforts in Japan it has met with mild success. Century Housing System is one example which has had little industry impact (Utida 2002) primarily because of: a) its complexity/ unfamiliarity and b) its minimum grasp of the holistic context, including social and economic (Matsumura 2009). The examples from Japan demonstrate the technical feasibility associated with designing for change, but not its sustainable or wider contextual application.

All of the above supports a re-structuring of how buildings are made and the inclusion of time into the design ‘consciousness’. It is here, where a designer may find useful the specific strategies we have proposed, removing some of the ambiguity of thinking about time and change under the OB philosophy. While the philosophy becomes a useful way of framing mindsets regarding time and change, its reductionist focus on levels (a determinate approach to design and use) limits its expression of adaptability to a particular approach. While more elements of the construction process have begun to accommodate the OB approach (Kendell 1999), it will inevitably take a broadened understanding of adaptability to expand its reach and sustain its application. This paper is not meant as an anecdote, but as an introductory provocation towards a re-conceptualization of adaptability which offer implications towards the OB approach.

CONCLUSION

This brings us back to the question posed in the introduction: How does one design for time? Technical feasibility alone does not accomplish a sustainable solution. If adaptability brings an understanding of time, it brings an emphasis on process and enabling the building to ‘learn’ and the users to ‘teach’ or shape the space themselves. Adaptability forces design to become an ongoing social process between designer and user over time. The designer must focus on enabling adaptation to take place; as opposed to attempting to control experiences and anticipate the future. Hertzberger (1991) stresses, “Architecture should offer an incentive to its users to influence it wherever possible, not merely to reinforce its identity but more especially to enhance and affirm the identity of its users.”

Architecture in reality is placed inside a highly volatile context where it is forced to respond to and act on exogenous demands or suffer premature obsolescence. It is here where good design takes place through the conscious understanding and negotiations of these demands towards a synthesized solution which recognizes the dynamic nature of the context in which the building exists and will continually evolve with time. It is our view that adaptability as a design principle brings time and change to the forefront of thought, but requires a re-conceptualization of time through shifting mindsets and (re)shaping of values. Placing architecture in context demands a balanced design approach between hard and soft as well as ‘big shed’ serviceability and ‘tight fit’ character. It may suggest to under design rather than over design; to leave space unfinished as a mechanism for engagement.

The overwhelming focus on regulating energy performance as the driver for sustainability standards has relegated building longevity into initial design considerations as just good practice. This situation leaves designers and government authorities with a lack of legal power to enforce ‘adaptable’ schemes on clients. This reality presents the conscious designer the challenge of embodying these strategies within their design philosophy, rather than finding them as part of a brief, in an effort to create more meaningful adaptability.

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TYPOLOGY-BASED EVALUATION (TbE) - CHANCES FOR SUSTAINABLE STRATEGIES FOR REFURBISHMENT

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ABSTRACT

The existing building stock has a considerable impact on the implementation of a more sustainable development. Within this context, the CCEM-Retrofit study focuses on the seminal sector of multi-family homes. It aims at making contributions to quality control and standardisation by focusing on prefabricated modules and holistic retrofit strategies.
Planners are asked to develop optimal retrofit strategies for existing buildings. However, more than technical deficiencies must be solved. Today, holistic strategies are required to meet the needs of investors, users and the public as well as to account for architectural relevance.
Using the typology-based evaluation this study identifies the potential of feasible utilisation strategies of existing buildings with only few criteria. Therefore the major characteristics of relevant building parts such as: balconies, windows, roofs, staircases and apartments are collected for a statistically relevant number of buildings. For the most important types building strategies has been drafted and evaluated. Finally, this typology-based evaluation is fundamental in the development of prefabricated modules and, it is essential for estimating the market potential of these newly-developed enclosure systems for retrofit.

Keywords: Typology, Architecture, Adaptability, Sustainability, Retrofit, Residential, Holistic strategies, Planning

INTRODUCTION

This article is based on the sub-project "Building Typology and Holistic Retrofit Strategies" of the project "CCEM-Retrofit – Sustainable residential building Refurbishment with prefabricated Retrofit Systems"[1]. It is the Swiss contribution to the international project "IEA ECBCS Annex 50 – prefabricated Systems for low energy Refurbishment of residential Buildings".

Holistic refurbishment strategies involve the whole building system and aim to get buildings "fit" and to adapt them for current and future needs [2]. The core element of every redevelopment measure should be an increase in value for the client (investor, building owner, tenants). Focusing solely on energy efficiency optimisation is ineffective and does not meet the overall requirements.

THE RESIDENTIAL BUILDING REFURBISHMENT CHALLENGE

The existing building stock is of key importance for sustainable development. Apart from energy requirements [3], other technical factors (such as earthquake resistance) and especially the ability to adapt to changing living requirements and to the market situation, play an important role. Martin Meier, member of management at Meier+Steinauer Partner AG and refurbishment expert, stressed that no refurbishment project should be approached by considering one aspect only. "We never approach a project from a technical perspective only". Refurbishment is a comprehensive service "which begins with each single tenant, when the construction manager sometimes also has to be a psychologist, up to professional advice and construction supervision for the building owner" [4].

This statement addresses the greatest challenge in planning residential building refurbishments. Existing buildings are living quarters which have their use, inhabitants, identity and atmosphere. At the same time, existing buildings have a given structure which planners have to take into account. Martin Meier adds "This is a different market to the one where you can design a beautiful structure for a greenfield site".

Complexity

The greatest challenge in the refurbishment market is to find new solutions for an existing situation (built structure and its use). Increase in value is achieved by a combination of usability, technological quality and the atmosphere created [7, 8]. Four fundamental building strategies can be defined [6]:

- value retention: The aim is to secure the future use of the building without jeopardizing habitability and rental revenue
- partial refurbishment: The aim is to secure earnings and value of the building in the long-term, or increase them accordingly
- total refurbishment: Building substance and market potential allow for comprehensive investments which lead to a clear appreciation of the building
- new build replacement: investing in the existing building is not worthwhile because of the building structure and its market potential. There is however, the potential of improved use of the plot

Planning aid

To be able to make the right decision in building refurbishment, it is vital to carry out an early potential assessment. Building owners need guidance in choosing the optimal strategy for their property. Therefore building strategies has been drafted within this study and evaluated considering the performance in energy, added value and multiplication effects. In addition the following aspects have been taken under account:

- earthquake resistance: Earthquake strengthening can prove very costly and can tip the balance for a new-build replacement strategy.
- heritage building preservation: buildings and housing estates from 1945-1970 are gaining attention as objects for building preservation.
- Lack of reserves: the optimal building strategy cannot be chosen because of lack of proprietary capital.
- Earlier investments made without a planning concept: investments which have already been made can hinder the optimal building strategy (e.g. recently replaced windows have to be dismantled for facade insulation, or the newly replaced footstep sound insulation turns out to be inadequate or the heating system over-proportional after retrofitting the building envelope).

The following planning phases are part of an optimal refurbishment strategy: Following the evaluation of client's needs, the building and location are evaluated and a target agreement is drawn up between client and planner. It provides the basis for the technical and spatial design construction planning which results in the building strategy. The planning phases may have to be repeated at different levels of detail (planning application, construction documentation) and can overlap in an iterative process. Realization of the building strategy can be carried out in several stages. It is important to carry out detailed overall planning beforehand. It is the only way to ensure that all refurbishment phases are co-ordinated. The final stage of the strategy is the efficiency evaluation of the finished building. [2, 9]

AIMS

Based on the above-mentioned challenges of residential building refurbishment, it is necessary to identify the complete picture for the object of investigation (multi-family homes) for the project building typology and holistic refurbishment strategies. This process must, however, be selective. Every single detail of each technical discipline in the construction industry cannot be recorded. Typology serves to reduce complexity. [10].

The project aims at the following:

- develop a catalogue of features: as an analysis framework to select a building strategy and to create types for the prefabricated retrofit systems.
- identify general types: for easy orientation using fewer characteristics.
- identify focus types: to develop prefabricated retrofit systems with high market potential.
- plan refurbishment strategies: to demonstrate refurbishment strategies with prefabricated retrofit systems as guidance for holistic project planning.

Type - Typology

Building types are similar buildings typically and frequently found in a particular geographical area. The definition of a building type should be based on a building typology and should describe the characteristics and parameters of the building. Building types can be identified from different points of view, e.g. by the construction industry and real estate experts through experience. However, they are not comparable because they are based on different parameters.

A building typology describes building types with the same set of parameters. It includes geographical distribution, age and other important building features related to the aims of the project. It allows the development of general strategies: building types are comparable because they are based on the same parameters. The typology can be statistically determined to show frequency of a building type and identify the most relevant ones.

Typology-based Evaluation

The method of typology-based evaluation developed at the Competence Centre Typology & Planning in Architecture (CCTP) is the systematic study of a building structure with regard to its use and benefit to society.

- It describes and assesses the building and its urban environment (structures and processes) holistically, systematically and within a set system limit in regard to their function (use and needs).
- It has an intelligent design in which the evaluation criteria adapt to each individual case study with variable options. The same holds for the tool to be used, the structure to be analysed and the interpretation of the results.
- It allows comparisons within and between different types of building construction and enables benchmarking and market analysis. In this way, the potential of the building is identified, inter-relationships determined and statements on efficiency and building performance given.

PROCEDURE

The Building Typology and holistic Refurbishment Strategy project is divided into 5 phases:

- sampling of buildings according to statistical criteria
- analysis of the building in 13 focus areas and recording features relevant for the building refurbishment
- determining system behaviour in respect of the key focuses design, economy, ecology and function
- planning holistic refurbishment strategies with different version
- assessing market potential of the pre-fabricated retrofit modules and technical guidelines

Sampling of Building

To establish a typology, buildings of a certain group have to be identified (statistical population). This typology focuses on multi-family houses. Buildings to be analysed were selected according to the frequency of the following characteristics recorded by the Swiss Federal Statistical Office (SFSO):

- located in the German-speaking part of Switzerland
- used only as a residential building (multi-family house as defined by the SFSO)
- minimum number of apartments 3 (multi-family house as defined by the SFSO)
- 3 to 8 storey-buildings

– constructed between 1919 and 1990

These buildings represent 62% (106,200 buildings) of all existing multi-family homes in German-speaking part of Switzerland [11].

By considering the frequency of statistically recorded features and how often these occur in the various building types, it is possible to assess the frequency of each individual building type. To be statistically sound, a building typology must analyse 1-2 per thousand of the building stock (Prof. H. Keller, HSLU) – 106 buildings. 127 multi family houses have been analysed and the data has been systematically collected by reporting forms [12].

For the market potential evaluation of the refurbishment solutions, a survey with 127 multi-family homes was done in urban areas of Basle, Lucerne and Zurich as well as rural areas in German-speaking part of Switzerland. This allows the development of holistic refurbishment concepts that identify the potentials of the buildings in its context.

Building Analysis

Each of the 127 buildings analysed are recorded in full in the catalogue of features which consists of:

– definitions of the relevant features
– coding the features for the database
– data collection sheet for recording the features

The catalogue of features contains the statistical characteristics and the relevant criteria for building refurbishment. (See results, catalogue of features). Types are identified based on similar features and combinations (characteristics) in the catalogue of features (method: data mining by Prof. T. Olnhoff, HSLU-T&A). The identified building types can be quantified on the basis of the recorded statistical features.

The type-relevant criteria are structured so that they can be combined with the features of a higher level. In this way, the individual features of a balcony (position on facade, construction and mounting method) can be combined to give a type of balcony. Only the required number of combinations is generated to cover around 80% of the recorded data sets. This structure reduces the variety of built structures and in turn allows the identification of fewer building types.

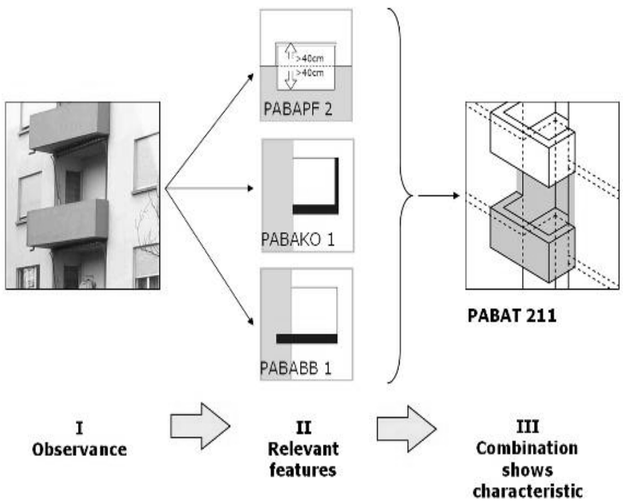

Figure 1: *the characteristic features of a balcony (Position on façade [PABAPF], Construction of balcony [PABAKO], Mounting method [PABABB]) can be combined to a type of balcony©cctp*

Establishing system behaviour with type-based evaluation

Residential building refurbishment comprises various components and can be divided into three groups: existing structures (hard factors), use (soft factors) and their typical links (topics). To reduce complexity the variety of structures are allocated to types, and the different uses are combined as clusters [13].

This model permits a holistic approach in construction planning. Altering a single building element can have an impact on several areas, e.g. on static, fire safety and usability. On the other hand, important objectives of a building project can only be achieved by good coordination of several factors (e.g. energy efficiency or keeping to the cost ceiling). This holistic approach is the key to sustainable strategies for refurbishment [9]: in every single case, an individual refurbishment strategy must be developed (with or without prefabricated modules).

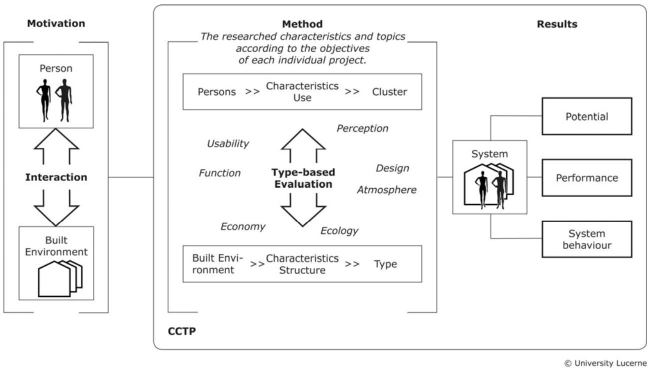

Figure 2: *functionality of type-based evaluation ©cctp*

The system of residential building refurbishment for each type of building is evaluated in this way. Not only have the hard factors of the existing structure changed (refurbishment measures) but also the soft factors of use (alignment to the needs of certain clusters). Different refurbishment strategies can be tested and the potential of a building type evaluated. Type-based evaluation allows the development of holistic, sustainable solutions with a more user-centred focus.

Planning holistic refurbishment strategies

Specific architectural strategies were designed on the basis of the evaluated potential of the building type and by integrating the retrofit modules developed in the process. Guidelines for the technical development of prefabricated retrofit systems were derived from this broad spectrum of structures, materialization and construction details.

Market evaluation method

Holistic refurbishment strategies designed for the identified building types are relevant for the market potential evaluation of each prefabricated refurbishment module. Every refurbishment strategy generates a certain set of prefabricated refurbishment modules. The same refurbishment module can of course be used for several different refurbishment strategies. The potential of a certain refurbishment strategy can be derived from the frequency of the building type and in turn, the market potential of each prefabricated refurbishment module based on its usability in different refurbishment strategies.

RESULTS

Catalogue of features

The catalogue of features has been programmed as a SQL-database. It is divided into 13 focus areas and consists of 71 features. In addition, characteristics of housing requirements (usability) [14], architectural design, and technical standards (fire safety and earthquake resistance).

There are features from which types are formed, and others that are specific to individual buildings. These are called specifications and include measurements (e.g. energy use intensity, openings, orientation etc.) The specifications are linked to the building types as default values in the database.

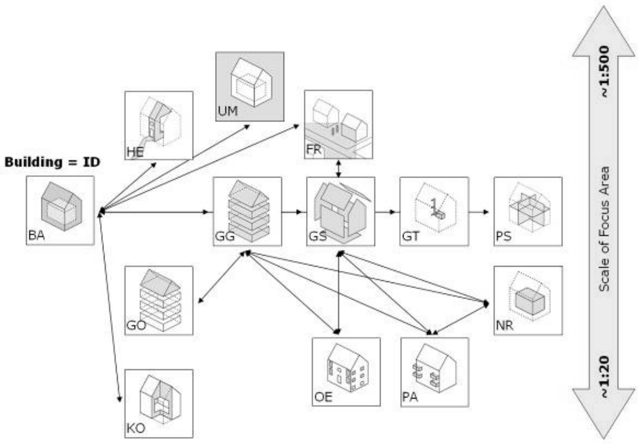

Figure 3: *structure of the catalogue of features. The diagram shows the relations (arrows) between the focus areas (pictograms) evaluated in the CCEM project. legend:*
BA Building, FR Outside areas, GG Storeys (incl. basement), GO Upper Floors (incl. roofs), GS Building envelope, GT Building technology, HE Access, KO Construction, NR Floor space, OE Openings, PA Private outside areas, PS Primary structure, UM Environment
©cctp

General types

Based on the building stock analysis, 11 building types have been identified for easy orientation. Each type is represented by 2-3 reference buildings. The system behaviour of these building types, representing apartment buildings with a similar structure, is analysed and strategies for building renewal are being developed.

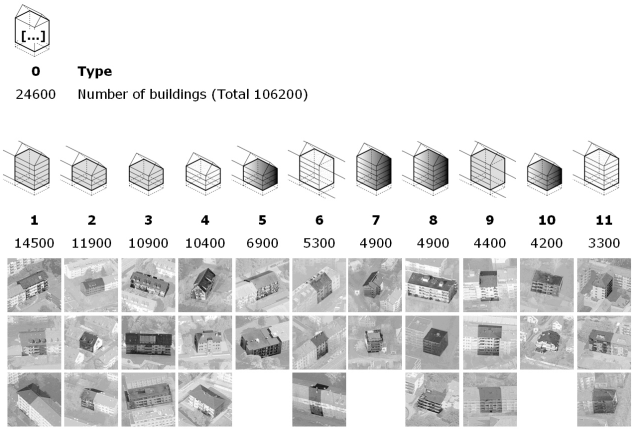

Figure 4: *identification of 11 building types and up to 3 reference buildings for easy orientation ©cctp*

Renewal strategies

Based on the data collection, use-specific and market-oriented retrofit strategies are developed. Three case study buildings are selected for further investigation (representative buildings of the most common building types). Technical and architectural requirements are combined and design criteria for prefabricated retrofit modules are defined. These architectural guidelines are coordinated with the technology development work packages of CCEM-Retrofit project.

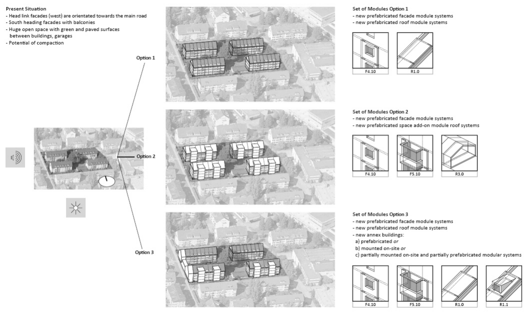

Figure 5: *renewal strategies for case study building 1 ©cctp*

Focus types and market potential of prefabricated retrofit modules

The focus types were identified from the recorded features in the focus areas OE opening, PA private outside areas and GO upper floors (including roofs). These types induce the design and construction requirements of the prefabricated modules (details, building physics and mounting process). Based on the frequency of the focus types, the market potential of the prefabricated modules was evaluated and technical guidelines were devised.

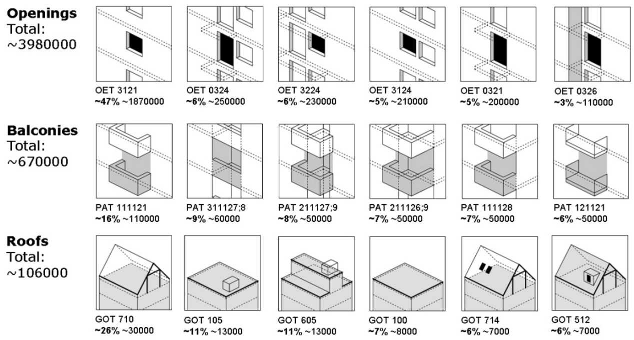

Figure 6: *main characteristics of the 3 focus types (Openings, Balconies, Roofs) in the analyzed building stock ©cctp*

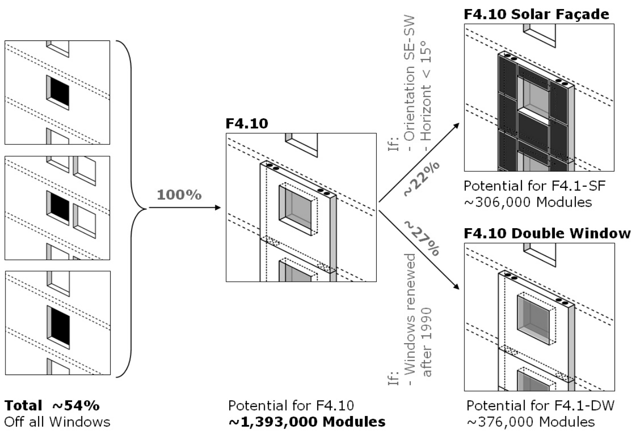

Figure 7: *the potential for module F4.1 and its mutants (PV/PT F4.2 and solution for already exchanged windows F4.3) ©cctp*

CONCLUSION

Type-based evaluation allows a holistic view and offers numerous application options. In the "Building typology and holistic retrofit strategies" project it was used to determine type-specific refurbishment strategies and to evaluate the market potential of prefabricated retrofit modules.

Type-specific refurbishment strategies serve as guidelines in strategic project planning. A building can be attributed to a building type using few characteristics. The potential of individual buildings or entire property portfolios can be evaluated in an easy way at an early stage [15]. Specific refurbishment strategies can be developed with architects and specialist planners, the necessary measures planned and where appropriate, implemented in a phased project.

Based on the market evaluation of prefabricated retrofit modules, trade and industry can concentrate on the technical development of the module which has the greatest impact. This system can help prefabricated retrofit modules to a rapid market breakthrough.

Holistic planning, modularization and quality of the prefabricated retrofit modules will trigger important impulses in the refurbishment market.

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"IFD" SYSTEMS = OPEN BUILDING "PLUS"

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ABSTRACT

The Open Building approach should benefit more from the actual strategies and technologies offered by an INDUSTRIALISED system, since it is aiming at offering adaptability to the large majority of people. Such a large market justifies the investment in a process capable, in return, of simplifying production and reducing the cost while assuring better quality and precision. The precision achieved in factory production can generate components detailed for easy and fast installation: when dry joints are employed, an easy installation naturally implies an easy disassembly, leading to adaptability through space and time. A FLEXIBLE system can be readily available by grouping the usual sub-systems composing the Infill: personalized exterior wall panels, movable or demountable partitions / equipment and variable service distribution network. When the needs for change go beyond the realm of the Infill, the Support Structure should by served by a DEMOUNTABLE building system, allowing for an easy reconfiguration and/or relocation of the building and/or the reuse of its components for another building. Industrialised, Flexible and Demountable (IFD) systems are available in the three categories of building systems; they are offering complete adaptability through space and time without any demolition, as per the sustainability agenda.

Keywords: Adaptability, Building System, Industrialization, Flexibility, Disassembly.

INTRODUCTION

In the residential Open Building approach, the base building is a generic framework, called “Support Structure”, meeting the goals of a community of residents and usually resulting from their participation in the development process. “The Support is the permanent, shared part of the building which provides serviced space for occupancy…Which criteria any given Support will have to accommodate becomes a function of project economics, site conditions, the preference of various stakeholders and so on” (Kendall and Teicher, 2000). The Support is accommodating a series of “Infill” components selected by the individual occupants of a dwelling unit and adaptable to their specific needs through space and time.

As our societies face ever changing needs, the Support itself will eventually require some form of transformation of its own; probably sooner than later. Industrialised, Flexible and Demountable (IFD) building systems should then be available to generate affordable and interactive Support Structures: innovative models have to be developed, addressing market dynamism and client demands in a more effective way (Di Giulio et al, 2005).

INDUSTRIALISED BUILDING SYSTEM

Duality within housing

The Open Building approach has always considered industrialised production as the natural source of Infill components. But “Housing is a bulky consumer-oriented commodity; yet at the same time it embodies a jointly held social asset … That housing has never achieved the straightforward match with consumer preferences achieved by other industrial products is partially a result of that duality” (Kendall and Teicher, 2000). As our societies are more and more experiencing Mass-Customization, that duality can perhaps operate differently; notably since the quality achieved by factory production can facilitate the jointing process.

Simplifying the production

Industrialisation is first and foremost a mathematical equation: a generic organisation will aim at a large market (quantity) to amortize the initial investment in a process capable, in return, of simplifying the production in order to offer an affordable and diversified product to the large majority of people (Richard, 2007).

The appropriate level of industrialisation is reached when an innovative technology is short-cutting the linear tasks of the traditional methods. In a single operation, for instance, the extrusion process generates the complex profile of a curtain wall frame. In a single operation, the extrusion process generates a pre-stressed hollow core concrete slab; thereby eliminating the setting and dismantling of formwork at the site, maximizing the compression features of concrete, minimizing the deadweight and reducing the construction wastes.

The immediate effect of simplifying the production is, by definition, a reduction of cost. But that is not the most important benefit. Factory production is generally capable of much more precision than traditional construction. To avoid spending the gains achieved at the plant, factory-made components or sub-systems have to be fast and easy to install at the site: when dry joints are employed, they are then fast and easy to disassemble.

Dry Joints

Dry joints are required to achieve full disassembly without destroying any significant part of the structural sub-system.

Dry joints exclude by definition any welding, bonding or cementing. Dry joint will be mainly mechanical: bolting, post-tensioning or locking. But a locking device requires a thorough quality control process, in order to make sure the slots are nested in the right place for good; that is perhaps the reason why they are rarely used.

Specificities of an industrialised building system

An industrialised building system is a set of parts where generic details are solved and made available before actual as well as different buildings are planned. In other words, the details and their rules are the same for a large quantity of buildings, but the planning of those buildings will vary.

Mass-customization and the Open Building approach

Industrialised building systems can offer individualised and personalized buildings by adopting the four "mass-customization" strategies enforced in most industries: 1- Flexibility of the Product, 2- Flexibility of the Tool, 3-Multipurpose Framework and 4-Combinability (Richard 2007-10).

The "Open Building" approach is already tuned to two of the four strategies: as mentioned above, the "Support Structure" is basically a "Multipurpose Framework" and the "Infill" is relying on "Flexibility of the Product" to operate changes notably with the partitions, the dwelling unit equipment (kitchen, bathroom, etc.) as well as with the facade panels. "Flexibility of the Tool" is the appropriate method to generate sub-variations whereas "Combinability" allows for multiple configurations out of a set of interchangeable components.

The sub-systems

Basically a building system is grouping the components required for each sub-system. Five sub-systems are usually recognized: Structure, Envelope, Partitions, Equipment and Services. Of course, some sub-systems may integrate more than one function. For instance a sandwich load-bearing wall will perform both as a structural component and as an envelope component; an interior load-bearing wall can also be a partition; a partition can accommodate the electrical/electronic wiring within the baseboard; a closet can also be used as a partition; a factory-made kitchen-bathroom 3D module can also contribute to the structure; etc.

FLEXIBLE SYSTEM

A flexible system will offer a coordinated set of components to serve the Infill. In a dwelling unit, for instance, the parents will want the bedroom of a young child close to their bedroom, but when that child becomes a teenager, an opposite layout is most likely desired by both parties. Various factory-made components are currently available:

- Demountable partitions, removable panels supported by notched studs;
- Partitions, responding only to a ceiling channel and dismantled in a single operation;

- Mobile 3D functional modules, like the individual booths in a landscaped office floor or the personal capsules on casters which can be moved freely in a “loft;
- Raised floor allowing for the relocation of mechanical and electrical services;
- Interchangeable envelope panels revealing the personality of the occupant, etc.

The best example of flexibility is the NEXT21 building in Osaka, designed under the leadership of Professor Yositika Utida and built by Osaka Gas Corporation (Osaka Gas, 2000). Each apartment is showing a different layout, governed by the specific needs of its occupants. Many layouts have been changed completely since the “initial” construction was completed, while maintaining 90% of the original components.

Figure 1: *NEXT21 Adaptable prototype in Osaka*

A simple raised floor technology accommodates the various layout changes: a filtered rod with a rubber pad at the bottom and an OSB square piece at the top is the basic component, completed by square under floor panels. The exterior façade components are composed of different glazing units completed by colourful stainless steel interchangeable horizontal laths.

A similar approach is now being implemented in Japan under the name of “Kodan Support & Infill” (KSI) in the many projects built by Urban Renaissance Agency (UR) and also in some major high rise condominium buildings built by private developers, including the recently completed Fukuoka Island Towers.

DEMOUNTABLE SYSTEMS

When the needs for change go beyond the realm of flexibility, the Support Structure should take advantage of a DEMOUNTABLE building system, allowing for an easy reconfiguration and/or relocation of the building and/or the reuse of its components for another building: without any demolition as per the sustainability agenda. Three categories of building systems can be outlined according to the distribution of the work between the plant and the site (Richard, 2007). Dry joints are available in each one of the three categories.

I- Site-Assembled Kit of Parts: All sub-systems are made at different plants and transported separately, which implies an important but fast & easy jointing operation at the site. The four types of systems (“A” to “D”) within that category are distinguished by the geometry of the structural sub-system.

A- POST & BEAM	Skeleton requesting horizontal and vertical infill	**Adaptability on three axes**
B- SLAB & COLUMN	Simplification through the introduction of a single horizontal element	**Adaptability on two axes**
C- PANELS	Load-bearing flat components distributing the loads and contributing to soundproofing	**Adaptability within (or partially through) the structural bay**
D- INTEGRATED JOINT	Monolithic component locating the joint outside the geometrical meeting point	**Adaptability conditioned by the geometry of the structural sub-system**

Table 1: *The Site-Assembled Kit of Parts*

II- Factory-Made 3D Module: All spaces and all components of the building are entirely made, assembled and finished at the plant as 3D modules. The two types of systems (“E” and “F”) within that category are related to the fact that the building is either partially or totally formed by those modules.

E- SECTIONAL MODULE	Small and easy to transport modules but incomplete, as they a need major complement once at the site	**The factory-made modules can be relocated, but not the site counterpart**
F- BOX	Autonomous unit entirely completed at the plant	**Variable clustering, but demountable only in low-rise configurations**

Table 2: *The Factory-Made 3D Module*

III- Hybrid: Manufacturing at the plant the complex parts of the building and entrusting the site with the operations requiring heavy transportation. The three types of Hybrid systems (“G” to “I”) aim at benefiting from the advantages of the Kit-of-Parts while avoiding the limitations of the Factory-Made 3D Module.

G- LOAD-BEARING SERVICE CORE	The “service” area (kitchen / W.C. / laundry / mechanical-electrical shaft / stairs / etc.) is built at the plant within a 3D module with structural capacity	**The Core is a closed sub-system, but demountable, whereas the served areas are entirely available to open sub-systems**

H- MEGASTRUCTURE	Framework to stack boxes in order to reach a high	**The framework can allow different boxes, but complex jointing and redundant structure**
I- SITE- MECHANIZATION	Bringing the factory and its tooling to the site as far as the structure is concerned	**Restrictive adaptability, but most sub-systems besides the structure can be flexible and demountable**

Table 3: *The Hybrid*

The Kit-of-Parts category is prolific in terms of adaptability, as many types of systems are more or less structural skeletons open to various “plug-in” components. The grouping of Factory-Made 3D Modules can adopt different geometries, but their feasibility is limited to low-rise constructions, to town-houses in the case of a residential system. As for the Hybrid, their duality does impose significant restrictions which are not necessary limits.

DEMOUNTABLE SITE-ASSEMBLED KIT-OF-PARTS

The Site-Intensive KIT-OF-PARTS involves a few simple factory-made components produced in large quantity and designed to be assembled at the site, which implies an elaborate series of jointing and connecting operations.

Bolted joints are the rule with both steel and wood frames. When fireproofing and soundproofing are prime criteria, precast concrete is prevailing since it can meet the criteria straight, without any additional covering or treatment: bolted steel connections are usual, but post-tensioning is an option.

Bolted joints for Site-Assembled Kit-of-Parts

Easy to dismantle bolted joints can be implemented for precast concrete components in any Site-Assembled Kit-of-Parts system. Anchored steel plates within a recessed pocket allow for the bolting process to take place. In order to facilitate the dismantling, the steel should be lubricated and an easy-to-break grouting applied to maintain the performances as well as to prevent rusting: the bolting will then be ready-to-undo with just a few hammer strokes. Perpendicular oval holes offer the proper tolerances.

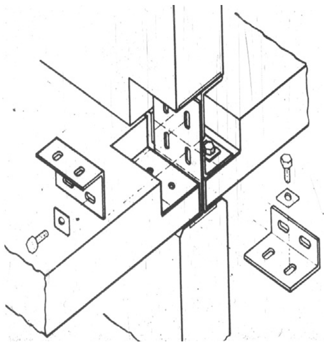

Figure 2: *Steel angles connections with perpendicular oval holes*

Post-tensioned joints for Site-Assembled Kit-of-Parts

Post-tensioned jointing is quite simple although sophisticated in its application, whereas the dismantling requires careful and progressive release whit the help of temporary supports. The most practical approach is the Dywidag thread bar which can be staged floor by floor, using couplers and simple high strength nuts & washers to spread the tension.

Figure 3: *Post-tensioned connection*

Multi-options components

The ”Meccano” kit is very often recognized as the iconic model of adaptability. Those pre-punched modular series of holes and their standard nuts & bolts allow for any type of configuration. Using the same components, the user will easily mount a simulation of the Eiffel Tower and/or the London Tower Bridge.

Otto Steidle applied that approach in his Munich Genterstrasse town housing project built in 1972 (Kossak, 1994). He introduced a continuous column with capitals available at each half-floor level, thereby allowing for split level floors as well as various (1, 1½ and 2 stories) ceiling heights.

Based on the same approach, an IFD system was proposed at the Université de Montréal to accommodate the ever changing contemporary university teaching and research spatial needs (Richard, 2008). Depending on the type of beam (“I”, “L” or reversed “T”), a large spectrum of floor to ceiling heights can be generated.

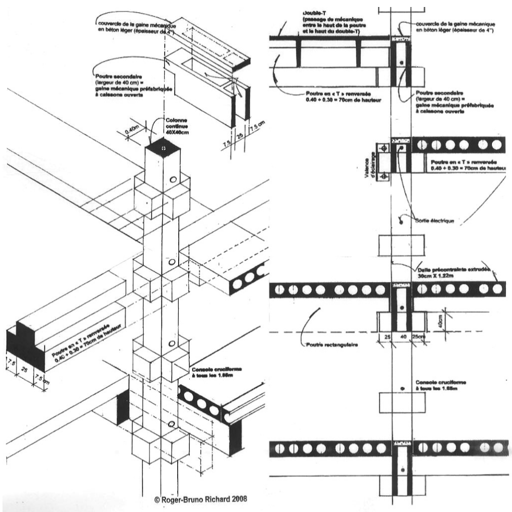

Fig. 4: *Multi-capital column of the IFD university building system developed in Montreal*

DEMOUNTABLE FACTORY-MADE 3D MODULES

In the Factory-Made 3D Module category, one of the best combinations of adaptability and sustainability is offered by the small boxes of the Sekisui HEIM system (Richard and Noguchi, 2006). Due to the road transportation limitations in Japan, the units measures 5.614m X 2.464m, which means that a regular single family house would require 12 to 16units. The units deploy a rigid framed-at-the-edges structure: a large room can be generated by grouping 2 or 3 boxes and partitions can be set anywhere within a single unit or between units. Multiple geometries are generated, as well as various interiors and façade treatments: actually, no two houses are similar.

At the site, the units are bolted corner to corner, which means that up to eight corners can get together when a unit is fully surrounded.

Figure 5: Bolted connections of 8 Sekisui Heim 3D modules

Sekisui Heim offers post-delivery services, allowing not only the possibility of adding units or renewing components, but also of dismantling the units to upgrade, recycle and even relocate the house, thereby accommodating the family scenario while achieving a full life-cycle operation.

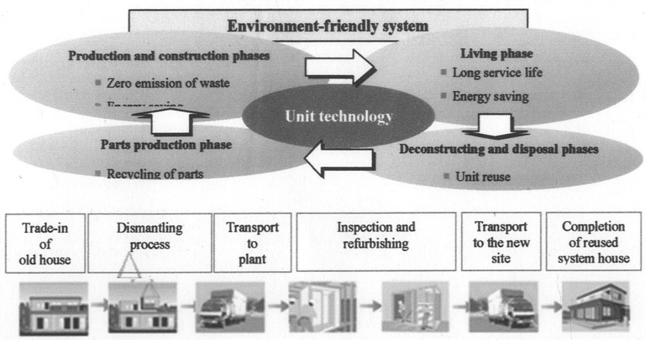

Figure 6: Interaction and compatibility between the sub-systems of Sekisui Heim 3D modules

DEMOUNTABLE HYBRID

The Hybrid category is aiming at "the best of both worlds", manufacturing at the plant the complex parts of the building and entrusting to the site the operations requiring heavy transportation. That very broad goal becomes a limit as far as adaptability is concerned.

With the LOAD-BEARING SERVICE CORE, the "service" area is built at the plant within a module with structural capacity. Spanning betweens those "Service Core" modules, large slabs are offering “served areas” open to different planning options (Richard, 2005).

As they are directly related to the Cores, those options are regulated by the system. Therefore, adaptability is quite large within the system, but the system is not adaptable to any type of planning.

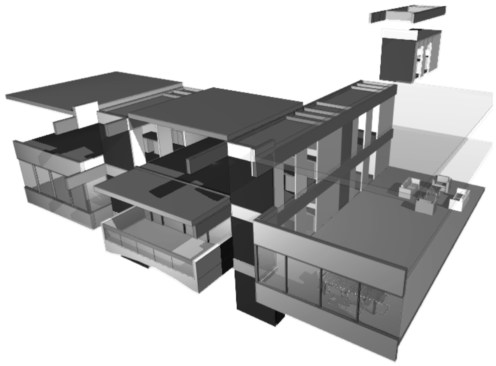

Figure 7: *Richardesign Load-Bearing Service Core System*

The MEGASTRUCTURE is a kind of framework to stack boxes. It offers no adaptability other than the possibility of removing the boxes. But those boxes, which are structures by themselves, become live loads to the Mega-structure: that redundancy is the main reason explaining the few examples built and the fact that some tentative implementations went into bankruptcy.

As for SITE MECHANIZATION, bringing the factory and its tooling to the site to produce the structure, its results are equivalent to the cast-in-place supports as far as adaptability is concerned.

CONCLUSION

Properly applied and using a dry joint technology, Industrialised, Flexible and Demountable (IFD) building systems are offering adaptability without any demolition, directly in line with the sustainability agenda (Richard, 2006.10). Three conditions must be met:

- Aggregating the market to amortise a series of processes capable of simplifying production;
- Using the precision available with factory production to deliver high quality components fast and easy to assemble and disassemble at the site;
- Implementing the four “mass-customization” strategies in order to meet not only the needs for change but also the individual specificities of the occupants.

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THE EXPERIMENTS OF INSTALLING AND CHANGING INFILL IN "INFILL LABORATORY GLASS CUBE" OF THE EXPERIMENTAL HOUSING NEXT21

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ABSTRACT

Experimental Housing NEXT21 was planned by Osaka Gas Corporation and was completed in 1993 as a future model for urban multi-unit housing complex. In NEXT21, there have been several experiments of remodeling dwelling units for the sake of realizing sustainable housing. "Infill Laboratory Glass Cube" is an experimental dwelling unit completed on the second floor of NEXT21 in 2006 in order to study house planning which is compatible with the aging society with declining birthrate and the environmental issue. From April 2007 to February 2009, the experiments of installing and changing infill in the Glass Cube were conducted by Kyoto University, Osaka Gas, Tokyu Construction, and Itoki. This paper is a report of the experiments in the Glass Cube.

Keywords: Experimental Housing, Skeleton Infill Housing, Skeletons with low ceiling height, Variable Infill Unified with Equipment, Movable Storage Furniture

INTRODUCTION

Experimental Housing NEXT21 was planned by Osaka Gas Corporation and was completed in 1993 as a future model for urban multi-unit housing complex ***(picture 1)***. In NEXT21, there had been habitation experiments only, but several experiments of remodeling dwelling units were carried out for the sake of sustainable housing system from April 1994 to March 1999 (the 1st phase) and from April 2000 to March 2005 (the 2nd phase).

Habitation experiments in the 3rd phase started from April 2007. Two concepts in the experiments are 'dwelling compatible with the aging society with declining birthrate' and 'dwelling compatible with the environmental issue.' “Infill Laboratory Glass Cube” is an experimental dwelling unit planned on the second floor of NEXT21 in 2006 in order to study infill technically achieving the concepts. From April 2007 to February 2009, experiments of installing and changing infill in the Glass Cube were conducted by Kyoto University, Osaka Gas, Tokyu Construction, and Itoki. This paper is a report of the experiments in the Glass Cube.

Main technical points of the experiments are as follows:

1) Consideration to the arrangement of sanitary equipment in skeleton with low ceiling height by comparing several arrangements in the Glass Cube

2) Consideration to the technical problems of variable infill unified with equipment.

3) Consideration to the ease of rearrangement of movable storage furniture.

Figure 1. *Next 21*

INFILL LABORATORY GLASS CUBE

Planning of “Infill Laboratory Glass Cube”

“Infill Laboratory Glass Cube” was planned with several conditions in order to enable dwelling compatible with the aging society with declining birthrate and the environmental issue in the Cube ***(figure 1)***.

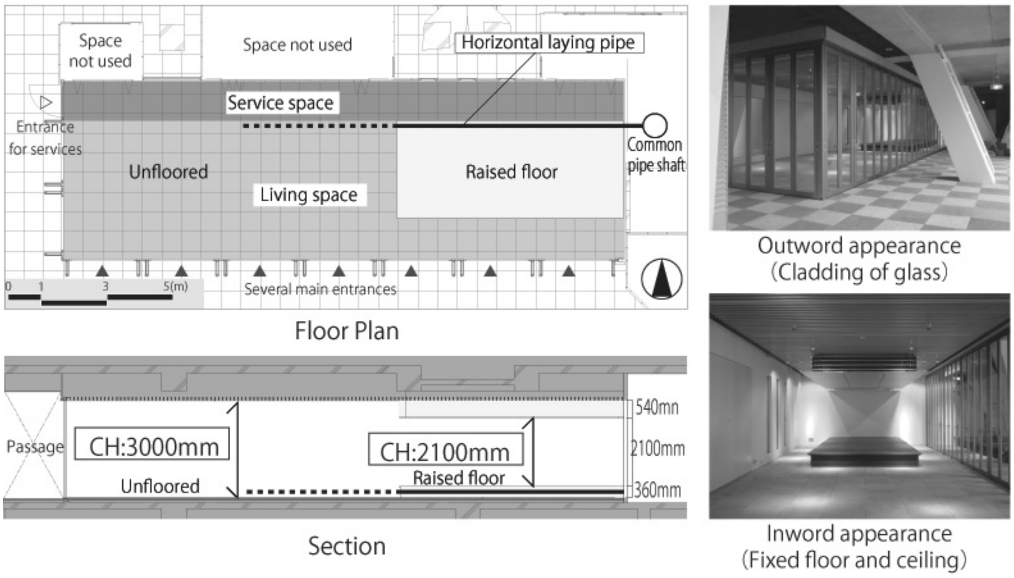


Figure 1:*Infill Laboratory Glass Cube*

Conditions concerning the aging society with declining birthrate

Two conditions were set assuming dwelling by independent individuals who use services.

1) To secure several main entrances from the southern passage by cladding designed to open and close.

2) To secure a service entrance separately from the main entrances by zoning service space and living space separately.

Conditions concerning the environmental issue

Two conditions were set assuming skeleton with low ceiling height through consideration to the necessity of long life housing.

1) To secure horizontal pipe space on the unfloored level by threading in the floating floor or variable infill with equipment.

2) Different ceiling height of 2100mm and 3000mm by using raised fixed floor with height of 360mm.

Infill planning in the Glass Cube

Infill used in the Glass Cube

Infill can be classified into fixed infill and variable infill. Fixed infill used in the Glass Cube consists of fixed floor, a modular bath, two toilets and a sanitary equipment in kitchen (hereinafter kitchen). In the experiments, we used movable storage furniture as variable infill. Also, we developed variable infill unified with equipments ***(Figure 2)***.

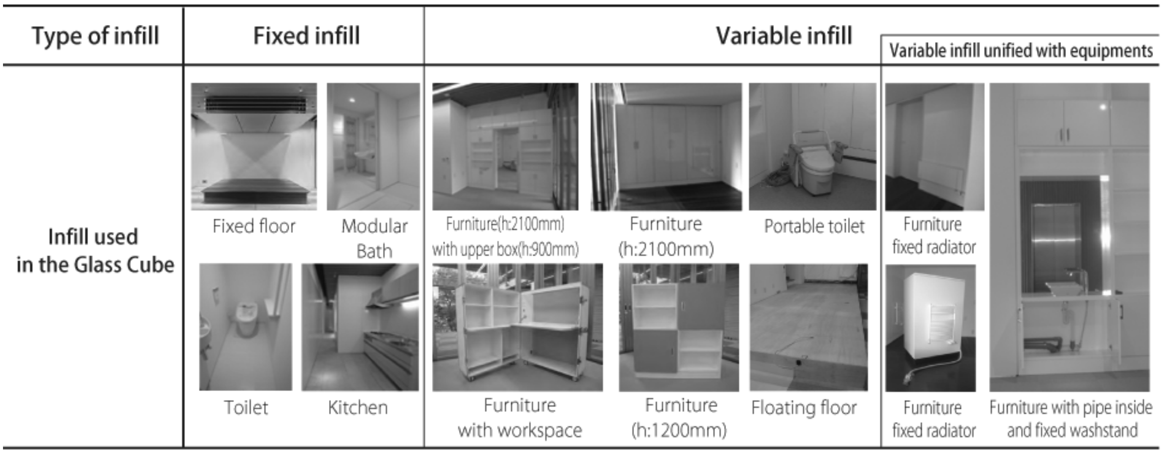


Figure 2: *Infill used in the Glass Cube*

Four scenarios

We set two family models. One is 'Dwelling for unrelated elderly people living cooperatively' and the other is 'Dwelling for single father and his child'. Then we set two further scenarios for each family model. One is 'a scenario at present' and the other is 'a scenario after ten years'. As a condition of the experiments, we decided to use the same infill when making infill arrangements in the total four scenarios ***(Figure 3)***.

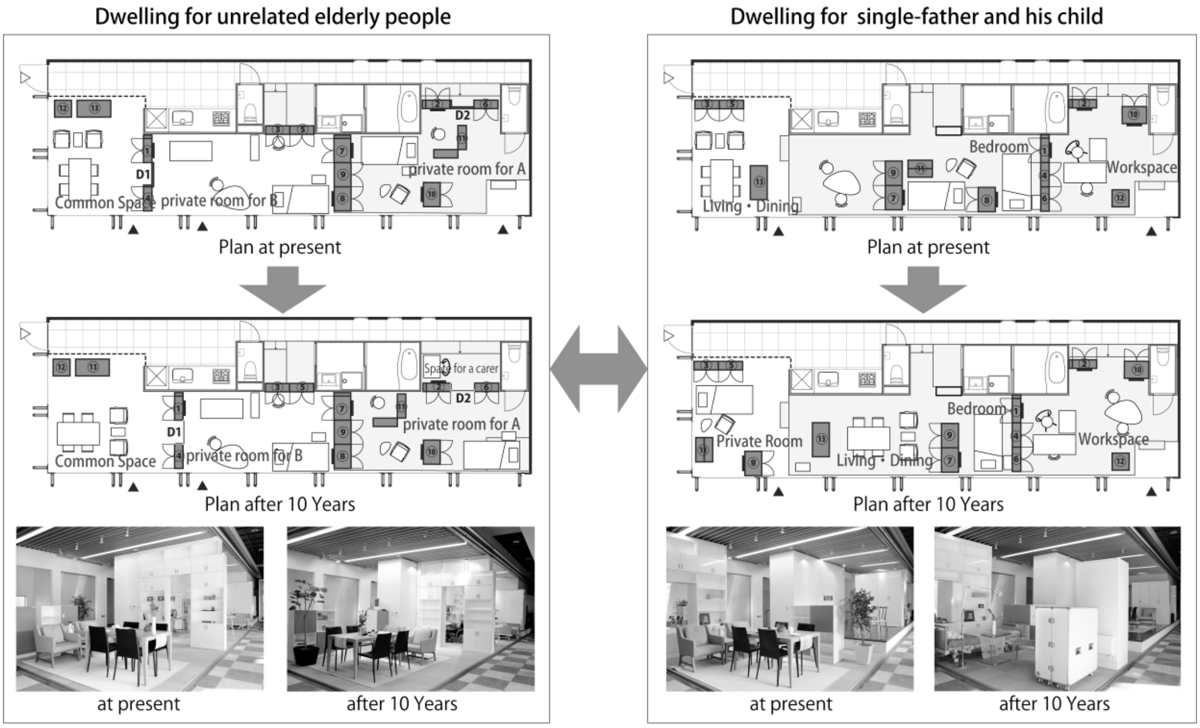


Figure 3: *Four Scenarios and Four Plans*

CONSIDERATION TO THE ARRANGEMENT OF SANITARY EQUIPMENT IN SKELETON WITH LOW CEILING HEIGHT

Installing sanitary equipments in skeleton with low ceiling height

It is general for skeleton-infill housings to secure horizontal laying pipe space in the raised floor by adopting the double floorings. However, in skeleton with low ceiling height, it is also effective to secure horizontal laying pipe space inside the wall.

In this chapter, we will clarify how residential planning could be influenced by horizontal laying pipe space of sanitary equipments through comparison between several sanitary equipments arrangements in the Glass Cube.

Frame of consideration to sanitary equipments arrangements

In the Glass Cube, through consideration to skeleton with low ceiling height, we planned raised floor area, where horizontal laying pipe space must be secured beneath floating floor, and unfloored area, where horizontal laying pipe space must be secured in the infill wall.

Because we assumed servers need to use sanitary equipments from the service space on the unfloored level, we had to arrange them straightly on the boundary between service space and residential space. We studied the arrangement of a kitchen, a modular bath and a toilet as the sanitary equipments used from the service space. The arrangement was classified by whether installing them in the raised floor area or in the unfloored area. In next paragraphs, we will compare three typical arrangements ***(Figure 4)***.

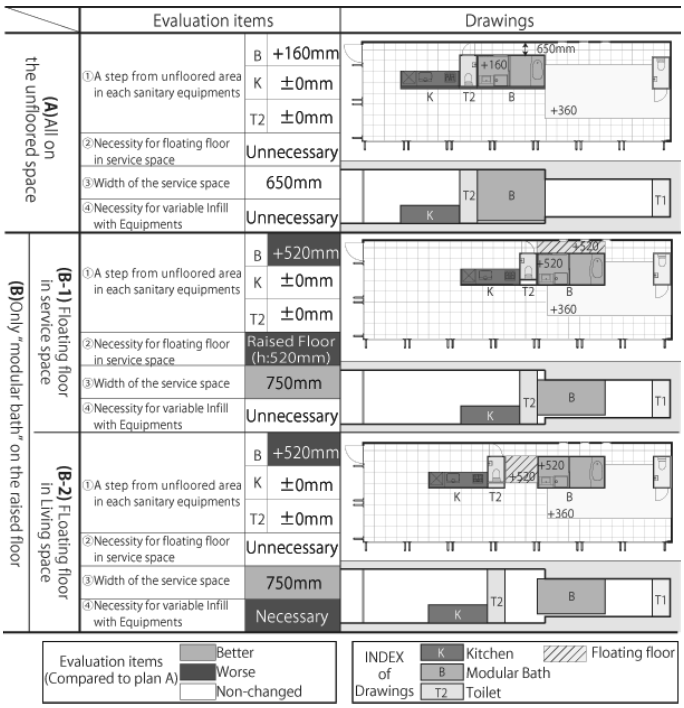


Figure 4: *Three arrangements of the sanitary equipments*

Comparing several sanitary equipments arrangements in the Glass Cube

In the Plan A, step between the sanitary equipments and the unfloored level is the lowest among three arrangements. However, securing pipe space inside the modular bath caused the width in the service space to be 650mm only, not enabling a wheelchair user to pass through.

The plan B-1 and B-2 arrange the modular bath on the raised floor area. Step between the modular bath and the unfloored space increased, but we could secure 750mm in width of the service space.

The plan B-1 needed the floating floor in the service space, but in the plan B-2 we could rearrange the floating floor from the service space to the living space by using variable infill unified with equipment.

TECHNICAL CONSIDERATION TO VARIABLE INFILL WITH EQUIPMENTS

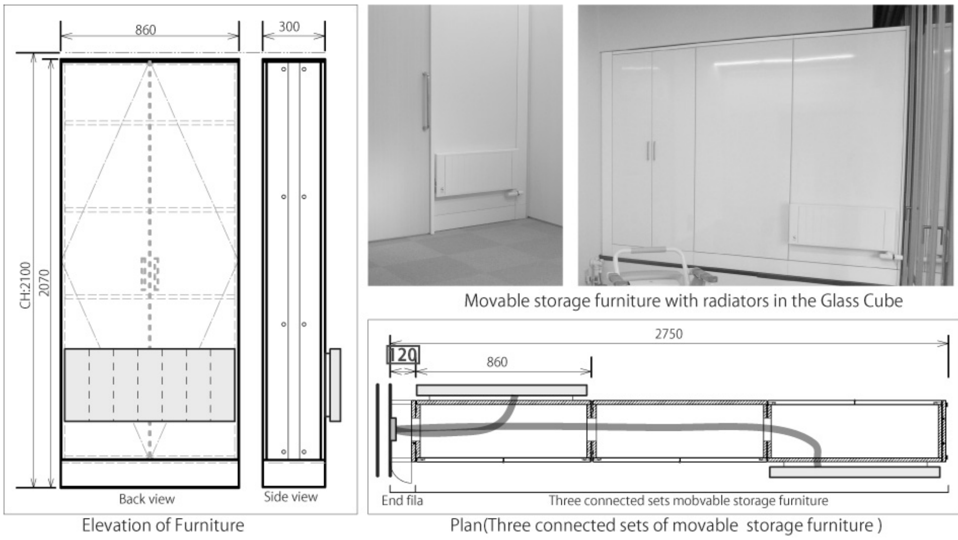
Two kinds of variable infill with equipments were developed in the Glass Cube. One of them has individual heater by fixing a radiator to itself. The other has laying pipe space by threading plumbing through itself. In this chapter, we will consider problems of the variable infill with equipment developed in the Glass Cube.

Movable storage furniture with fixed radiator

When securing the variability in residential space with variable infill, the variability of air-conditioner is also necessary because it cannot stay in the same position. In the Glass Cube, we separated individual air-conditioner from base air-conditioner by adding individual heater to variable infill with equipment.

Movable storage furniture with a fixed radiator was developed as infill with individual heater. The radiator was placed behind the movable storage furniture. Hot-water plumbing was set inside the movable storage furniture. Several sockets for hot-water were set on the walls of fixed infill or on the raised floor.

We could not arrange this infill without securing 120 mm from the wall for inserting to or pulling out from the sockets. Therefore we hid the gap by installing end fila panel. In the experiments, we pointed out the interface problem between fixed infill and movable storage furniture with radiator ***(Figure 5)***.



Movable storage furniture with plumbing inside

In the Glass Cube, we developed variable infill unified with equipment which has pipe space inside by threading plumbing into movable storage furniture.

We needed to make two openings on the side and the back of movable storage furniture in order to thread the pipe into the furniture. In spite of 300mm in depth of the movable storage furniture, we could not make openings larger than 100mm square because of hinges and screws. With the opening, it was impossible to thread all pipes (drain pipe, water pipe, hot-water pipe, and gas pipe) without touching each other.

In the experiments, it was pointed out that there is not enough space inside movable storage furniture when threading the plumbing ***(Figure 6)***.

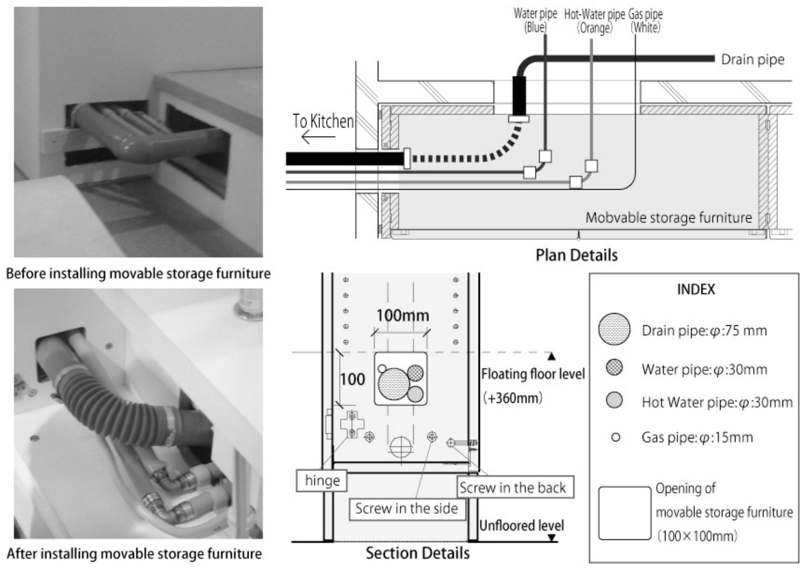


Figure 6: *Movable storage furniture with pipe inside*

CONSIDERATION TO THE EASE OF REARRANGEMENT OF MOAVABLE STORAGE FURNITURE

The rearrangement experiments with variable infill

Two kinds of rearrangement experiments with variable infill in the Glass Cube were done. One is the experiment which satisfies needs for changing usual residential space, such as the change in lifestyles. The other is the experiment which satisfies needs for changing residential space ***(Figure 7)***

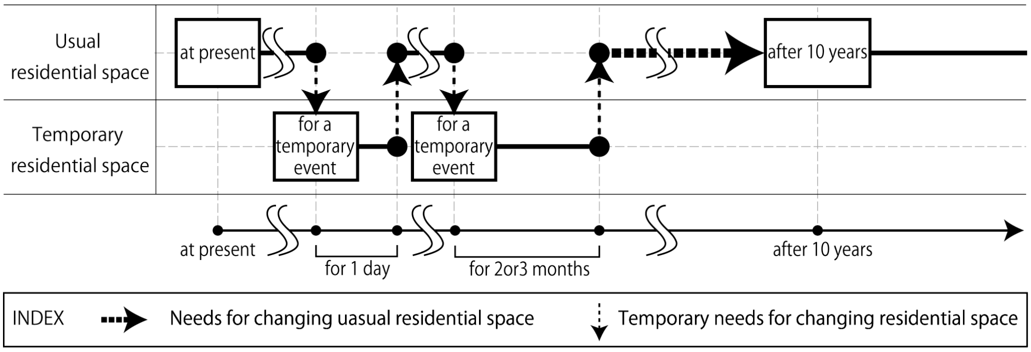


Figure 7: *Two kinds of needs for changing residential space*

How to rearrange the movable storage furniture

Movable storage furniture used in the experiments is fixed by stretching out between the ceiling and the floor. Rearranging process of the movable storage furniture can be classified into three steps: unfastening, moving and fastening. Unfastening process consists of stripping skirting board, releasing the connection with adjacent furniture, stripping shackle, turning handle, and releasing the connection with upper box ***(Figure 8)***.

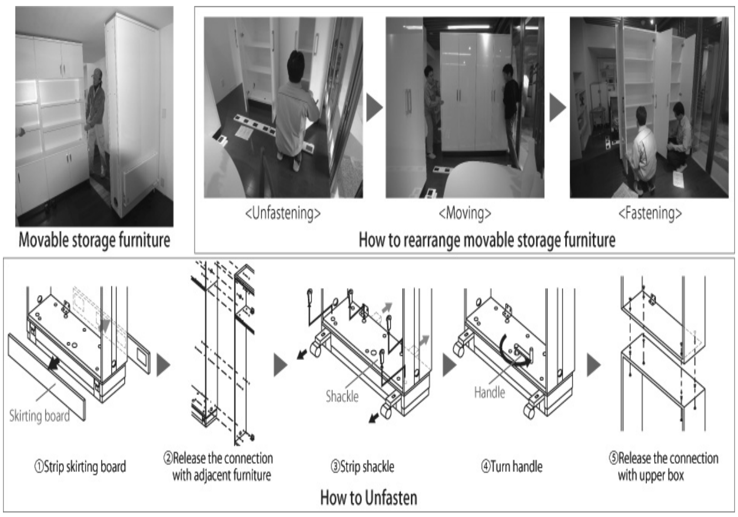


Figure 8: *How to rearrange the movable storage furniture*

The experiment satisfies needs for changing usual residential space

Two specialists in infill were chosen as workers. The most difficult part is the rearrangement of movable storage furniture with sliding-door (hereinafter sliding-door). When rearranging the sliding-door, the workers needed to adjust its position for several times before fastening, and the position adjustment took most of the time in moving. Also they did the same work more than twice ***(Table 1)***. Major factor for the difficulty in rearranging the movable furniture is the wasted time caused by adjusting its position and angle ***(Figure 9)***.

Type of Work	Number	Contents of Work
Unfastening	①、④	Stripping skirting board
	D1	Stripping door panel
	①	Releasing the connection with side panel
	①-D 1	Releasing the connection with adjacent furniture
	D 1 -④	Releasing the connection with adjacent furniture
	D1	Releasing the connection with upper box
	①	Stripping shackle
	①	Turning handle
	①	Releasing the connection with upper box
	④	Stripping shackle
	④	Turning handle
	④	Releasing the connection with upper box
Moving	①	Moving to the next position
	④	Moving to the next position
Fastening	①	Connecting with side panel
Moving	①	Position adjustment
	④	Position adjustment
Fastening	①	Connecting with upper box
Moving	①	Position adjustment
Fastening	①	Connecting with upper box
	①	Connecting with side panel
	①	Turning handle
Moving	④	Position adjustment
Fastening	④	Turning handle
	④	Connecting with upper box
Moving	①	Position adjustment
	④	Position adjustment
	④	Turning handle
Fastening	D1	Connecting with upper box
	D 1 -④	Connecting with adjacent furniture
	①-D 1	Connecting with adjacent furniture
	④	Fastening shackle
	①	Fastening shackle
	①、④	Fastening skirting board
	D1	Fastening door panel

INDEX of the table
Position Adjustment   Work done more than twice

Table 1: *The rearrangement process*

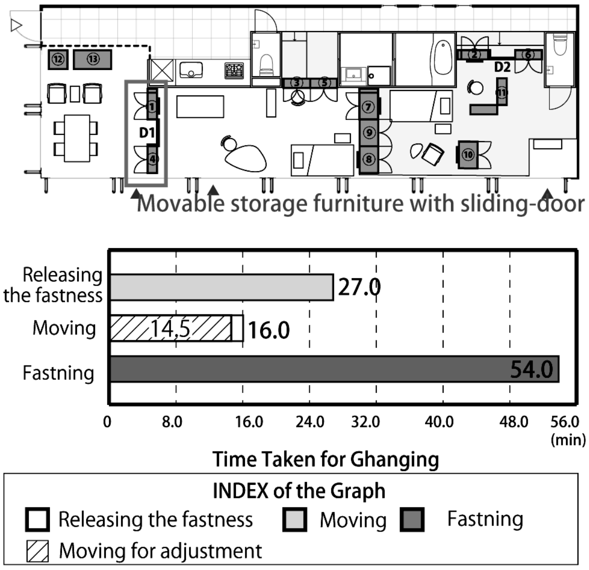


Figure 9: *Rearrangement the sliding-door*

The experiment satisfies temporary needs for changing residential space

Two non-specialists in infill such as residents were chosen with the restriction on the use of no tools. The workers needed to rearrange the connected movable storage furniture without releasing the connection because of the restriction.

In order to study the ease of rearranging the connected movable storage furniture, we let specialists in infill make the same rearrangement in order to compare the working time between the non-specialists and the specialists in infill. As a result, moving time by non-specialist does not differ very much from that by the specialists. However, unfastening time and fastening time by non-specialists are longer than those by specialists ***(Figure 10)***.

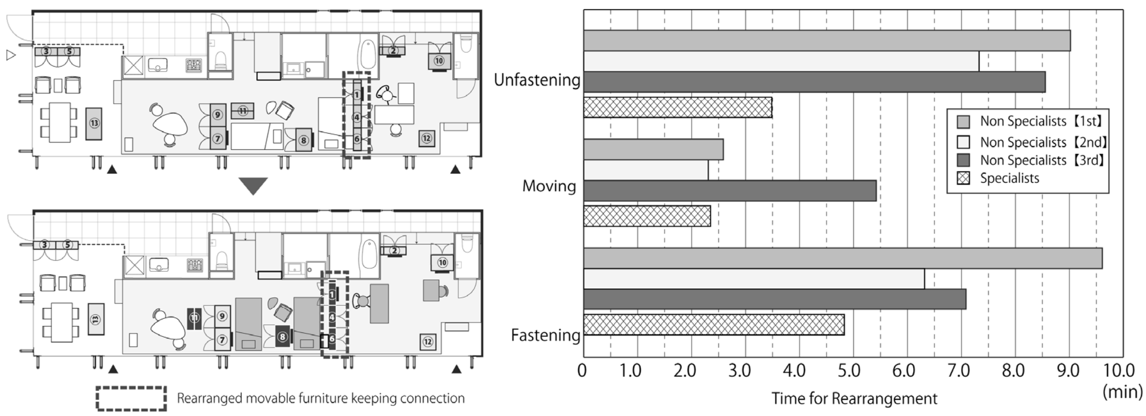


Figure 10: *Comparing the working time between specialists and non-specialists*

CONCLUSION

This paper reported the experiments of installing and changing infill in Infill Laboratory Glass Cube. Results are as follows:

Influence which pipe space of sanitary equipments has on the planning of residential space in skeleton with low ceiling height

1) We confirmed the influence not only on the sectional residential space but also on the plane residential space by securing the pipe space.

2) In skeleton with low ceiling height, it is effective to use variable infill unified with equipment which has pipe space inside.

Technical problems of variable infill unified with equipment

1) We clarified that movable storage furniture with radiator has an interface problem with fixed infill.

2) We clarified that movable furniture with pipe inside is lacking in space for laying pipe.

Technical problems of the ease of rearranging movable furniture

1) We clarified that the accuracy of rearranging works is influenced by construction accuracy of skeleton or fixed infill.

2) We confirmed that non-specialist workers could rearrange the movable storage furniture by themselves without any tools although it took more time for unfastening and fastening compared to specialists.

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BARCODE HOUSING SYSTEM: APPLYING ICT TO OPEN BUILDING AND MASS HOUSING

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ABSTRACT

BARCODE HOUSING SYSTEM is a computer-supported housing design and building system which adheres to the principles of open building in two ways: by distinguishing between support and infill systems, and by enabling the participation of different actors in the processes of designing, building and using the dwellings. A rule-based generative system creates the housing units automatically and stores them in the system's database. Optimization techniques are used to assemble the units into housing buildings which can be constructed in multiple ways using industrial components stored in a catalogue. The different actors (architects, users, manufacturers, builders) participate at the different stages of the design process, interacting with and through the system.

Keywords: Open Building, User Participation, Mass Customization, Collaborative Design

INTRODUCTION

The concept of Open Building stems from the theories developed by Habraken and the SAR around forty years ago (Habraken 1972, 1976), in particular from the distinction between supports and infill systems. According to those theories, a support is a structure that accommodates a multiplicity of housing units, which in turn make up the infill. Both of them –support and infill– are independent systems, although they are strongly interrelated. More important than the physical distinction between both systems –as supporting skeleton and as housing unit– is the fact that each delimits a specific decision-making sphere in the design and construction process of mass housing. Hence, the support is the collective domain controlled by the community, whereas the infill is the private domain in command of the individual household. This twofold nature of the support, as a material structure and as an abstract space of control, characterizes the original formulation of Habraken's theories. The ultimate purpose of Habraken's approach was to bring the individual user back in the design and building process of mass housing: by ascribing a specific realm in the decision-making process to the individual user – the infill– he or she could participate in the creation of a dwelling.

As formulated by Kendall and Teicher (2000), Open Building (OB) is based on three key concepts adopted from Habraken's theories: levels, supports and infill. Firstly, OB acknowledges that decision-making is distributed among different levels –technical, aesthetic, financial and social– where different professionals intervene in the process of the design, construction, occupation and lifetime of the building. A support is then defined as "the permanent, shared part of a building which provides serviced space for occupancy" (p. 32), while infill "represents a relatively mutable part of the building" (p. 4). Building upon these concepts, the aim of OB is to lend a "formal structure to traditional and inherent levels of environmental decision-making, while offering design methods based on the new insights and supported by current applied research" (p. 6).

THE SYSTEM APPROACH TO THE BUILT ENVIRONMENT

Habraken's theory of supports is an example of the systems approach to the built environment that emerged during the 1960s and 1970s. As Fergusson (1975) explained, at that time the application of system theory to architecture and urban planning was "stimulated by the obvious need and desire to improve design and planning decisions", as well as by the need "to justify decisions once they have been made" to the various participants involved in the design process –such as individual clients as well as corporate bodies, community representatives and building committees– who had diverse interests and objectives with regard to particular urban or architectural problem. According to Fergusson, the system approach is based on two main principles: holism, a perception of the relatedness of things in approaching reality or a problem, and rationality, applying methods and procedures to problem-solving.

The holistic view in Habraken's theory of supports is manifest in understanding the building as the result of a complex decision-making process in which different experts participate. From this complex reality, Habraken derives an abstract model composed of supports and infill. As Fergusson contended, in system theory the concepts of "model" and "system" are inextricably interrelated: "the system one constructs is formulated in terms of a model and, conversely, the model is usually that of a system" (p. 18) Based on this abstract model, Habraken elaborates an analytic method to analyze –rather than to design– the interrelations between support and infill systems which represents the rational component of his system approach to housing design. The starting point of this method is the organization of the spatial structure of a support system in zones. Then, a dwelling unit is made up of sectors, that is, of aggregations of areas located at different zones. The intrinsic limitations of the physical components of the support system –building services, structural components– constrain the position and size of the dwelling units. By the same token, the standards applied to living spaces –minimum sizes, illumination– and the functional requirements –furniture, kitchen and bathroom fixtures– impose limitations on the configuration of the dwelling spaces. In this way, through an understanding of the rules inherent to systems and their multiple interrelationships, a method to analyze and evaluate alternatives of both support and infill systems is then formulated.

Habraken's method epitomizes the distinction between building systems and systems building (Fergusson 1975). The former refers to "an assembly of building subsystems and components, and the rules for putting them together in a building" (p. 62). Systems building, on the other hand, has to do with "the application of the systems approach to construction, normally resulting in the organization of programming, planning, design, financing, manufacturing, construction, and evaluation of buildings under single, or highly coordinated, management into an efficient total process" (p. 62). With building systems, for example, it is possible to achieve better management by producing building components in the factory, whereas with systems building, "the architect is not simply incorporating new technology; he is asking society to transform radically its economic organization so as to provide shelter more efficiently" (p. 69). Habraken's theory of support and infill, therefore, is an example of systems building applied to housing design.

BARCODE HOUSING SYSTEM

The objective of BARCODE HOUSING SYSTEM is to integrate ICT in the design and construction of collective housing in line with the principles of open building. The system started to be developed in 2002, and the first prototype was completed in 2005. The early version was a rule-based system which made it possible to generate housing units and blocks by means of a stand-alone application (Madrazo & Sicilia 2005). The development of the prototype conveyed both the design of a housing system as well as a generative system that automatically generates the variations of housing units and blocks. Afterwards, a grant from the Spanish 2005-2008 National RDI plan allowed us to develop a complete new system after the experience gained with the prototype, a comprehensive on-line environment that would facilitate interaction between the different actors involved in the design and building process.

SYSTEM STRUCTURE

BARCODE HOUSING SYSTEM is based on holistic view of housing building, which encompasses a comprehensive building model based on the distinction between support and infill, building subsystems –spatial layout, structure, building services and envelope– and building components defined and stored in the system's catalogue. It embodies both building systems and systems building approaches insofar as it integrates industrialized building components within an overall system which regulates the design, construction and use of the building.

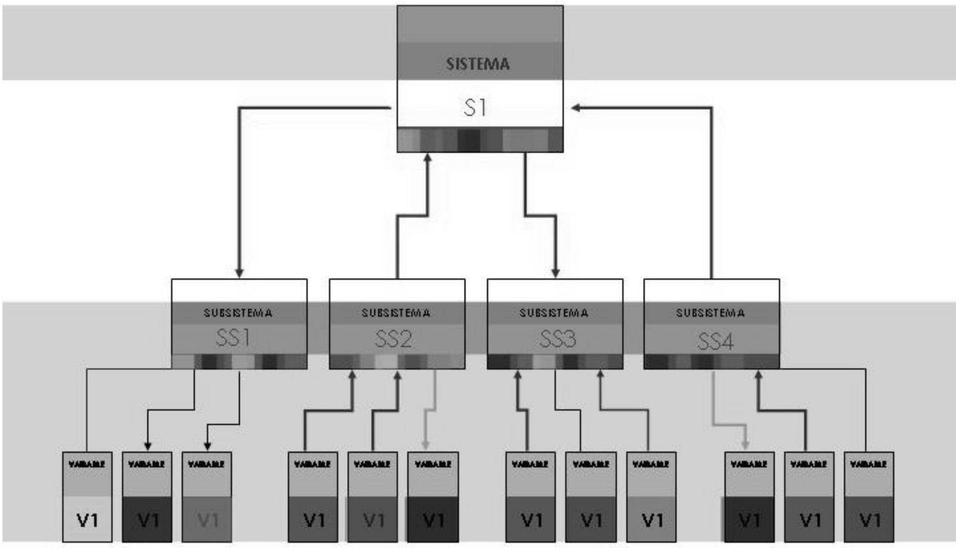


Figure 1: *Structure of the system.*

The structure of the system is composed of three layers (Fig. 1). The lowest level describes the specific conditions of the building components that will be used in the housing design and construction, such as the orientation of the site, the building components or the material to be used in the structure. The intermediate level contains the information on four building subsystems: spatial, structure, building services and envelope. At the top level, the system regulates the relations between subsystems by setting up the rules by which elements from different subsystems can interact with each other.

At the outset, there is a clear separation in this structure between the generic, abstract system components (support structure, rules of assembly, dimensional coordination and rules of transformation) and the specific components for each building subsystem. This separation guarantees the versatility and adaptability of the housing produced by the system, enabling a design to be materialized in various forms using multiple combinations of building components from different manufacturers. This disentangling of building systems conforms to the principles of open building (Kendall & Teicher, 2000, p. 47).

SYSTEM COMPONENTS

Support structure

Housing units are based on a spatial structure made of horizontal bands and vertical bars placed over a modular grid (Fig. 2). A similar division of floor plans into bands or zones was already considered by Habraken in his seminal work. Maximum and minimum dimensions are established for each of the bands. For instance, the intermediate areas Z2 and Z4 can vary from 2.4 to 3.6 meters. These thresholds guarantee that the rooms placed within these zones (e.g., dining and living rooms, bedrooms) will have the right size. This is an example of the way in which a priori principles (e.g., a spatial structure made up of vertical bars and horizontal bands) and conditions imposed by a subsystem (e.g., Spatial Layout subsystem) are built into the system. This interweaving of support and infill systems makes it possible to automatically generate housing designs according to the rules built into the system, a unique feature of our project that distinguishes it from previous works.

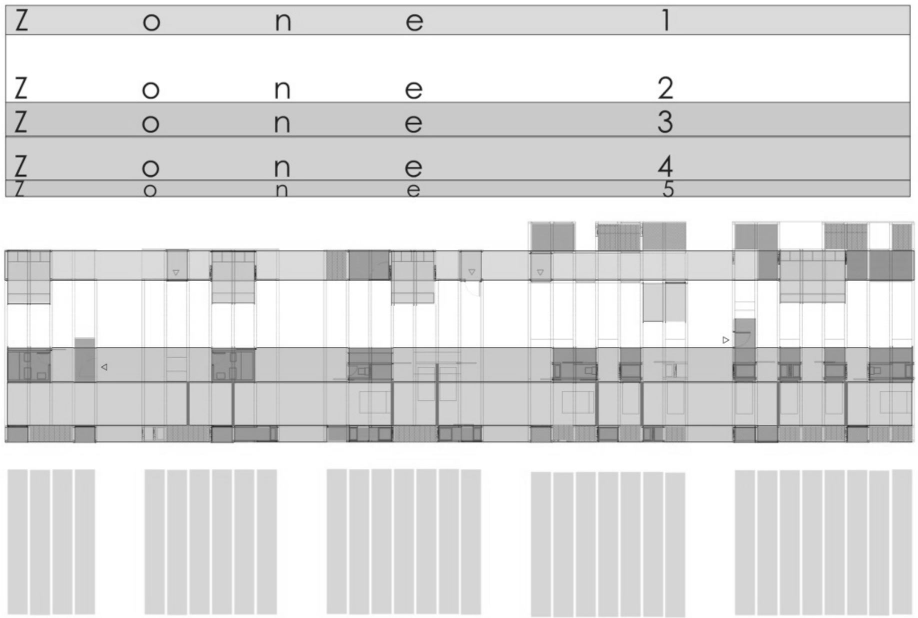


Figure 2: *Support structure divided in bands and bars*

At the intersection of a horizontal band and a vertical bar lies a cell, the minimum spatial unit with a function. Some of the attributes of a cell (function, maximum and minimum dimensions) are determined by its location within the structure of horizontal bands and vertical bars (see Spatial Layout subsystem). This underlying spatial structure based on the grouping of cells –which belong to both a band and a bar– into rooms distinguishes our approach from the one adopted by Habraken. In fact, this division of the space of the support structure into cells is necessary in order to model the procedure which generates the floor plans automatically based on the spatial relations embedded in a graph and complemented with lists of constraints and aggregation rules (Madrazo et al. 2009).

This spatial structure is the expression of an abstract support system whose purpose is to ensure that the dwelling units that it accommodates will fulfill the functional requirements imposed by the structure, circulation and building services (Fig. 3).

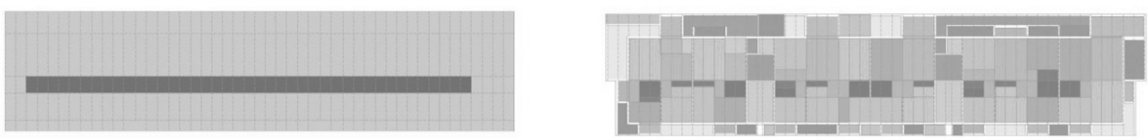


Figure 3: *Support and infill systems*

Rules of assembly

The materialization of an abstract spatial configuration into a building made up of building components is regulated by the system “connectors”. A connector is an element of a subsystem (typically, a structural element and/or a block of building services) which embodies methods that regulate the interactions with the elements of different subsystems (Fig. 4).

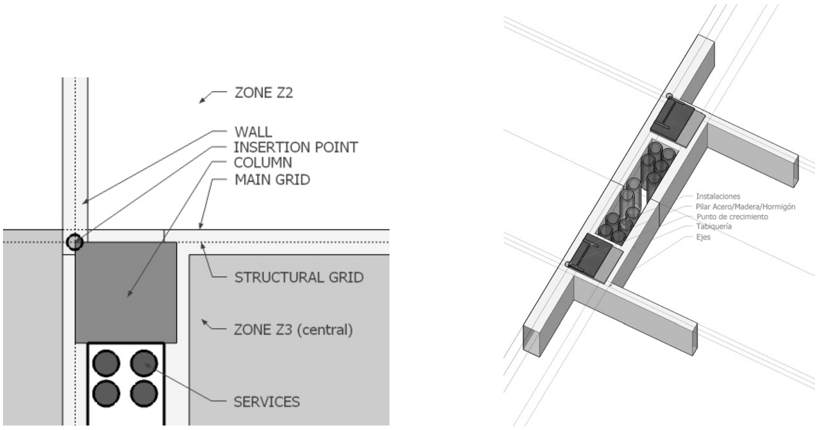


Figure 4: *Relationships between subsystems within a connector*

The resulting grid of connectors is an expression of a “material” rather than an “abstract” support structure made up of structural elements and building services (Fig. 5).

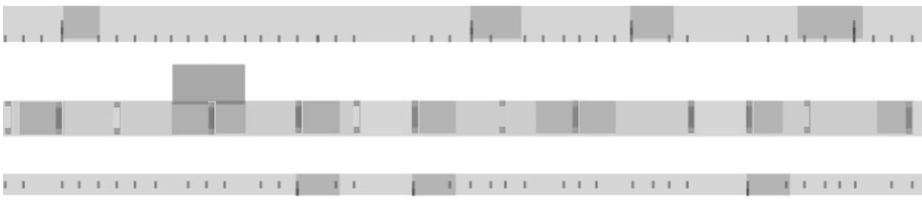


Figure 5: *Connectors placed on a floor plan*

Dimensional coordination

A spatial 1.20 m. grid (4 x 0.30 m) regulates the relationships between the façade, the internal partitions, the structural elements and the building services. Columns can occupy the grid points at will, and their form and dimensions can vary depending on the height of the building, the material of the structure and the dimension of the cantilevers. The façade elements, on the other hand, occupy all the grid cells and their form and dimensions are more homogeneous than those of the structural elements. The internal partitions are placed in a 0.30 cm. grid. (Fig. 6)

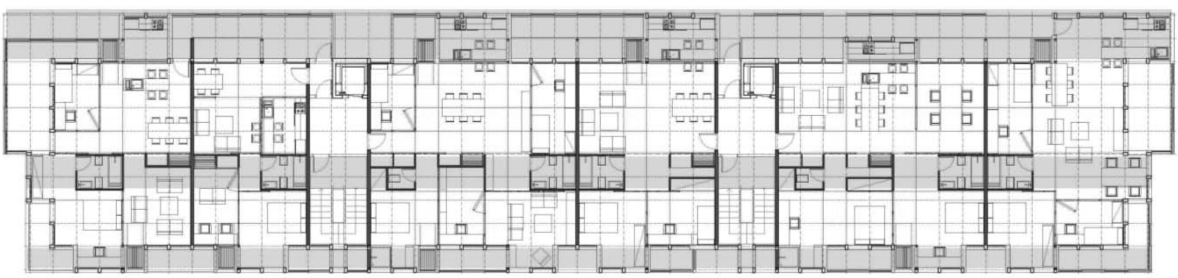


Figure 6: *Grids, zones and partitions.*

Rules of transformation

The location of the partitions is regulated by the grid and by the Spatial Layout subsystem. A specific type of partition is assigned to each qualified area of the support structure (Fig. 7). Thus, the serving zones (Z1, Z3 and Z5), where the less flexible spaces are located, require fixed partitions while the intermediate zones (Z2, Z4), which contain the most flexible spaces, require mobile and dismountable divisions.

The infill system includes four different kinds of partitions with regard to the degree of transformability of a space over time:

- Fixed elements: To be used in those spaces which are likely to remain unchanged over the building's lifetime (e.g., bathrooms, dwelling divisions).
- Dismountable elements: To be used in spaces which can vary on a middle-term basis (e.g.. bedrooms)
- Mobile elements: To separate spaces that change often, even on a daily basis (e.g., the separation between a working area and a bedroom)
- Auxiliary elements: To be used as mobile partitions (e.g., sliding doors) or as space-filtering elements (e.g., a shelf)

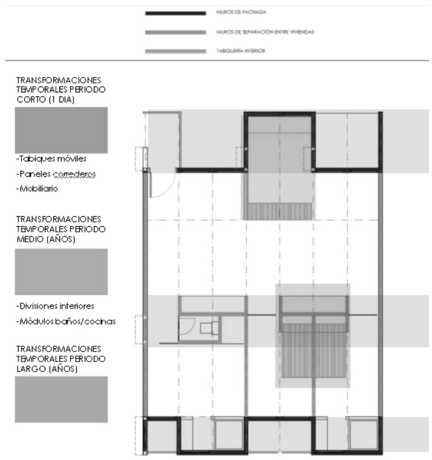


Figure 7: *Different kinds of partitions*

By considering the partitions at both the support and infill levels, it is possible to create "flexible housings" (Schneider & Till 2007) both at the design stage –when the future tenant can explore different alternatives of the housing layout in interaction with the system– and afterwards, when the dwelling is occupied, by easily transforming the space delimiting boundaries.

SUBSYSTEMS

After having described the basic abstract principles that make the system, we will briefly describe each of the four subsystems: Spatial Layout, Structure, Building Services and Envelope.

Spatial Layout Subsystem

The Spatial Layout subsystem consists of all the components and rules to generate floor plans and housing buildings (blocks, towers) resulting from the aggregation of housing units. In order to generate a floor plan, cells placed at the bands and bars of the spatial grid are grouped into rooms, which in turn are assembled to create a dwelling. A generative procedure ensures that the aggregation of cells gives rise to rooms having appropriate dimensions and functions. Likewise, the procedure ensures that a group of rooms makes a functional dwelling by checking the constraints and the adjacency rules. The procedure generates floor plans in a batch mode and stores them in the system database. The floor plans that result from the application of the generative processes can have a width of between 3.6 and 10.2 m. and a depth of between 8 and 12 meters (Fig. 8). Over 10.000 different floor plans have been automatically generated and stored in the system

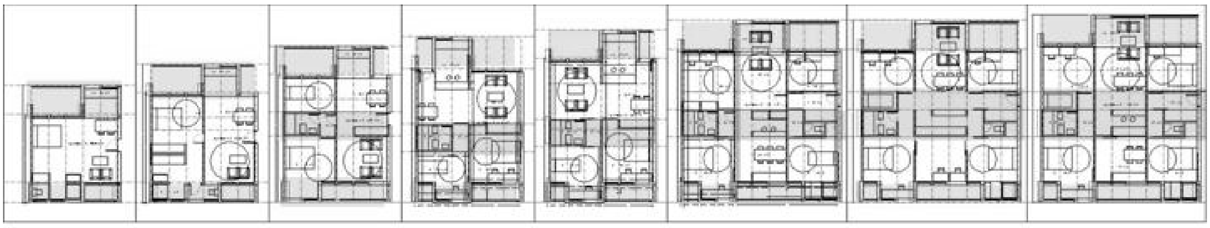


Figure 8: *Housing layouts sharing the same spatial structure*

Structure Subsystem

This subsystem encompasses the structural elements (excluding the foundations) and the procedures to determine their positioning and pre-dimensioning. The 'connectors' created by the system for each particular building embody the information about the structural requirements which will call for a different structural solution depending on the materials and dimensional and load-bearing constraints of the structural elements.

All possible structures conform to a unique structural model composed of frames placed at the facades, shear walls and rigid slabs (Fig. 9). Structural elements are not flexible elements in a building. Therefore, they should be attached to elements or zones with low flexibility like circulation cores, service zones, façades and ducts. Shear walls are placed in the circulation core envelop, and structural frames can be aligned to three horizontal service zones (Z1, Z3 and Z5).

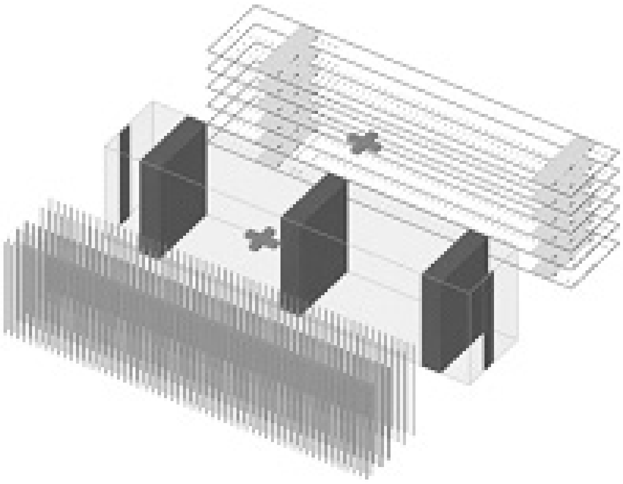
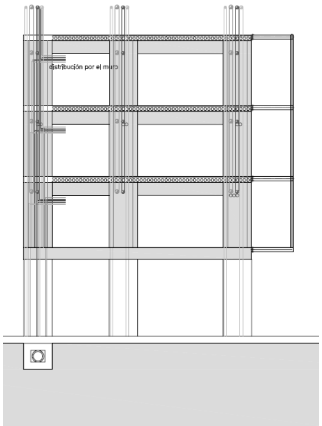


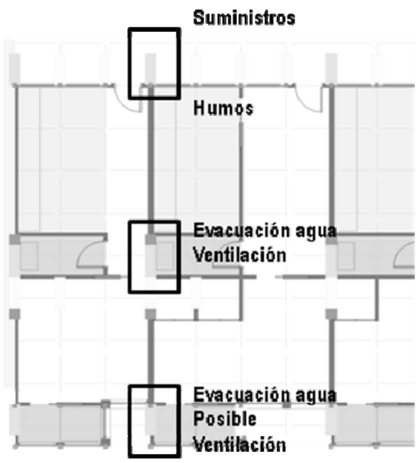
Figure 9: Structural and building services model

Building Services Subsystem

This subsystem encompasses the supply (water, electricity, telecommunications) and evacuation (waste water, air, fumes) services of the building. Services are located in a gallery at the base of the building or underground, from which ducts and pipes run upwards through vertical conducts (Fig. 10). The location of the vertical conducts is defined by the information on the connectors, just as it was for the structural elements. Therefore, the building services are planned in close relation with the other subsystems, spatial layout, structure and envelope.

The spatial configuration based the vertical bars and the horizontal bands determines the position of the ducts that deliver building utilities. According to this spatial structure, service wells can be placed at each horizontal band (Fig. 11). The wells are sized to allocate all ducts (supply, exhaust, sewage pipes). The dimension of the well takes into account the spatial grid module as well as the size of the columns. The largest dimension (120 cm.) corresponds to the width of a water closet. This is also the size of the Z1, Z3 and Z5 zones. The smallest dimension (40 cm.) matches the maximum size of the standard column. The inner size of the service well is the result of subtracting the dimension of the column.





***Figures 10 and 11:** Location of service wells in the zones.*

Envelope Subsystem

The envelope subsystem encompasses the outer and inner surfaces that surround the interior space and the building, respectively. Inner partitions also adhere to the 1.20 m. grid. Most of the industrialized products used to create the partitions can adapt to this modular dimension. A variety of partitions, with different materials, thickness and performance levels, can be used to make the fixed and mobile divisions.

The design criteria for the elements making up the external envelopes (Fig. 12) are the following:

- A light façade composed of three layers: exterior, core and interior. The outer cladding is made of light plates of different materials: clay, fiber cement, metal, stoneware, synthetic composites and others.
- Windows and exterior doors are a mixed product made of timber and aluminum.
- The flat roof is constructed with a built-up system which provides a good thermal behavior and simplifies maintenance.
- Internal divisions and ceilings are built with plaster boards and light steel profiles.

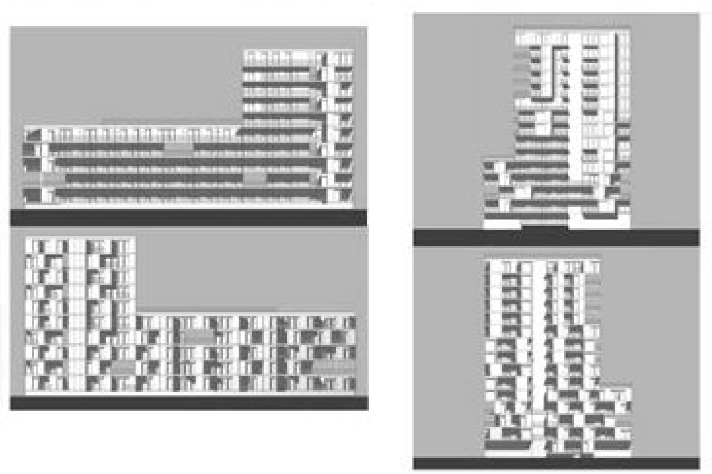


Figure 12: *External envelopes for different building types.*

WORKING SPACES AND LEVELS OF DECISION-MAKING

The computer-based environment of BARCODE HOUSING SYSTEM consists of interwoven workspaces where different actors (architects, developers, manufacturers, occupants) participate in a synchronous and asynchronous manner through a distributed process of designing and constructing collective housing projects (Fig. 12). Each of these workspaces represents a level of decision-making where different actors intervene in the design and building process in interaction with the system and each other.

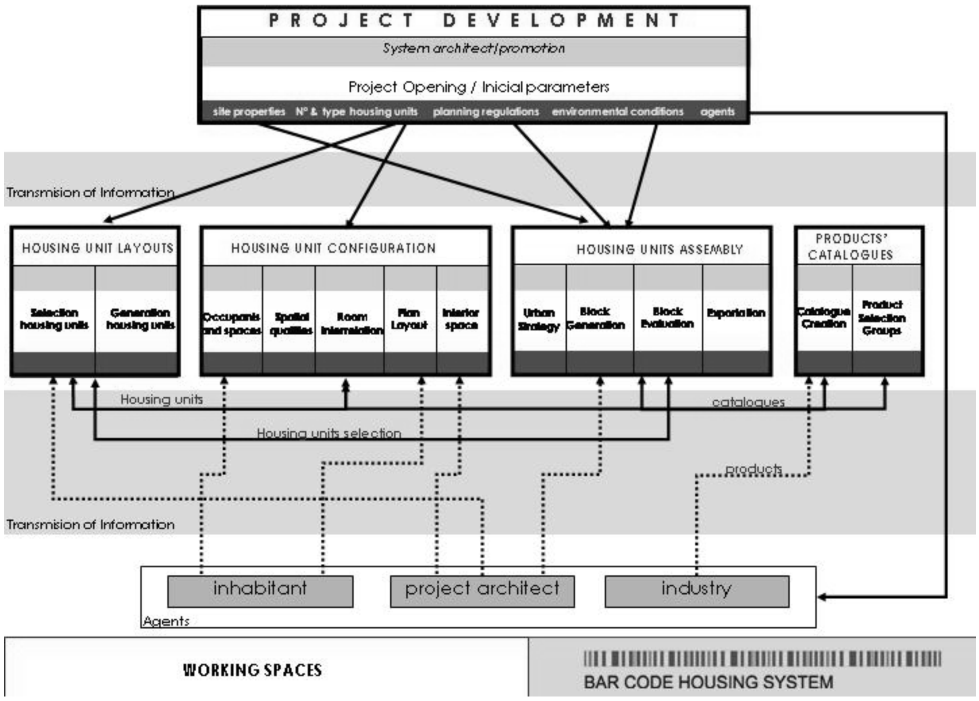


Figure 12: *Structure of the working environments.*

The system workspaces and their functionalities are the following:

Project development

In this workspace, developers, architects and building managers specify site properties (area, size), number and type of housing units, building and planning regulations (building volumes and height) and environmental conditions (climate, orientation). Alternative solutions for buildings (massing, location) can then be explored for the given site conditions and brief.

Housing unit layouts

In this space, architects select a set of units that will be used later to generate a building among those contained in the system. Searching for housing units in the system database becomes a "discovery" process. Should an adequate layout not be found among the existing solutions, the architect can invoke the generative process to create alternative layouts that conform to the desired criteria (area, number of rooms, number of bathrooms, open or closed kitchen), which then will be stored in the system.

Housing unit configuration

The occupants describe the characteristics of the dwelling (number of occupants and rooms, lifestyles, room interrelationships) by interacting with the system through a sequence of user-friendly interfaces that represent the dwellings in a graphic language that can be understood by laypeople with no knowledge of the conventions of architectural representation, using non-dimensional plans and diagrams as well as photographs (Fig. 13).

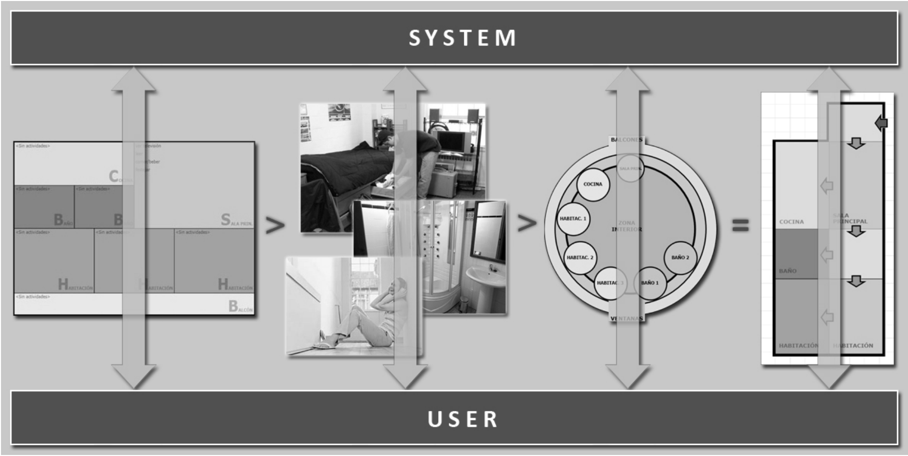


***Figure 13**. Interfaces to define dwelling characteristics*

The sequence of interactions is structured in such a way that the information acquired in one interface becomes an input for the next. Following the information collected from different users, a process of generation is prompted to assemble the housing units in a building. Then, after each housing unit has its place in the building, users interact with the architect in a 3d interface which enables them to choose finishes and partitions selecting components from the system's library.

Assembly of housing units' assembly

In this workspace, the architect defines the design criteria for the assembly of living units, for instance: degree of compactness of the housing block; degree of optimization of building services; minimum distances to access cores (staircases, elevators); material of the structural skeleton, and so on. Once the design values are set, a generative process creates the solutions that meet these criteria.

Catalogue of building components

The online catalogue allows manufacturers of various products enter descriptions of their components, using templates which include 3-D models of type components. The components can be introduced into the catalogue through an interactive interface or via external forms in XML format.

This structure of autonomous and interrelated workspaces supports open and non-linear design and construction processes. In order to interact with the system, it is not necessary to proceed along the workspaces in a linear fashion: the workflow through the workspaces can start at different points and at different times. The only prerequisite is to start the Project Development workspace by describing the characteristics of the program (site, brief) and registering the users who will participate in the process. All other spaces can be activated later at any time during the project lifecycle. In this way, the system can support non-linear design and construction processes by exploiting, as Kalay (2004) has argued, the potential of ICT technologies to transform established design and construction practices. For example, the system can support the creation of a network of small interconnected companies collaborating in the construction process (Worst 2007).

CONCLUSIONS

BARCODE HOUSING SYSTEM adheres to the systems building approach to architecture insofar as considers the building a complex whole which is the result of procedures that embody the design rules. It also supports a buildings system approach insofar as it operates with industrially produced building components which are part of the system. Likewise, it shares some of the basic ideas of open building, in particular the distinction between support and infill and the need to integrate the different levels of decision-making in the design process. The structure based on differentiated workspaces fosters the participation of different actors at different levels of the design and building process. Altogether, the system exemplifies one way to use ICT to support the principles of open building.

ACKNOWLEDGEMENTS

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EVOLUTIONARY ALGORITHMS IN ARCHITECTURE

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ABSTRACT

Change is a reliable constant. Constant change calls for strategies in managing everyday life and a high level of flexibility. Architecture must also rise to this challenge. The architect Richard Buckminster Fuller claimed that "A room should not be fixed, should not create a static mood, but should lend itself to change so that its occupants may play upon it as they would upon a piano [1]." This liberal interpretation in architecture defines the ability of a building to react to (ever-) changing requirements. The aim of the project is to investigate the flexibility of buildings using evolutionary algorithms characterized by Darwin. As a working model for development, the evolutionary algorithm consists of variation, selection and reproduction (VSR algorithm). The result of a VSR algorithm is adaptability [2]. If this working model is applied to architecture, it is possible to examine as to what extent the adaptability of buildings – as an expression of a cultural achievement – is subject to evolutionary principles, and in which area the model seems unsuitable for the 'open buildings' criteria. (N. John Habraken). It illustrates the significance of variation, selection and replication in architecture and how evolutionary principles can be transferred to the issues of flexible buildings. What are the consequences for the building if it were to be designed and built with the help of evolutionary principles? How can we react to the growing demand for flexibilization of buildings by using evolutionary principles?

Keywords: Evolution, Typology, Adaptability, Variation, Selection, Replication, Darwin

INTRODUCTION

Change is a reliable constant. Constant change calls for appropriate strategies and a high level of flexibility. Architecture must also rise to this challenge. The architect Richard Buckminster Fuller claimed that "a room should not be fixed, should not create a static mood, but should lend itself to change so that its occupants may play upon it, as they would upon a piano." This liberal interpretation in architecture defines the ability of a building to react to ever-changing requirements. Just as animal species have changed during the course of evolution, buildings have been adapted to meet new requirements since the beginning of civilisation. Over time, some buildings have proved to be better suited to change than others. They were better able to adapt to the new requirements of their environment, either through active intervention or because the building already met the changing requirements. It is evident that they were equipped with the more appropriate characteristics to meet the new requirements, or that characteristics which were not originally foreseen, could be activated to meet these demands. It follows that they are more successful in comparison to other buildings and possibly have characteristics which are also relevant for other buildings (designs) and are therefore widespread in the building stock. Buildings which are unable to withstand the pressure for adaption due to lack of flexibility become obsolete.

VARIATION, SELECTION AND REPRODUCTION IN THE DESIGN PROCESS

The origin of adaptability in nature was explained by Charles Darwin in the mid 19th century with his theory of natural selection. Precisely because certain traits helped organisms to survive and successfully reproduce in the past, they have remained – as opposed to those with unfavourable traits – to the present day. Only the favourable traits have a chance of survival in the long-term. Individuals with such traits outclass the competition. They are more likely to reproduce, and because of heredity, their most favourable traits are found more frequently in the next generation which in turn, give their offspring a further advantage. In this way, an advantageous variation automatically becomes more common and within time, spreads through an entire species. Single traits compete for survival [3] in which the three fundamental elements, **variation, selection und reproduction** from Darwin's evolution theory play a key role. Together they form the evolutionary algorithm (VSR-algorithm) which aims at adaption for a particular niche and reproduction success.

But can biological evolution theory be translated without restriction to architectural design? Is not architecture a cultural achievement and therefore subject to other principles? And are not cultural works, in general, a deliberate, purposeful process, which is not the case in biological evolution which depends on mutation and genetic recombination. Nevertheless, the planning process of a building is characterized by variation, selection and reproduction.

The process from design to realization of a building is an iterative process which presents and selects solutions. At the end of this sequence of creating and critique, the solution appearing most suitable is chosen, giving the codified planning result. This is a four-phase process:

Phase 1 – Defining the Program

The program for the projected building is defined in this phase. The client commissions a planning specialist to design his building. As a rule, the client already has concrete ideas about the building and its use. These ideas are culturally embedded. Guided by experience, his knowledge and his architectural preferences, the architect (ideally) takes up these ideas, evaluates, reflects and discusses his client's precise needs. He compares these with the fixed parameters such as location, orientation, building regulations, finances etc., highlights conflicting goals and sets priorities by selecting specific concepts. At the end of this phase, the requirement profile of the projected building has been determined and the target agreement (e.g. space allocation plan, use, cost ceiling, deadlines etc.) has been formulated.

Phase 2 – Planning the desired program by generating variants and selection

Variants are generated, selected and further developed in the design phase. In this internal generation of variants, ideas are generated in a creative process, reviewed and compared with the target agreement. Appropriateness and feasibility are key factors in the process. Deciding on a building component (e.g. a closed façade) allows only specific further architectural combinations which lead through internal selection to variance reduction. In addition to internal selection, there is also the external selection – in the sense of Rittel's development etc.) - which the planner can hardly influence. The concept is reworked until all influencing factors contribute to a sustainable compromise. This process can only be brought to a satisfactory conclusion, when priorities which enable different weightings to allow subsequent selection, are set between the parameters. Alberti's definition of beauty pleasing architectural expressionis a high and only very difficult to achieve aim. For him, beauty is a particular harmony of all the parts, whatever the object, such that nothing can be added, taken away or altered without making it less attractive. Referring to his definition, Alberti also emphasizes that it is necessary to exert all creative and mental powers to reach this achievement. [5]

Phase 3 – Codified Design Concept

To evaluate the design concept, discuss it with colleagues, present it to the client and involve experts, ideas needs to be communicated on a level which is objective, understandable and clear. This level is termed by Bertram as the level of planning reality [5] where design concepts are determined by mathematical spatial concepts and represented in an objective, unprejudiced manner. As a rule, plans, sketches and models serve to illustrate the outlined building concept. The ideas, that is, the codified design concept in the building plan, are documented at the end of the design process. In doing so, the planner not only considers the invariable building elements (e.g. glass facades), but also imagines the variable elements such as change of mood (light, rain, time of day etc.). His professional knowledge enables him to arrange built elements in order to visualize the intended phenomenological variances of a particular setting. This serves as a guideline for the realization of the building [6].

Phase 4 - (Re)Production

The building can now be built based on the codified planning concept. Each projected building therefore holds a magnitude of information and embodies awareness potential. Buildings at location or on paper conveyed architectural phenomenon offer potential for future solution models [6]. A building can be exemplary for planning problems of a similar kind and selected elements (e.g. building components, constructions details, design, spatial framework etc.) can be reproduced. Once the building has been realised, it is in competition with other buildings and subjected to different degrees of continual selection pressure. When a building no longer meets requirements, the selection pressure becomes too strong and the building has to be adapted. Certain elements (e.g. heating system) are completely renewed or the existing floor space allocation has to be adopted. Seen evolutionarily, the appropriate characteristics can be reproduced in the second phase of the building's use.

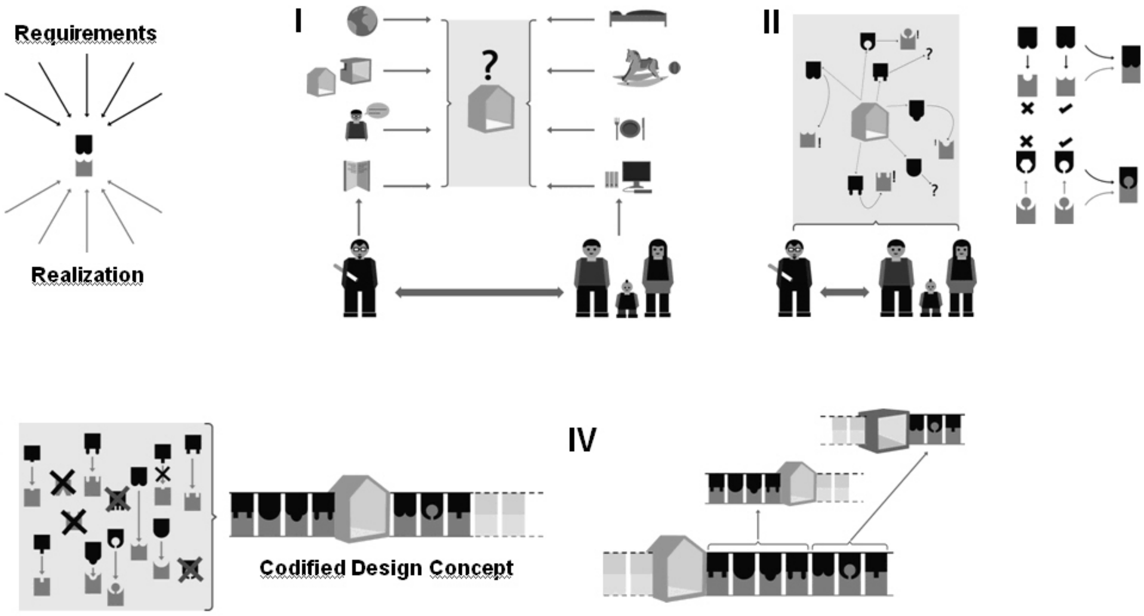

Figure 1: *Variation, Selection and Reproduction in the design process ©cctp*

EVOLUTION IN INFORMATION PROCESSING

In biological evolution, reproduction follows by passing on hereditary traits through genes. As part of a chromosome, they are responsible for the phenomenological characteristics (e.g. brown eye colour). All the genetic information found in an organism is collectively known as the gene pool. Different hereditary traits can emerge depending on gene constellation and dominance. This is known as phenomenological plasticity.

In architecture, there are no genes which are responsible for the features of a building. However, as mentioned earlier, each building has a set of information [6] which can be extracted by the observer's respective cognitive agent [7]. A building's appearance is the sum of all discernable features. In addition, every individual has a schema i.e. an internal representation of the outer world. This structure is also known as knowledge. Amongst others, this is where instructions (behavioural patterns) are stored. These enable us to react to situations accordingly. When a certain situation arises and no behavioural pattern is to hand, organisms find themselves in a state of uncertainty. Only by changing the structure of the internal schema, e.g. getting informed and creating new solution models, can knowledge be enriched. If the architect does not have a solution, he has to inform himself and create a new systema new variation which enables him to solve his planning problem. To develop and evaluate solution variations, the architect depends on certain information. Besides his own repertoire, he also taps into other information sources: his memory, built and documented projects. Apart from accessing information, the architect also generates information whilst working on the problem. He will document the results of his own work and compare notes with others involved in the planning process.

It is apparent that evolution, in both biological and cultural understanding, is information processing which triggers a series of actions.

- In natural science, evolution is understood *"(…) as the gradual development of a system which reacts to external influences depending on experiences made in the past."* [3]
- For social science evolution is *"(...) a process which memorizes and multiplies information, constantly producing new structures and characteristics.* [8]

Unlike Darwin's evolution theory, in architecture, knowledge is consciously applied, information processed and other buildings are evaluated as an information memory. This information transfer can be explained by Richard Dawkins' theory of the meme. For the evolution biologist Dawkins, the cultural analogy to a gene is a meme. Just as "genes propagate themselves in the gene pool by leaping from body to body via sperm or eggs", Dawkins theorizes "so memes propagate themselves in the meme pool by leaping from brain to brain" transferring ideas, concepts, ideologies and behavioural patterns. The external manifestation of a meme of a built structure corresponds to the characteristics of the phenotype in gene theory. A meme is a unit which can replicate itself. The reproduced information unit becomes effective in the coded planning result. The building is an external manifestation, or in Dawkins' sense, a vehicle [9]

In architecture, memes are both genotypic and phenotypic effective. In analogy with the evolution phenotype, the architecture phenotype carries all physical characteristics of a building. The phenotype is not restricted to morphological characteristics, but also includes physiological (heat transfer coefficient of the chosen wall structure) and functional characteristics (e.g. comfort). In contrast, the genotype of a building is to be considered as the entirety of the existing knowledge for this particular building type, its use and problems. During the planning phase, this knowledge is contrasted with the "achievable" in the process of generating variants and selection. At this point, we are reminded of the selective effect of the constraints resulting from building regulations, location, finances and social conventions etc. The codified planning project - the construction plan - is a result of these processes. Memes are therefore active on both the genotype level in generating information on the building type, as well as on the phenotype level. By selecting relevant features and system characteristics, they influence the decision as to which function, construction and interpretation of design ideas can be realized in the building project. The information memory "building" is therefore a meme pool of architecture. Besides functioning as replicators, memes are important for mutations and variance in cultural evolution. Development in architecture is not possible without memes.

MUTATION AND VARIATION

Accidental variation is the driving force and a condition of evolution. Variation within a population is the result of mutation and genetic recombination, and genetic rearrangement through sexual reproduction [2]. No two individuals of a population are alike. Some traits give better potential of survival, others encourage biological fitness increasing chances of reproduction. Others are disadvantageous because they make survival and reproduction more difficult. Variations occurring in a population always happen by chance and not systematically. Depending on the niche (the relational position of the population in its ecosystem), variations can be an advantage or possibly wasted potential.

In architecture, innovation can be regarded as the counterpart to mutation. Although innovation is often "developed" purposefully, due to easier access to information sources and knowledge transfer outcomes are frequently characterized by powerful inherent dynamism which is controllable to a limited extent only. A "recombination" of knowledge is for example prefabricated parts. Successfully applied in the automobile industry for decades, they are now making an impact in building refurbishment with prefabricated retrofit modules i.e. for façades [10]. Another example of recombination is the current discussion on greenhouse gas emission reduction into the atmosphere, which has a significant influence on the typology of future buildings.

The result of mutation and recombination is variety and variance. These factors make it possible for the niche to be used optimally in the sense of an advantageous environment, which means, to successfully defend it against other competitors or to occupy it respectively.

In this context, *adaptive radiation* seems especially worthy of mention. It describes the process of species splitting within a relatively short period of time into several species, each of which is adapted to different ecological niches. Adaptive radiation occurs when there are a lot of unoccupied ecological niches, geographical separation and a less specialized parent species. "An evolutionary species is a line of ancestors-offspring-populations which maintain their identity against other such lineages and have their own evolutionary tendency as well as historical destiny." [2]. The architectural equivalent to the evolutionary species is the building type. Adaptive radiation is its variance, through which many modifications of a basic pattern (e.g. ground plan) are achieved by adapting to different topographical, urban, climatic and user-specific conditions.

Variance is also a key factor for success in spreading its own meme in the meme pool. Highly specified solutions are often one-way solutions. For example, *Gründerzeit* (Wilhelminian style) apartments are still today very appealing and of stable value because of their high use flexibility. On the other hand, apartments with specific solutions for a specific way of life are at an evolutionary dead end. Lack of flexibility e.g. apartment layouts of the 60s, nowadays makes them difficult to let because society values and in turn, tenant’s requirements have changed fundamentally. These are solutions with an inadequate degree of flexibility which results in restriction of use and therefore not suitable for further distribution. Buildings which have memes with the necessary phenomenological plasticity in construction, design or layout are fitter than other buildings.

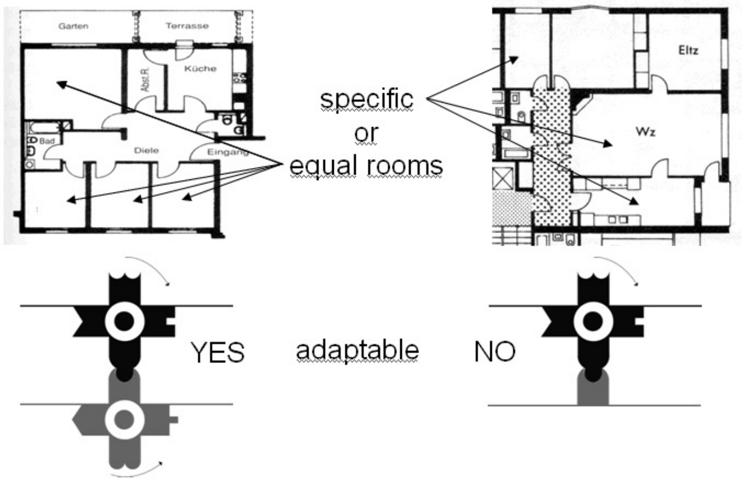

Figure 2: *Specification as a key factor for Adaptability [11] ©cctp*

If existing building types have an "evolutionary" past, they also have characteristics which help them to "survive". These characteristics are accurately reproduced when planning future buildings (seen from an evolutionary point of view: to propagate – to reproduce) and to find their use in existing and future building stock more easily. The result of these suitable characteristics is adaptability which shows its flexibility potential. That means buildings which can be adapted have a higher flexibility potential than other buildings. Flexibility is an indication of long-term value retention [12]. The building can react quickly to new requirements at acceptable cost, time and effort.

Based on concepts described by the Fraunhofer Institute and supported by typology-based building evaluation [13], four main building types of adaptability were identified [12].

- ***Extension Flexibility*** (E) refers to extension and retrofit in architecture. This involves analysing and classifying the positioning and structural properties of extensions and retrofit systems
- ***Internal Flexibility*** (I) defines the adaptability of a building: In which degree are modifications within an existing structure possible. What are the risks and time requirements? How does the extension influence the building?
- ***Use Flexibility*** (N) analyses building flexibility in relation to how it reacts to change of use. Concepts concerning the reversibility of changes and the future mono or multi-use are also considered.
- ***Planning Flexibility*** (P) refers to characteristics which determine whether and how a building reacts during the entire planning and construction phase. It also investigates which measures can be implemented during the planning phase in order to facilitate flexibility during a building's operation time, with the least possible cost and effort.

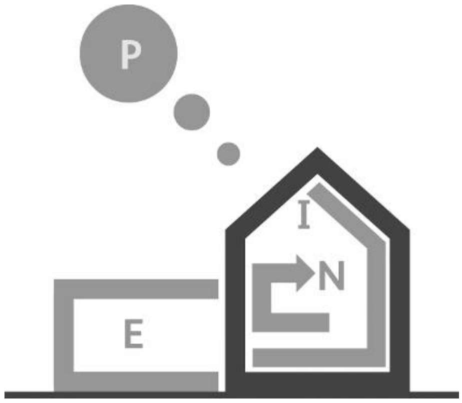

Figure 3: Typology of adaptability [12] ©cctp

Extension, internal, use, and planning flexibility are building strategies to be able to resist selection pressure as long as possible and to retain high value stability over the entire (renovation) life cycle.

SELECTION AND SELECTION PRESSURE

Selection is a key mechanism of evolution. Selection is responsible for different levels of reproduction success (= fitness) of selected individuals [3]. This means an irregular heredity of traits from different individuals in the gene pool of the next generation, leading to a deliberate change of traits in the population over time.

In analogy to the biological, the cultural evolution underlies a selection process which corresponds to natural selection. When two or more buildings become competitors, the construction which best satisfies market needs "survives" and through the meme pool, its characteristics will have a stronger influence on the future building stock.

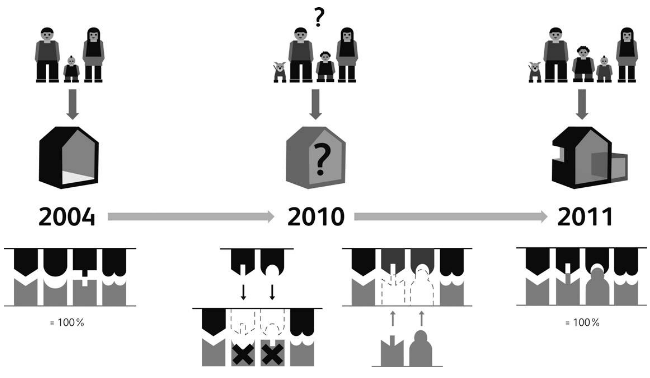

***Figure 4:** Refurbishement as a Selectionprocess ©cctp*

Selection can be differentiated by the type of selection strength, level, direction and intensity (Zrzavý et al, 2009). These principles have been assigned to architectural themes in the following table.

Types of selection

Special field	**Type I** Type of selection force	**Type II** Level of selection effect	**Type III** Direction of selection	**Type IV** Intensity of selection effect
Biology	**Environmental selection** (e.g. a climate which is too cold causes the coat to grow thicker)	**Gene selection** Genes compete for maximal frequency in the population	**Stabilising selection** Selection of individuals with extreme character values	**Soft selection** Selection of individuals who do not achieve specific relative values in the given characteristics
Analogy to Architecture	*Climate change promotes CO^2 – neutral buildings*	*Meme (tech-nology, design etc.) competing for maximum frequency in the building stock* *Building part level*	*Design plan:* *- Utilization factor* *-Height restriction* *- Type of roof*	*Modernization* *- All buildings with single glazing independent of building type*
Biology	**Sexual selection** e.g. Competing for females leads to a size difference in some animal species	**Individual selection** Selection of characteristics (phenotype) which are advantageous for the individual	**Disruptive selection** Selection of individuals with average values of a characteristic	**Hard selection** Selection of all individuals who do not fulfil a specific criteria or quality
Analogy to Architecture	*Architectural fashion trends* *Corporate Design in the typology of office buildings (e.g. open space)*	*Meme (Technology, Design) competing for maximum frequency in the building stock* *> Building level*	*Functionalism in architecture* *Highly specified buildings*	*Extension through addition of storeys* *- legal requirements* *- load-bearing capacity of existing supporting structure*
Biology	**Parental selection** e.g. Parents of some bird species prefer to feed chick with yellow mouths	**Relative selection** Selection of characteristics which are advantageous for groups of relatives	**Directional selection** Selection of individuals with characteristic values at one end of the distribution curve	
Analogy to Architecture	*Intersubjective and cultural preferences e.g. for building types and usage*	*Meme (technology, design) competing for maximum frequency in the building stock* *> Typology level*	*Energy efficiency:* *- optimal A/V - rating* *- Heat transfer coefficient* *> Tendency: Swissbox*	

CONCLUSION

In summary, it can be said that it is possible to explain and illustrate adaption processes in architecture on the basis of Darwin's principle of natural selection. It is essential to always exploit the niche, to occupy an advantageous environment by being more successful than the competition. Transferring this principle to flexible buildings ie. buildings which successfully resist selection pressure as long as possible, the following requirements for sound, future-oriented concepts can be deduced:

Transferring this principle to flexible buildings ie. buildings which successfully resist selection pressure as long as possible, the following requirements for sound, future-oriented concepts can be deduced:

– **Variance**: Flexible buildings have a number of concepts which can react individually to their context. Variance makes it possible to successfully occupy the niche and in

Darwin’s sense, to be “fitter” than the other buildings. This variance concerns the genotype as well as phenomenological variance.

- **Fault tolerant:** Flexible buildings are planned and built knowing that their value can only be maintained over a longer time period if they can adapt to meet future demands. With this in mind, buildings are fault tolerant and not highly specified.
- **Deconcentration:** Flexible buildings have predetermined breaking points to allow building parts and systems (e.g. telecommunication) to be exchanged with little effort. Separation into primary, secondary and tertiary systems is an essential requirement..
- **Open mind:** Flexible buildings have innovative building concepts which are sustainable. Innovations thrive on an open mind and foresight. These can be achieved by exchanging information and transferring knowledge in the interests of improving the current and future environment. Interdisciplinarity and an open mind can prevent the evolutionary dead end.

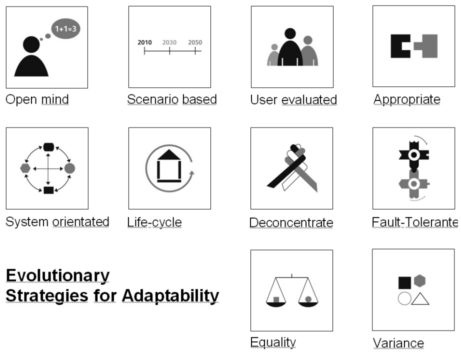

Figure 5: *Evolutionary strategies for adaptability ©cctp*

OUTLOOK

This paper is the start of a research cycle on VSR- Algorithms in architecture. More extensive research on selection and variation is already being done. Further publications on this theme are in progress.

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A COMPARATIVE STUDY ON THE SPATIAL PATTERNS OF CHINESE ROW HOUSES IN COLONIAL CITIES IN THE EARLY 20th CENTURY

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ABSTRACT

This paper aims at finding the diversities of morphological features of the urban housing complex and their transformations built around early 20th century in Qingdao, Tianjin, Shanghai, Wuhan, and Guangzhou the five colonial cities of China. These housing estates are successful past attempts at procuring change-ready buildings to live in and hence a valuable asset from which the current people can derive benefit especially in today's context of economic globalization. The paper firstly introduces a general background of these houses by focusing on their evolution and the current status. Then it introduces the representative cases selected from these cities on the spatial characters of typical unit layout. Based a systematic morphological framework, the paper compares characteristics of these housing estates in different spatial levels. It concluded that the diversity of row housing in different cities were largely credit to the traditional house patterns in the contexts.

Keywords: Row house, locality, morphological pattern.

INTRODUCTION

The early 20th century, i.e., from 1900 to the beginning of the War of Resistance against Japan (1937), marks the boom period for early urban housing development in China, especially in the early colonial cities, which played an important role in Chinese modern culture, economy, and politics. (Yang, 1993; Lü et al., 2001) During this period, rapid changes occurred in these cities with the influence from the Western powers. On one hand, the urban population has been greatly increased since many farmers came to cities to make a living, which pushed up the price of land and housing. On the other hand, transforming in family size and lifestyle led to changes in the layout and arrangement of housing. Family size was getting smaller and the multi-generation structure of family was broken down. Because of the changes in family size and the rapid increase in land cost caused by population growth, there arose the demand for compact and convenient small-size units instead of large ones. (Wang and Chen, 1987; Yang, 1993; Lü et al., 2001)

Chinese row houses are a new and unique type of urban housing that resulted from the specific historical background and evolved along with the development of the society. They are mass houses for ordinary people and play a major part in forming the urban fabric of a city. A physical environment that fully expresses the historical background of an area is an important asset to any healthy and expanding society in an advanced level of civilization. (Cozen, 1981). These housing estates are storehouses of previous experiments in creating living environments and hence a valuable asset from which society can benefit. Furthermore, different types of row houses often are indicative of their locality in terms of spatial characteristics and reveal the continuity of the local typological process. Currently, however, most scholars have only investigated row houses from a single background (Li et al., 2008; Liang, 2006; Lin, 2001; Wang and Chen, 1987), thereby forfeiting the opportunity to identify what pertains to that particular localized building culture, what distinguishes it from other cultures, and intrinsic characteristics originating from that locale.

This paper will comparatively analyze the representative row houses in different regions of China with various geographic, cultural, and socio-economic backgrounds: Qingdao and Tianjin located in the North China, Shanghai and Wuhan in the central east China, Guangzhou and Hong Kong in the South China. These cities have experienced a colonial modern history, yet they are the central and most significant cities simultaneously facing the strong pressures of development now. Additionally, this paper will discuss their distinguishing and location-adaptive features and indentify the inherent rules that were maintained in the evolution of Chinese row houses, which could benefit housing proposals for future designs.

METHODOLOGY

The forms created in one period are different from those created in another, and similar types have been grouped together over time, thereby giving rise to distinct morphological periods (Whitehand and Carr, 2001). These groupings are fundamental to the understanding of how a new type of housing generated and developed over time. Every period defined a different meaning for the concept of a house. In any case, when we look beyond the differences, we see a significant continuity among analogous objects that are as easily discernable as the differences, which is the essence of the typological process. Moreover, it is a model of the history of the city based on the notion that history is a system of spatiotemporal individuations that are discernable through the process of their formation (Carniggia, 1979). Gu and Whitehand (2008) suggested that the concept of the typological process is a useful means for extending the study of residential buildings beyond the recognition of individual types; additionally, it stimulates hypothesis testing that can provide a basis for a more general developmental framework within which descriptive categories of buildings can be placed.

In the historic investigation of the cases, this research first selected the more representative cases which are from different regions of China to provide a more comprehensive base for comparison. The main considerations that influence the choice of specific examples are as follows:

- Their significance in the history of Chinese row houses,
- The representation of a certain type of row houses in their locale, and
- The availability of adequately documented archives.

Secondly, for effective comparison, it is necessary to establish a consistent method of analysis using a specific framework for all cases. The methodology framed by Kropf (1993) is implemented in the analysis of the cases. Two modes were carried out in parallel. One is a physical hierarchy-structure analysis that discusses the physical structure of some typical units in light of the components of the rooms, including layout, function, circulation, and facilities. The other is a chronological comparative analysis that focuses on how the housings have evolved through time. We will choose two typical cases in each city in the chronological way and compare them to find the how the housings evolved. The relationship with the local traditional housing will also be examined.

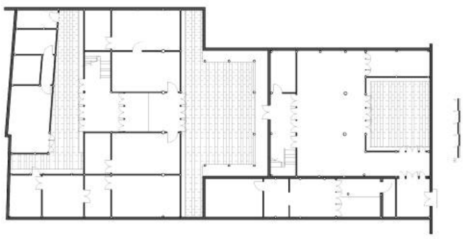
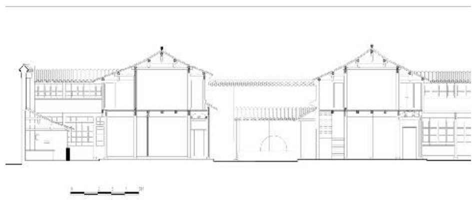
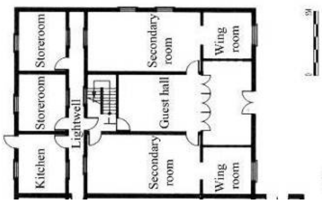
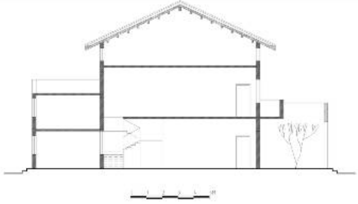
Finally, the evolution of these cases will identify the relationship between the Chinese row houses and traditional housings .Additionally, the similarities and difference between these row houses with various backgrounds will find their distinguishing and location-adaptive features and identify the inherent rules that were maintained in the evolution of Chinese row houses, which could benefit housing proposals for future designs.

Analysis of housing patterns in six cities

Case 1: From Jiangnan House to Shanghai Lilong.

Shanghai is located at the midpoint of China's eastern coast and sits at the mouth of the Yangze River, which supplies a spacious and strong backdrop. The region represents one of the strongest cultures in China and is famous for its water town houses and gardens. It was opened as a treaty port in 1842, and foreign countries were permitted to found each of their foreign settlements individually. The construction and enlargement of these areas accelerated Shanghai's urbanization. The city witnessed the birth of modern industry, commerce, and architecture and was the largest colonial city in China in the 1930's. Lilong housing, which is dominant in this region, demonstrated the unique urbanization and commercialization of Shanghai.

Table 1. *House transformation in Shanghai*

Local traditional house		
 *Ground Floor Plan (Redraw based on Chen,2003)*	 *Section (same with plan)*	 *Photo*
Early Row house		
 *Ground Floor Plan (Redraw based on Cao,2004)*	 *Section (Redraw based on Wang&Chen,1987)*	 *Photo (Field survey)*
Later Row house		
 *Ground Floor Plan (Redraw based on Lü et al., 2001)*	 *Section*	 *Photo(Field survey)*

Lilong housing was constructed for a long period of time in Shanghai. From the 1860s to the 1910s, the type of old shi-ku-men or lilong housing was the prevailing type. This kind of lilong housing was originally designed for middle–class Chinese families; thus, the plan reflected the traditional lifestyle of the Chinese people. Lilong housing was characterized by its fairly large size, strong central axis, and situating all rooms to face an inward courtyard. Although this kind of lilong house is more compact, the basic spatial layout still shares a lot of significant similarities with that of traditional housing in Jiangnan (Table1)

First, as previously indicated, the majority of rooms within lilong housing in Shanghai face an inner courtyard, and family activities are generally focused inward with high walls surrounding the home and few windows to the outside. This is typical for Chinese traditional courtyard houses. Second, in terms of the spatial layout, rooms were arranged symmetrically along the main axis, and the house actually offered two courtyards. The front courtyard was surrounded by a guest hall, secondary rooms, and wing rooms, while surplus rooms and the kitchen were open to the back courtyard. One functions as the open space for the family, while the other is very small and functions as a source of ventilation for the rooms. The proportion of the courtyards is quite practical in terms of adjusting the micro-climate of the house. Thirdly, the old lilong housing form also follows a same space sequence that is similar to that of the traditional housing in Jiangnan (i.e., front courtyard-living room - backyard - accessory rooms). Furthermore, the structure and building materials that were used are essentially those that were traditionally used in Jiangnan courtyard housing. In old lilong housing, the rooms facing the front courtyard were separated from the courtyard with a row of down-to-floor lattice windows, which are hinged-connected for easy installation and removing. This is one of the main elements of traditional housing found in Jiangnan.

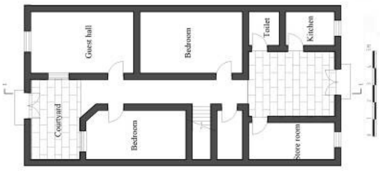
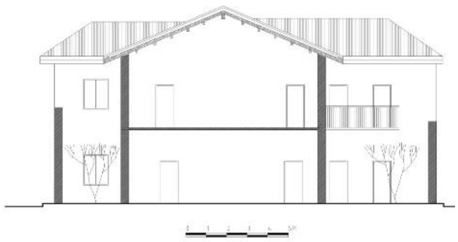
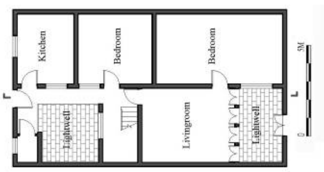
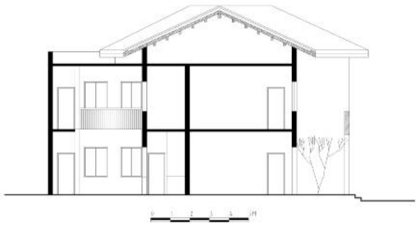
After the revolution in 1911, due to the changes in family size and the rapid increase in land cost caused by population growth, new units with more compact characteristics became popular. As compared to old shi-ku-men lilong housing, this new form still retained the traditional space sequence in the vertical axis starting from the courtyard, living room to the backyard with the ancillary rooms. The main activities of the family still centered on the courtyard. Additionally, two courtyards were still included in the plan, but they were smaller in size.

However, some changes were clearly included mostly on the attached rooms in order to adapt to the smaller width and depth. First, the kitchen was connected directly to the living room, while a small backyard was formed longitudinally by reducing the width of the kitchen. Second, the kitchen section was built with two stories, and the upper floor was used as a small bedroom, which was called the Tingzijian (i.e., the pavilion room). The area of the kitchen and tingzijian was small such that the height was reduced; thus, the roof of the tingzijian could be used as a balcony. Structurally, modern elements, such as concrete and trusses, were applied. Plans also became more open and included more windows and openings to the outside. The heights of the walls in the yards were also reduced. The new lilong housing underwent a series of shifts and gradually became more Westernized and modern.

Case 2: From Shanghai Linong to Wuhan Li-fen housing.

Wuhan is the capital of the Hubei Province in China. The Yangtze River and the Hanshui River divide Wuhan into three parts. It possesses strong economic and regional advantages since it is the center of communications for almost three-fourths of the territories in China, thereby relaying goods, persons, and information. Wuhan reflects deep cultural tolerance with a great number and variety of people coming from different areas. Hankou became an open trading port in 1861, and the British, French, Russians, Japanese, and Germans formed their concessions independently. All of the concessions prospered, and Hankou became one of the industrial centers of modern China.

Table 2. *House transformation in Wuhan*

Early Row house  *Ground Floor Plan (Redraw based on Yu and Li,2009)*	 *Section*	 *Photo (Field survey)*
Later row house  *Ground Floor Plan (Redraw based on Li and Sun,2008)*	 *Section*	 *Photo*

The layout of the li-fen housing units was quite similar to that of the new lilong housing units in Shanghai since it was directly introduced into Wuhan by the developers from Shanghai in the 1910s.(Table 2) Having undergone the process from imitation to producing varieties, li-fen housing has become a harmonious part of the urban environment. The different patterns of this type of housing include three-bay, two-bay, and single-bay widths. Li-fen housing also offers a front and back yard, which serve as a special space to insulate the house from outside disturbances instead of acting as a connective, transitional space between supplementary houses and the main house. Li-fen attaches importance to the full use of the limited amount of land by changing the courtyard between the wing-room and principal room into a dooryard, which is smaller than courtyard, separating the kitchen from the living area in the backyard. The backyard is used for transition and ventilation. The Tingzijian which is the typical characteristic of the new lilong housing in Shanghai did not appear in li-fen housing, and the back yard of the li-fen housing was a bit larger than that in Shanghai. This may be partly due to the smaller population and the larger hinterland that could provide for housing construction. Since Wuhan is an extremely hot city, li-fen is designed to adapt to the unique climate using good ventilation and sun shading facilities to cool the inside rooms.

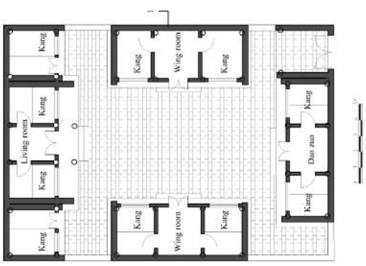
Case 3: From the north courtyard house to Lilong housing in Tianjin and Li-Courtyard in Qingdao.

A. Lilong housing in Tianjin.

Tianjin, the second largest treaty port in China and the largest city in North China in the early 20th century, is located at the northeast part of the North China Plain west of the Bohai Sea. It is only 137 kilometres southeast of Beijing. Water transport plays a significant role in the economy of Tianjin, and the main urban areas were situated along the rivers, which is different from other traditional Chinese cities. Tianjin was opened as a treaty port in 1860 and was shared by the following nine foreign countries: Italy, Germany, France, Russia, Great Britain, Austria, Japan, and Belgium, all of whom established self-contained concessions along the river front. No systematic and comprehensive city planning was ever implemented since every concession developed individually; as such, the city contains more than one center.

Table 3 *House transformation in Tianjin*

Local traditional house

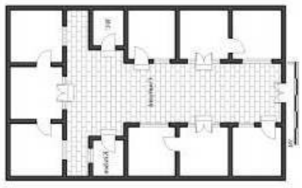


Ground Floor Plan (Redraw based on Liu,2007)

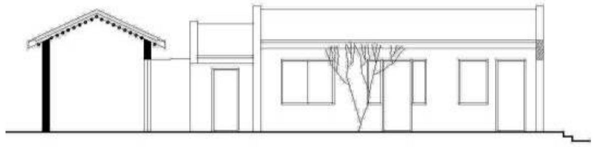
Section (same with plan)

Photo

Early Row house

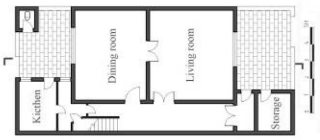


Ground Floor Plan
(Redraw based on Wang & Chen,1987)



Section

Later Row house



Ground Floor Plan
(Redraw based on Wang & Chen,1987)

Section (same with plan)

Photo
(Field survey)

A typical unit of the early row house in Tianjin as initiated by Chinese developers is based on a rectangular pattern with a courtyard surrounded by rooms. No distinctive differences can be identified between the rooms in terms of width and depth, but a central axis is still incorporated in the spatial organization, which is also characteristic of a traditional northern courtyard house. However, equal arrangement of the rooms was utilized regardless of their different orientations. Service rooms, such as the kitchen and bathrooms, were located in the courtyard and shared by all the families in the unit. Additionally, a distinctive hierarchical structure of the family organization was not incorporated, which is the characteristic of the traditional northern courtyard housing.

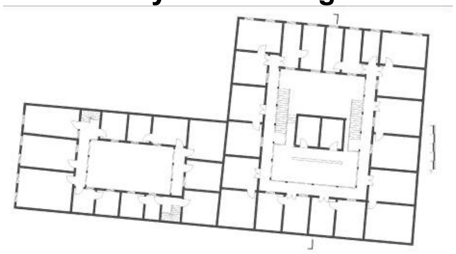
The row house in the concession, which developed greatly due to the booming commerce and increasing population in 1910 to 1937, was more similar to the new lilong housing in Shanghai. The typical unit plan, for example, also contained courtyards both at the front and back of the house, and the basic layout of the rooms were similar to the new lilong housing in Shanghai. However, the courtyards were much bigger in order to access enough sunlight in the climate of Tianjin.

B. Li-courtyard housing in Qingdao.

Qingdao, a coastal hilly city, lies on the coast of the Yellow Sea and on the south portion of the Shandong Peninsula. It is different from Shanghai, Tianjin, and Wuhan since it was founded by Germans and was thus free from the influences of other powers. It does not seem like the typical Chinese city since it was originally planned based on western urban planning theory and considering topographical conditions. Qingdao was once under colonial rule by Germany and Japan. Although the foreign powers politically ruled the cities for only a short period, they exercised extensive control over their colonies, influencing the society, economy, culture, urban planning, and architecture of these cities in the long term.

Table 4 *House transformation in Qingdao*

Li-courtyard housing

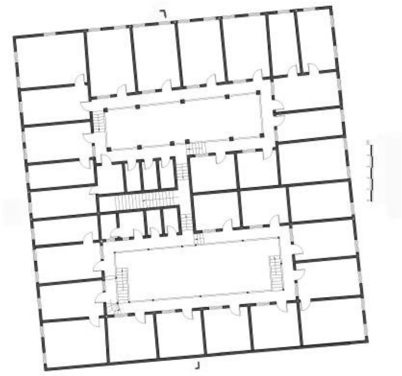


Typical Floor Plan(Field survey)

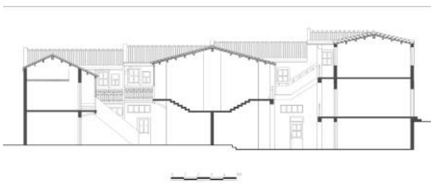
Section

Photo (Field survey)

Later row house



Typical Floor Plan(Field survey)



Section

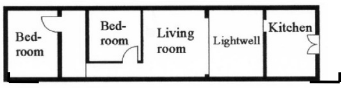
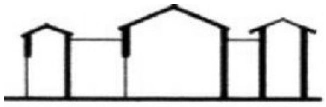
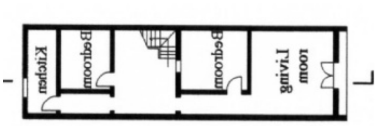
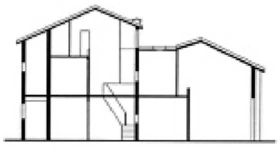
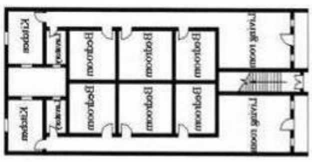
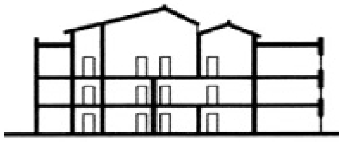
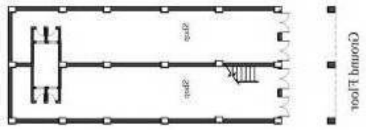
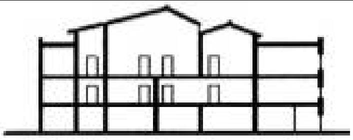
Photo (Field survey)

The close and rectangular space pattern of the li-courtyard housing is very similar to the traditional northern courtyard housing of China. Specifically, it involves a compound with rows of rooms built on four sides and an inner courtyard in the center. However, no central axis is included in the spatial organization, and all of the rooms are equally lined up on the outer part along all sides and connected by public corridors that directly face the courtyard. The houses are two or three stories as allowed by the topographical conditions. The first floor is usually directly open to the main road and is rented out as commercial space. The courtyard offers water supplies and toilets, which are shared by all the families. Furthermore, the scale of the li-courtyard housing is much larger in three-dimensions than the traditional northern courtyard housing.

Case 4: From Zhutongwu housing to Qilou housing in Guangzhou.

Guangzhou is the capital of the Guangdong Province, which is located north of the Pearl River Delta. It is the political, economic, and cultural center of the Lingnan region, which is removed from the political and cultural focus of China and thus has its own distinct cultural identity. It is also China's Southern Gateway to the world. Thus, Guangzhou is characterized by a mixture of local and foreign cultural influences. In contrast to most traditional Chinese cities, Guangzhou has focused more on a functionally inclined approach to city building. The traditional Zhutongwu house in Guangzhou also reflects the unique urban context of the city, i.e., a commercial city with a comb-like urban fabric.

Table 5 *House transformation in Guangzhou*

Local traditional house  *Ground Floor Plan (Gu&Whithand,2008)*	 *Section*	 *Photo(Field survey)*
Early Row house  *Ground Floor Plan* (Gu&Whithand,2008)	 *Section*	 *Photo (Field survey)*
Later row house  *Ground Floor Plan* (Gu&Whithand,2008)	 *Section*	 *Photo (Field survey)*
 *Ground Floor Plan* (Redraw based on Liu,1997)	 *Section*	 *Photo(Field survey)*

In the late-nineteenth and mid-twentieth centuries, a mixture of indigenous and Western characteristics became widespread in Guangzhou. On one hand, versions of Zhutongwu with two or more stories appeared with the increase of land prices, thereby becoming the major residential building type; on the other hand, Qilou (i.e., colonnaded shop houses), which also have a long rectangular unit plan, began to appear in Guangzhou in the 1910s. They were built on major shopping streets or on frontage roads along the riverside (Gu and Whitehand, 2008). Internally, they were rather similar to Zhutongwu; nevertheless, concrete was frequently used in their construction, and their street façades were predominantly Western. In some cases, a more economical use of the land has been attained by constructing two multi-story Zhutongwu with a shared staircase and courtyard. The staircase and backyard changed from the areas that were used by a single family to shared areas, and the house was constructed with more stories to make the best use of the land. Except the arcade incorporated in the front of the plan of the Qilou, the basic space layout of the

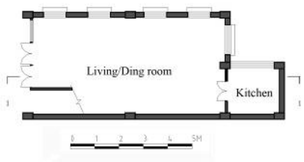
Qilou is the same as the Zhutongwu. However, most grounds floors of Zhutongwus are used for personal residence space, while the ones of the Qilou housings are used for shops or workshops. As compared to other row houses in China, the row houses in Guangzhou were much narrower and developed vertically rather than horizontally, but the basic size of the rooms and the numbers of stories for most houses were still acceptable (Table 5).

B. Tanglou in Hong Kong.

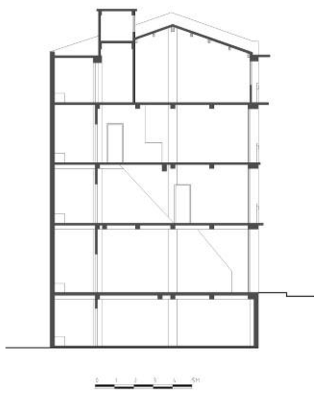
Hong Kong is located on the south-eastern coast of the East Asia landmass to the east of the Pearl River estuary. Hong Kong has always faced a shortage of land, in particular land that can easily and economically be developed because of the hilly topography and complexity of land transformation. Hong Kong became a British possession and entrepot in 1842 at the end of the First Opium War. The rapid growth in population has compounded the problem. The people in the coastal areas of eastern southern Fujian and eastern Guangdong were exposed to opportunities for business and employment in Hong Kong. The British colonial administrations of Hong Kong welcomed the Chinese immigrants because the newly established colonial territories needed the cheap labour and services, cottage industries, and the trade and investment that the Chinese brought with them. The rapid urban growth forced many residents to live in a compact environment. Tanglou were densely built, which were three to four storeys. Each storey consisted of one long room, a yard (usually occupied by the house keeper) and a tiny kitchen at the back. It is the common building type since 19th century with unique Chinese-Western architectural type in Hong Kong.

Table 6 *House transformation in Hong Kong*

Early Row house



Ground Floor Plan (Redraw based on A compilation of Measured Drawings of Tenement Building in Urban Areas of Hong Kong, 2003)



Section (same with plan)

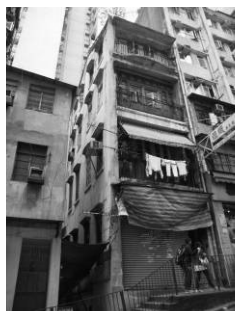
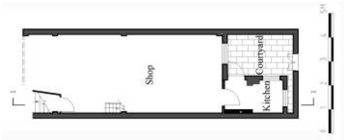


Photo (Field survey)

Later row house



Ground Floor Plan (Redraw based on Measured Drawings of Department of HKU Vol.1,1999)

Section(same with plan)

Photo (Field survey)

From the aspect of layout, Tanglou is rather similar to Zhutongwu. The living unit had an elongated shape, with the kitchen located at the back. There is no clear division between living rooms, dining rooms and common spaces. The width of the structure is limited by the maximum usable length of the China fir pole which is used as joists and beams in the construction of these buildings. There are only limited sanitary facilities provided in the building. The ground floor is usually for commerce use and the upper floors are for residence. Although the architecture of early Tong Lau in Hong Kong was broadly similar to those in Southern China, there are noticeable differences due to “European influence and example, but principally to the necessity for economy of space on account of the high price of land and the great cost of preparing level sites for building” (Faure 1997, 34). This means that the local conditions did have an effect in transforming even the early Tong Lau, which featured Western Classical decorative elements and were smaller and more compact.

The development of Tang lou in Hong Kong has a close relationship with the statutory control. The layout of Tanglou didn’t change a lot with the development but mostly on the depth, height and some physical features that related to natural lighting and ventilation for the building and the surrounding environment. Ordinances were set successively in 1903 and 1935. First, the back lane or open spaces were regulated in 1903 to allow in lighting and ventilation, as well as for waste disposal. Secondly, the height of Tanglou was controlled to not more than four storeys, or higher than 76 ft (about 23 m) which ensured that the surrounding streets, would receive adequate natural lighting and ventilation. Thirdly, the depth of Tanglou was limited to 40ft (about 12 m) ,which was an attempt to curb the number of under lit and badly ventilated tenement cabins in a long narrow building. (Lee, 2009) The building regulations under Building Ordinance 1935 are essentially a continuation of those introduced in 1903, but with more stringent control. The building height was limited to 3 storeys, unless constructed of fire-resistant materials, and not higher than 5 storeys for domestic. The depth of Tanglou was constrained to 35ft (about 11 m). The shorter building depth than that allowed in the 1903 regulations would further limit the partitioning of dark and badly ventilated tenement cabins or cubicles. Furthermore, adequate light and ventilation should to be provided at every storey on every staircase. This regulation would give the late pre-war Tong Lau its character-defining feature—a naturally lit and ventilated common staircase. (Lee, 2009)

CONCLUSION

From the analysis of the row houses which were developed from the end of 20th century to 1937, we can find these row houses in the colonial cities have a similar historical socio-economic background. For example, a steadily rising urban population, the different social strata with varied ways of life which resulted in varied types of housing and housing standards, and a general trend towards small-sized families. So these row houses which generated and developed in this historical environment bear a lot of similarities in terms of morphological characteristics:

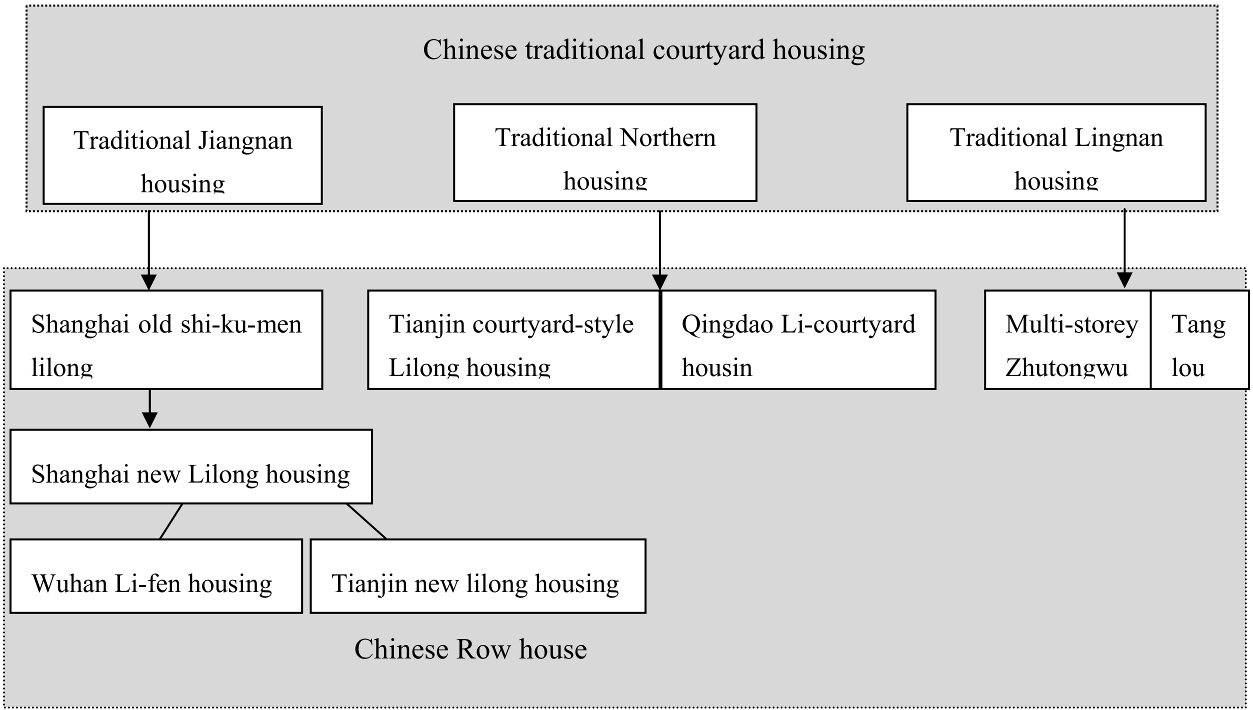
1. The basic layout of the typical unit of each type shares many similarities with local traditional housing. They can be recognized as an outgrowth of the traditional indigenous houses in the typological framework.
2. The row houses became more compact than the traditional ones. As the lot size shrank, the width and depth of the units became smaller and more stories were built to increase the efficient use of the land. Corresponding to this trend was the transformation from ground-related pattern to concentrated pattern of building mass.
3. Besides the spatial and volume evolution, architectural characteristics also changed. Traditional inward-looking character gradually died out, Western open elements prevailed.

However, these row houses still vary a lot since because of their different prevailing city environments and different geographical and cultural conditions. From the comparison of row houses in different cities, we can find the multiple and colorful architectural forms interact with each other:

1. Lilong housing in Shanghai which was developed from traditional Jiangnan housing finally influenced the li-fen houses in Wuhan which is also in the central east China. They have the most similar layout. However, new lilong house in Tianjin also has almost same spatial layout with them. Tianjin is a special case since the row houses in the Chinese district and concessions are different. The courtyard-style house in Chinese district has relationship with the traditional northern courtyard house which will be examined in next point. While new-style lilong housing is similar to later lilong housing in Shanghai. This maybe because they are all in the concessions and inflected by the Western powers.
2. Row houses in Qingdao and Chinese district of Tianjin, which are in the North China, can be recognized that they developed based on the traditional northern courtyard housing but became more compact to meet new demands. However, the dimension of li-courtyard house in Qingdao is much bigger than the counterpart in Tianjin. On one hand, the row houses in these two cities have

similarities since the cities have the similar geographic location and climate. On the other hand, there still some difference in the planning ,such as the size of lot, since Qingdao was planned and governed by German,

3. As the first open city in China, Guangzhou by contrast keeps most of its own traditions and identity. The traditional housing in Guangzhou also influenced the Tanglou in Hong kong .This maybe partly because the immigrants who has brought their concept of housing and also these two cities have the same geographic locations and climate.



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COMPARATIVE ASSESSMENT OF THE SUSTAINABILITY OF INDUSTRIALIZED CONSTRUCTION SYSTEMS

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ABSTRACT

The starting point of this paper is a reflection on the integration of Industrialized Building and Sustainable Development concepts and, more specifically, the aim to compare the different systems of industrialized components for collective housing construction from the point of view of sustainability.

The final intention is achieving the development of “Full Functional Building Units” with an optimum level of Industrialization and Sustainability, from the viewpoint of Technologic innovation and also the Economic Efficiency. That means the development of COMPETITIVE PRODUCTS FOR NOWADAYS MARKETS.

It involves introspection on sustainable industrialization of construction in regard to energy conservation and natural resources, reuse of these resources and life cycle management of materials and components.

The study is under development. This paper aims to summarize the objectives achieved so far as it purports to achieve in the future.

Keywords: Assessment, Comparison, Industrialized construction systems, Traditional construction systems

INTRODUCTION

The starting point of this paper is a reflection on the integration of Industrialized Building and Sustainable Development concepts and, more specifically, the aim to compare the different systems of industrialized components for collective housing construction from the point of view of sustainability.

The final intention is achieving the development of “Full Functional Building Units” with an optimum level of Industrialization and Sustainability, from the viewpoint of Technologic innovation and also the Economic Success. That means the development of COMPETITIVE PRODUCTS FOR NOWADAYS MARKETS.

It involves introspection on sustainable industrialization of construction in regard to energy conservation and natural resources, reuse of these resources and life cycle management of materials and components.

The first approaches have been made from very different ways all conclusive, a priori, that the evaluation of sustainability in architecture, far from being an exact science, is influenced by such diverse factors that make it impossible to value in an objective manner.

The environmental assessment systems, environmental labels, as well as different specific regulations approach the problem from different perspectives, many of them overlapped in an attempt to objectify the assessment of sustainable architecture. A preliminary analysis of these procedures seems necessary to find criteria that allow us to establish a system of evaluation as unambiguous as possible.

The ultimate goal of this study, will be to establish benchmarks for assessing the degree of sustainability of the overall process that involves each of the industrialized building systems. Thus, pre-set targets are necessary tools to carry out the assessment. The study is organized, then in five stages:

1. State of the art of the assessment system for sustainability in building construction.

Compilation, analysis and redefinition of objective indicators to ensure comparability.

2. Development of a benchmarking methodology. To systematize comparative analysis of industrialized building systems that can serve as a basis for conducting quantitative and qualitative comparison of the sustainability of industrialized building systems.

3. Collection of Data.

4. Design and assessment of the fully-functional units.

5. The ultimate goal of the work is the **comparative assessment** of industrialized construction systems used in collective residential buildings with traditional systems used in analogue conditions. This comparison will be done through the prism of sustainability.

The developed methodology will allow us to deliver critical judgments supported by a factual basis about the degree of sustainability of some systems over others. Thus, the work could lead to an analysis of the current state of the industry and opportunities for improvement in terms of sustainability guidelines to conclude that would improve existing systems.

MEASURING AND RATING SUSTAINABILITY IN BUILDING INDUSTRY

Although still in force the debate on the concept of sustainability, there are available today different assessment system of sustainability in building employed and contrasted enough to serve, analyzed together, as a reference to measure the sustainability of industrialized building systems.

The development of environmental management systems that enable organizations to control themselves, according to compliance with environmental regulations and to improve their performance with respect to the environment, represents one of the priorities of the new environmental policies relating to industry.

In the European Union, the implementation of management systems aimed at improving the environmental performance of production systems has not been made binding yet, although they have taken steps to encourage voluntary compliance.

It is expected that the analysis of the indicators and benchmarks which reflect the main environmental evaluation systems applied to the building can lead to the development of an instrumentation to assess the industrialized systems for sustainable collective housing in a systematic way. The choice of these systems has prioritized those who are regulated, recognized and certified by government agencies or reputable bodies. We find essentially two types of methods the ones which refer to materials and those related to buildings.

The main assessment systems, taken into account in the development of our own assessment system, are as follows:

ISO 14000 Environment Management

Given the massive presence and incorporation of new environmental standards, the International Organization for Standardization has developed in recent years a number of standards encompassed within the ISO 14000 that try to be an universal indicator to assess the efforts of any organization to achieve reliable and appropriate environmental protection. The first two standards of the family deal with Environmental Management Systems (EMS) providing the requirements for an EMS and giving general EMS guidelines. The other standards and guidelines in the family address specific environmental aspects, including: labelling, performance evaluation, Life Cycle Analysis, communication and auditing.

Life Cycle Assessment

From an ecological point of view, the environmental assessment systems have adopted the term Life Cycle to quantify the environmental impact of a product, system or activity from the moment it is extracted from nature until it returns to the environment as waste within a systemic process in which natural resources are consumed and wastes emitted.

We have studied the environmental impacts considered in the development of environmental certifications in order to select those whose analysis can be important in our study.

Building Environmental Assessment Schemes

BREEAM (Building Research Establishment Environmental Assessment Method) was the first system to offer an environmental label for buildings. Today we can find many different schemes throughout the world, most of which are based or inspired by it, reflecting the specificities of each region (country) where they are to be applied. Apart from the UK BREEAM system, the American system LEED (Leadership in Energy & Environmental Design), Japanese CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) and Australian Green Star have been considered in this study.

Environmental Profiles of Building Products

Also the BRE Environmental Profiles have been taken into account. BRE has produced The Green Guide to Specification, which provides simple environmental ratings of construction elements based on LCAs.

Common features of assessment tools

The study of these systems has allowed conclusions to be directly applied in the further development of evaluation method.

Assessment based on impact indicators

The assessments are based on the verification of the fulfilment of sustainability indicators related to different environmental impacts.

Balanced Scorecard

Basic rating systems for sustainability impacts score a series of sustainability issues, giving each a unit weight and then adding the individual scores to obtain an overall rating. Other systems use a balanced scorecard approach to summing the relative performance of each issue and then add those weighted scores to obtain an overall score.

Choice of credits

As we don't know at any one time the relative costs of achieving each level of performance for each sustainability issue, most advanced rating systems allow the practitioners retain the flexibility of choosing which credits to achieve, and to what level, considering the rating tool an open system that may vary over time and from market to market.

DEVELOPMENT OF A BENCHMARKING METHODOLOGY

The systematization of comparative analysis of industrialized building systems includes the development of our own methodology that can serve as a basis for conducting quantitative and qualitative comparison of the sustainability of industrialized building systems.

The evaluation is based on the verification of the fulfilment of sustainability indicators related to materials consumption, fabrication, transport, staging and reusing.

Development of the methodology

Goal

To gather and assess comprehensive and reliable information regarding the sustainability of industrialized building systems used in defined application which are generated over a defined lifetime.

Scope

Analysis of the sustainability of the system in two areas:

a) Determination of Functional Units placed in work and fulfilling a specific function.

b) Comparison between industrialized and traditional Functional Units.

The Functional Unit consider the materials in the context in which they are used, e.g. as a wall, they do assume a life and will fulfil various function for a set amount of time, they will have maintenance requirements and will have to be dismantled at the end of their role in the building. Different materials can then be compared on a like-for-like basis, as components that fulfil the same or very similar functions. This means that important variables such as the mass of a material required to fulfil a particular function are therefore taken into account.

The choice of Functional Unit instead of Industrialized Components allow us make the comparison not only between industrialized construction systems (based in the assemble of components) but also between industrialized systems and traditional ones.

Assessment

The evaluation will take into account the three pillars of sustainable development:

a) Effective technological development, including economic development.

b) Integrity of the natural environment, environmental dimension.

c) Social dimension and its implications on the human factor of production, user and maintained efficiently.

Indicators

It is intended to assess and quantify the causes and effects over the systems of both, the measurable indicators and the difficult to quantify ones. In the first group we include those related to consumption of raw materials, energy and water consumption, solid waste, etc, whose study constitutes the conceptual approach to the LCA; in seconds, will be necessary to use other tools for that purpose, in order to assess aspects related to rational design, social consequences, etc.

The parameter indicators are intended to cover the overall process of designing, manufacturing, assembling and recycling of a particular building system.

Strategies for this purpose have been divided into five categories: Design, Materials and Components, Fabrication, Execution and Others:

D	**DESIGN**	
D.1	RATIONAL DESIGN	D.1.1 SYSTEM ADAPTABILITY TO ANY MEASUREMENT
		D.1.2 UNIVERSAL JOINTS COMPONENTS
		D.1.3 MATERIALS AND COMPONENTS REUSABILITY
		D.1.4 ICT USE
		D.1.5 TECHNICAL APPROVAL (DIT)
D.2	DURABILITY AND RELIABILITY OF COMPONENTS	D.2.1 SERVICE LIFE OF COMPONENTS. EXTERNAL FINISHES
		D.2.2 SERVICE LIFE OF COMPONENTS. INTERNAL FINISHES
D.3	CONFORT STRATEGIES	D.3.1 THERMAL INSULATION
		D.3.2 PREVENTION OF CONDENSATIONS
		D.3.3 NOISE PROTECTION
		D.3.4 BIOCLIMATIC IMPROVEMENTS IN DESIGN
D.4	FUNCTIONALITY	D.4.1 HOUSING USE
		D.4.2 MAXIMUM NUMBER OF FLOORS
M	**MATERIALS AND COMPONENTS**	
M.1	ENVIRONMENTAL IMPACTS (LCA)	M.1.1 CO2 EMISSIONS
		M.1.2 EMBODIED ENERGY
		M.1.3 WASTE
		M.1.4 LOW-EMISSION MATERIALS
M.2	RESPONSIBLE SOURCES	M.2.1 RESPONSIBLE SOURCE LABEL
		M.2.2 REGIONAL MATERIALS AND COMPONENTS
		M.2.3 RAPID RENOVATION MATERIALS
		M.2.4 USE OF RECYCLED MATERIALS AND COMPONENTS
F	**FABRICATION**	
F.1	FACTORY AUTOMATION	F.1.1 VOLUME OF PRODUCTION
		F.1.2 SPECIALIZED EQUIPMENTS
		F.1.3 ASSEMBLY LINE
F.2	WORKING CONDITIONS	F.2.1 SOCIAL CONDITIONS
		F.2.2 ENVIRONMENTAL CONDITIONS
E	**EXECUTION**	
E.1	TRANSPORT	E.1.1 DIMENSION / MAXIMUN WEIGHT
		E.1.2 NEED FOR SPECIAL TRANSPORT
E.2	ASSEMBLY	E.1.1 REDUCTION OF LABOUR TIME
		E.1.2 SIMPLICITY OF THE SYSTEM
		E.1.3 SYSTEM LEVEL OF INDUSTRIALIZATION
O	**OTHERS**	
O.1	SYSTEM EXPERIENCE	0.1. UNDERTAKEN HOUSING PROJECTS
		0.1.2 COMPARATIVE STUDIES
		0.1.3 DEGREE OF SATISFACTION STUDIES

Weightings

Every indicator will be evaluated on a numerical scale from 1 to 3 (with some exceptions which may include up to 5). The score will be associated with a level of sustainability for each indicator. The levels go from 1 (level 1) to 3 (level 3).

As a general rule level 1 corresponds to systems that meet the minimum requirements enforceable regulations or other minimum conditions laid down. Level 3 is considered the optimum.

COLLECTION OF DATA

We have collected all necessary information required to evaluate every trace of sustainability, obtained from the following sources:

a) Directly from a good sample of Spanish manufacturers of construction materials, components and systems, through a selection process documented.

b) Overall figures will be used for industrial activity collected at the institutional level.

C) Those materials or products that you can not obtain data directly, then data from commercial databases may be used.

Selection of the components of the Functional Units

In order to develop the study, we have chosen a series of open industrial components forming complete Functional Units that are part of the building. The test of these

Functional Units will allow us to improve the method and the possibility of extending it to any building system, whether or not industrialized.

The choice of these systems and components has been based on the following key factors in the study:

a) The need for different products and manufacturers.

b) Collaboration with the manufactures: getting in touch with experts and visiting the factories.

c) The availability of built housing samples to study issues related to durability.

d) The availability of testing data and verification models in buildings or 1:1 scale models.

Manufacturers

We have worked with several manufacturers such as:

INDAGSA: Engineering and fabrication of prefabricated concrete components.

PLADUR: Leader Company in plasterboard fabrication

SEIS: Company highly specialized in the Building area covering conventional and modular construction, prefabrication of concrete components, GRC panels, etc

TDM: Company dedicated to industrial design applied to architecture and building.

DESIGN AND ASSESSMENT OF THE FULLY-FUNCTIONAL UNITS

Once the components and systems have been selected from the database, and studied in collaboration with the manufacturers technical support services, the fully-functional units would be developed.

This Units are evaluated in its technical, functional and economical features in all the production stages (Design, manufacturing, on-site assembly and maintenance).

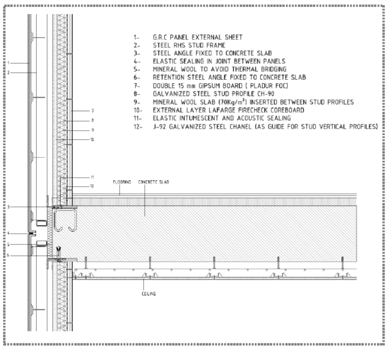
Starting with the obtained data, and applying the described Methodology, a numerical value will be obtained. This value shows the degree of Sustainability and Industrialization obtained by the fully-functional unit, which is valid for its comparison with other analyzed units.

Moreover, this evaluation is also an indicator of the possible weaknesses of the analyzed systems, related to the sustainability, which allows us to diagnose those aspects suitable to be improved.

Assessment example of a fully-functional enclosure unit

F.U_1. Collection of data

F.U_ 1: NON LOAD-BEARING FAÇADE_ G.R.C PANELS + PLADUR CH BACKING BOARD



MATERIALS

	WEIGH		VOLUME		CO_2	ENERGY	WASTE		PRTR	ORIGIN	RAPID RENOVATI	REC	USEFUL LIFE
	Kg	%	m^3	%	Kg	MJ	Kg	m^3				%	YEARS
GRC PANEL	40,00	35,97%	0,01	7,58%					NO	NO	NO	0,00%	40
ZINC-COATED STEEL FRAME	15,00	13,49%	0,00126	0,95%					NO	NO	NO	0,00%	40
PLADUR CH	21,70	19,52%	0,025	18,95%					NO	NO	NO	0,00%	20
GALVANIZED STEEL FRAME	4,86	4,37%	0,005	3,79%					NO	NO	NO	0,00%	
FASTENERS	0,88	0,80%	0,0002	0,15%					NO	NO	NO	0,00%	
MINERAL WOOL	4,20	3,78%	0,06	45,47%	6,41	101,03	0,122	2,8E-05	NO	NO	NO	0,00%	50
GIPSUM BOARD	24,00	21,58%	0,03	22,73%					NO	NO	NO	0,00%	20
PLASTIC PAINTING	0,55	0,49%	0,0005	0,38%	4	27,11	0,37	0,00614	NO	NO	NO	0,00%	5
TOTAL	111,19	100,00%	0,13196	100,00%									

ELEMENTS AND COMPONENTS

	WEIGH		VOLUME		MANUFACTURING MEASURES	UNIV.CONECT.	DISMANTLING
	Kg	%	m^3	%			
GRC PANEL	55,00	49,46%	0,01126	8,53%	MADE-TO-MEASURE MANUFACTURING 22 m^2 máx 3,5 ml	STANDARIZED WELDED	NO DETACHABLE
PLADUR CH	51,44	46,27%	0,0602	45,62%	STANDARIZED MEASURES, EASY MANIPULATION	BOLTED TO GALVANIZED STEEL FRAME	EASILY DETACHABLE
MINERAL WOOL	4,20	3,78%	0,06	45,47%	STANDARIZED MEASURES, EASY MANIPULATION	INSERTED BETWEEN FRAMES	EASILY DETACHABLE
PLASTIC PAINTING	0,55	0,49%	0,0005	0,38%	-	PHYSICAL ADHERENCE	NO DETACHABLE
TOTAL	111,19	100,00%	0,13196	100,00%			

ICT USE	MANUFACTURING	CONSTRUCTION	MAINTENANCE	DISMANTLING

CONFORT STRATEGIES

THERMAL INSULATION	PERSONALIZED
PREVENTION OF CONDENSATIONS	NO RISK OF CONDENSATIONS
NOISE PROTECTION	FITS REQUIREMENTS OF THE SPANISH BUILDING REGULATION (CTE)
BIOCLIMATIC IMPROVEMENTS	NO

CONSTRUCTION EFFICIENCY

HOURS MANUFACTURING + ASSEMBLY ON-SITE	TOTAL		FABRIC		ON-SITE	
SYSTEM SIMPLICITY						
SYSTEM LEVEL OF INDUSTRIALIZATION						

F.U_ 1: Evaluation: rating

				MAX. POINTS	ASIGN POINTS	PONDERAC	TOTAL PUNCTUATION
D	DESIGN					0,4	8
D.1	RATIONAL DESIGN	D.1.1 SYSTEM ADAPTABILITY TO ANY MEASUREMENT		0-3	3	0,4	1,2
		D.1.2 UNIVERSAL JOINTS COMPONENTS		0-3	3	0,3	0,9
		D.1.3 MATERIALS AND COMPONENTS REUSABILITY		0-5	4	0,25	1
		D.1.4 ICT USE		0-3	0	0,1	0
		D.1.5 TECHNICAL APPROVAL (DIT)		0-1	1	0,1	0,1
D.2	DURABILITY AND RELIABILITY OF COMPONENTS	D.2.1 SERVICE LIFE OF COMPONENTS. EXTERNAL FINISHES		0-5	5	0,15	0,75
		D.2.2 SERVICE LIFE OF COMPONENTS. INTERNAL FINISHES		0-5	5	0,15	0,75
D.3	CONFORT STRATEGIES	D.3.1 THERMAL INSULATION		0-3	3	0,3	0,9
		D.3.2 PREVENTION OF CONDENSATIONS		0-3	3	0,3	0,9
		D.3.3 NOISE PROTECTION		0-3	1	0,3	0,3
		D.3.4 BIOCLIMATIC IMPROVEMENTS IN DESIGN		0-3	0	0,3	0
D.4	FUNCTIONALITY	D.4.1 HOUSING USE		0-1	1	0,3	0,3
		D.4.2 MAXIMUM NUMBER OF FLOORS		0-3	3	0,3	0,9
M	MATERIALS AND COMPONENTS					0,4	0,75
M.1	ENVIRONMENTAL IMPACTS (LCA)	M.1.1 CO2 EMISSIONS		0-3	0	0,4	0
		M.1.2 EMBODIED ENERGY		0-3	0	0,3	0
		M.1.3 WASTE		0-3	0	0,3	0
		M.1.4 LOW-EMISSION MATERIALS		0-3	0	0,2	0
M.2	RESPONSIBLE SOURCES	M.2.1 RESPONSIBLE SOURCE LABEL		0-3	0	0,2	0
		M.2.2 REGIONAL MATERIALS AND COMPONENTS		0-3	3	0,15	0,45
		M.2.3 RAPID RENOVATION MATERIALS		0-3	1	0,1	0,1
		M.2.4 USE OF RECYCLED MATERIALS AND COMPONENTS		0-3	1	0,2	0,2
F	FABRICATION					0,2	3
F.1	FACTORY AUTOMATION	F.1.1 VOLUME OF PRODUCTION		0-3	2	0,4	0,8
		F.1.2 SPECIALIZED EQUIPMENTS		0-3	1	0,3	0,3
		F.1.3 ASSEMBLY LINE		0-3	2	0,4	0,8
F.2	WORKING CONDITIONS	F.2.1 SOCIAL CONDITIONS		0-3	2	0,4	0,8
		F.2.2 ENVIRONMENTAL CONDITIONS		0-3	1	0,3	0,3
E	EXECUTION					0,2	4
E.1	TRANSPORT	E.1.1 DIMENSION / MAXIMUN WEIGHT		0-1	1	0,4	0,4
		E.1.2 NEED FOR SPECIAL TRANSPORT		0-1	1	0,3	0,3
E.2	ASSEMBLY	E.1.1 REDUCTION OF LABOUR TIME		0-3	3	0,4	1,2
		E.1.2 SIMPLICITY OF THE SYSTEM		0-3	3	0,3	0,9
		E.1.3 SYSTEM LEVEL OF INDUSTRIALIZATION		0-3	3	0,4	1,2
O	OTHERS					0,2	1,4
O.1	SYSTEM EXPERIENCE	0.1. UNDERTAKEN HOUSING PROJECTS		0-3	2	0,4	0,8
		0.1.2 COMPARATIVE STUDIES		0-1	1	0,3	0,3
		0.1.3 DEGREE OF SATISFACTION STUDIES		0-1	1	0,3	0,3
						1	5,18

5,18

COMPARATIVE ASSESSMENT

As a final goal of this methodology we intend to study the real possibilities of industrial systems in actual construction from the point of view of technology and sustainability, and to see the gains that could be compared them with traditional construction systems that serve the same function within the building.

At the end of the study, it is intended to develop complete functional units with an optimum degree of industrialization and sustainability from the perspective of technological innovation and economic viability, thus competitive products on the market today. This will facilitate the choice of architects, engineers, public and private promoters etc. for use industrial products in both new construction and rehabilitation application.

In order to achieve a real and objective study, collaboration agreements with the most innovative companies in the industrialized construction sector will be established, making comparative studies of systems consisting of functional units or industrial components and functional units composed of elements used in traditional ways.

All functional units will be encompassed within 5 comparison groups covering a large part of the whole building system. The items included in each group fulfilled the same role in the construction of a building, and therefore, the study gives us extensive information on the degree of sustainability and industrialization in the face of choice in developing a housing project of a solution or another. The 5 comparative groups are:

Comparison Group 1_Work unit. Load Bearing Facade

Comparison Group 2_Work unit. Non Load Bearing Facade.

Comparison Group 3_Work unit. Complete bathroom

Comparison Group 4_Work unit. Structural Frame Systems

Comparison Group 5_Work unit. Horizontal Divisions

CONCLUSIONS

This study is still in development. So far we have been conducted the first two points and now we are developing those related with data collection and the valuation of the Functional Units.

However, the search and analysis of environmental assessment systems and the evaluation of specific indicators and benchmarks of industrialized construction have led us to be able to outline preliminary conclusions in order to set the trend in which the industrialized construction should proceed to achieve sustainability in the building and to provide strategies for achieving it. In general, we could identify the following guidelines to sustainable industrialized construction:

Choice of materials and low environmental impact components

And not without risk to human health. This criteria is based in the Life Cycle Analysis of the whole process taking into account all stages from manufacturing, construction to deconstruction.

Use of responsibly source materials

This means to avoid using materials that are endangered and those that produce a great impact on the area and the ecosystem. It will support the use of regional materials and autochthonous resources.

Reuse of materials and components

In their dual role: use of recycled materials and components in opposite to the traditional tendency of the extraction of natural materials and the possibility of reuse (reusability) of materials and components involved in the system coming from replacement work or demolitions.

Rational design methods

Consisting in the management, production and technological leading to improve productivity, profitability and sustainability. This will take particular account of the universality of the system regarding the use of modular and dimensional coordination internationally accepted design standards union connections and the possibility of future disassembly or deconstruction of the components.

Use of Information Technology and Communication

Emphasis on the changing needs of developers and users and a close relationship with customer satisfaction and sustainability of the processes (higher performance and lower environmental impact).

Quality System

Development of elements and components of high durability and reliability. This may involve higher cost in previous stages but ultimately is a wise investment because it saves energy and reduces waste.

Research of bioclimatic design solutions

Achieving greater interior comfort with minimal energy can pass to regain the traditional architecture strategies by giving them a contemporary reading through the use of technology and natural resources. In this sense, we must be especially careful with the import of industrial solutions in other countries because they can be completely alien to our culture, climate and way of building.

Maximum efficiency in construction

The term efficiency is reflected here in reduction of costs, execution time and labor on the site. It will automate as much work as possible and will be used prefabricated components.

Simplicity of the system

Sometimes high-tech disguises the true needs, not by chance sometimes the simplest solutions are the most sustainable.

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THE TENDENCY OF THE "OPEN BUILDING" CONCEPT IN THE POST-INDUSTRIAL CONTEXT

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ABSTRACT

When N.J. Habraken proposed the conception of support-infill in housing construction in 1960s, housing issues was centered by drawn material construction and consumption, although the needs of involving in the final occupants' participation emerged. It reflected a transition from the industrial economy to the post-industrial economy. Since the rapid development and evolution in the field of technology and social culture in the last several decades, both the social structure and ideology have been changing. The consumption conception of dwelling has also shifted from physical substance to some invisible items, such as knowledge and service. Therefore, open building, as an architectural design method, should adapt to this situation in its future development. This paper firstly describes the characteristics of the post-industry society. Based on analyzing and summarizing the theories and some examples, this paper tries to re-explain the definition of "flexibility" in the context of the post-industrial society. It concludes that the possible tendency of open building is to establish a service system for future occupants to adapt to the changing living environment in addition to physical changeability of the building.

Keywords: Open Building, Post-industry, Knowledge-service society, Participation, Housing

INTRODUCTION

In discussions and studies related to housing, especially mass dwelling construction, the well-accepted theory is that housing is mainly influenced by the particularities of culture. Rapoport stated that the primary concern is that the house form must not simply be the result of physical forces or a single causal factor, but the consequence of a wide range of socio-cultural factors seen in their broadest terms (Rapoport, 1969, p. 47). Meanwhile, Habraken proposed the theory of “support-infill” in mass-dwelling construction, the very top level of which is the relationship between “field” and housing. He considered the field was not merely a physical environment, but included the population within it and the inhabitant culture shaped for years, which was a manifestation of the social ideology and culture of the particular area (Habraken, 2005, pp. 36). He gave it the unambiguous definition of “the framework within which architecture, the self-conscious building that deliberately transcends the thematic, occurs” (p. 77). Accordingly, its definition is implied not as “an aesthetic preference” but “the product of an entire culture with the meaning that the technological and social values could not be separated” (p. 95). Although they used different terms, Rapoport and Habraken both explained the important and indiscerptible relationship among society, technology, and housing: a certain social culture is established according to the evolution of technology; and as one superstructure, housing utilizes the technology while reflecting the ideology of the culture.

Since the middle of the last century, obvious global social transformations have appeared. A new global economy brokered a variety of new ways of thinking, working, interacting, managing, producing, and distributing (Frankel, 1987, p. 27). Several of these include the transition from the production to the service industry, especially now that the era of material scarcity is about to end and the service industry population has continuously increased in the past several decades; the evolution of the electronic industry, which has been changing human participation- and communication-related activities in all fields; and the awakening of individual consciousness and the gradual realization of the importance of social participation. All these phenomena remind us that social culture has shifted increasingly with the transition of the industry and economy.

The Open Building concept is proposed as a transformation mechanism from quantity and function to quality. It aims to address changeability with individualized characteristics. In retrospect to the development of Open Building in the past several decades, most of the attention has been focused on the aspect of technology. Faced with issues related to housing mass-production, Dutch architects have focused on separating a structure into levels based on their various durations. This pattern has expanded to the fields of real estate and management (Fassbinder & Proveniers, 2009). In Japan, Open Building is applied as an approach to sustainable technology, as in the case of utilizing recycled resources. In America, Kendall indicates that the conception of long-term adaptability to environmental and social shifts in residential buildings has been more utilized in non-residential buildings in the past decade (Kendall & Teicher, 2000, p. 3). Despite the ideas related to housing based on a socio-cultural context as proposed by Habraken in the 1970s, less work has been done compared to the studies devoted to technology. Faced with the problems and dilemma that have emerged in the latest decade, discovering and studying the shift of the relationship among the main players involved in the entire housing process within the context of the post-industrial society may lead to the suitable direction of the development of Open Building and housing.

THE EMERGENCE OF THE POST-INDUSTRIAL SOCIETY

During the past half century, human society has experienced earth-shaking changes in all aspects. Social scientists around the world have tried to describe and summarize these changes with new terms to distinguish them from the previous ones. The term "post-industrial society" was first mentioned in a forum held in Salzburg in 1959 (Bell, 1973, p. 44). By observing the development of the three major industries and the alternation of the relationship among them, Daniel Bell divided the entire social process into three parts: the pre-industrial society, the industrial society and the post-industrial society, which are the formulations for competitions against nature, fabricated nature and among human beings respectively. The root of the differences among the three is the mode of production. In the post-industrial society, service and knowledge based on information are parallel with machinery (p. 146).

Service industry and economic restructuring

A surprising but prevalent social phenomenon around the world is that "economic decisions and struggles no longer possess either the autonomy or the central importance they had in an earlier society which was defined by the effort to accumulate and anticipate profits from directly productive work" (Touraine, 1971, pp. 4-5). In his work, Bell states that the post-industrial society is on the basis of the service industry, the core of which is no longer pure physical strength or natural resource but information and knowledge. The most obvious facts point to the rate of the service industry's increase since the 1960s. This became the first pillar industry whose population surpassed those of the other industries. Toffler expressed the belief that a new shift has taken place between use-value and exchange-value of goods and services, and that the post-industrial society will be based on a do-it-yourself (DIY), non-market economy with a social structure composed of individual and communal goods and services (Frankel, 1987, pp. 27-28).

Information-knowledge society and new social class

Just as mass-production made products affordable to all classes that a queen and a worker can wear the same stockings, the richness of material is no longer the rule among different social classes. The rule nowadays is the occupation of knowledge and information. This period is known as the information age within which men, knowledge, and production are connected together in a comprehensive and open pattern that has never existed before. This transition gives the public abundant opportunities to share knowledge and information; meanwhile it places people with specialized expertise in dominant societal roles (Bell, 1973, p. 156).

Compared with the industrial society, the post-industrial society is considered as a knowledge society with scientists and technologists as its main resources (Bell, 1973, p. 273). Bell believes that the primary social issue is the status and nature of the national science, the politicalization of science, and the role of scientists in providing support to solve social problems, all of which combine science and technology with politics, paving the way for the emergence of a new social class consisting of politicized scientists and technologists (pp. 148-150). This new class obviously has an extremely close relationship with the social decision-making process. On one hand, they give consultations to the ruling class and on the other, they communicate, explain, or disseminate knowledge to the public to make the decision making and strategy more open.

Public participation and control

Owing to widespread knowledge and technology, the public now enjoys more opportunities and privileges to understand and participate in the course of making any decision related to them. This gives birth to two developmental trends: further individualization and further integration into a whole. For the former, mass, standardized products and institutions of industrial societies give way to diversified and demassified products and processes (Frankel, 1987, p. 27) and individualized features of personal life where small communities and local societies are emphasized (Touraine, 1971, p. 5). For the latter, large scales of economic, political, cultural, and scientific institutions are developed to replace the roles played by the central government by providing various new ways of performing daily operations (Frankel, 1987, p. 27). As a result, new social conflicts arise between the centralized decision-making and those who intend to retain or express individual characteristics. Soon, this becomes a societal issue. However, simply collecting various requirements from the subsequent small units or individuals cannot overcome the conflicts, and could only result in a deadlock. For the sake of both sides, effective communication and negotiation are indispensable, which form some sort of “democratic participation” (Bell, 1973, p. 444) or “communal society” (Bell, 1973, p. 157) to give consideration to both parties involved in the conflicts.

THE DEVELOPMENT TENDENCIES OF HOUSING CONSTRUCTION

Evolving from the industrial society, post-industrial society and production can be considered as a successor of the former, resulting in similar characteristics shared by the post-industrial housing with that in the industrial society, including prefabricated components and their manufacture according to materials, functions, and costs (Demchak, 2000, p. 76). Apart from the development following industrial production, some other housing tendencies may be found on the basis of the distinctive characteristics of the post-industrial society.

Industry based on knowledge-service consumption

As a reflection of economics, culture, and politics, architecture inevitably cannot continue without any changes while the industry gradually shifts from production to service. Since the public has obtained more opportunities to obtain knowledge on materials and construction, its concern at present is not merely on the final products, but also on the assorted services that come with the products. For instance, the respective maintenance periods of all kinds of commodities now draw much more attention than ever before; and the so-called service apartment and its conception appears in the center of some metropolitan areas as a kind of deluxe residence option.

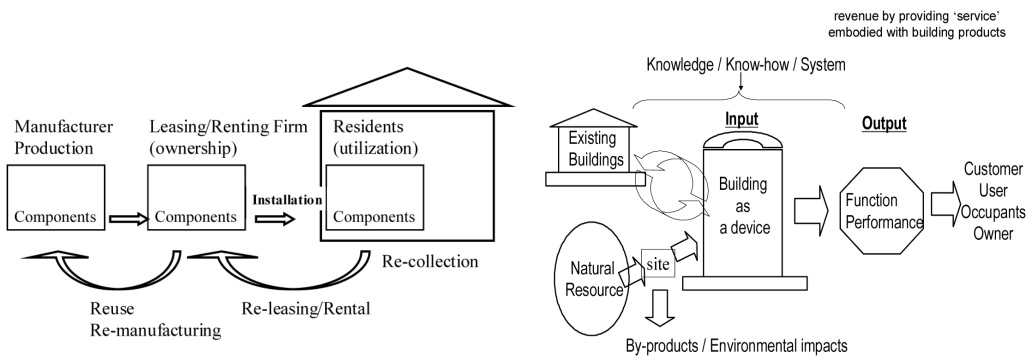

Figure 1, 2: *The idea of service provider and leasing model*
Source: *Yoshida, S., Yashiro, T., Nishimoto, K., & Shida, H. (2005). Dematerialization of Construction Related Industry by Application of Service Level Agreement Contract. The 2005 World Sustainable Building Conference. Retrieved from http://www.baufachinformation.de/aufsatz.jsp?ul=2007061000036*

In Japan, based on the objective of resource productivity and sustainability of construction, Yashiro and his colleagues conceive an alternative business model suggesting that the construction industry and business should shift from production to service (Yashiro, 2000) (Figs. 1 and 2). In this entire system, construction parts and buildings are neither the final goods, nor the resources of the total revenue, but are devices for realizing and manifesting the quantity and quality of service with the support-infill structure. The main structure and infill are provided to customers with the related knowledge and service, with which the customers can deal with the two major parts under their requirement. These integrate as material outputs, but the essence is the function and performance of the building(Yashiro & Nishimoto, 2002). When one lease ends, the former customer moves out and a new customer signs a new contract with his or her particular requirements; afterwards, the former infill system is dismounted and carried back for re-manufacturing and re-renting in the next turn while the main structure is retained. This model is applied in the market of building rentals, which includes not only housing but also any other kind of building (Kawagishi, Yashiro, Nishimoto, & Shida, 2005; Yoshida, Yashiro, Nishimoto, & Shida, 2005). The realization of this conception is based on the platform established by the support-infill system of the Open Building concept.

The conception of the service providing system coincidently reflects the transformation of the society from production industry to service industry as the basis of the post-industrial society. Widespread knowledge on construction making, which allows the public to understand the primary principles and rules, finally heightens the public's concern about things beyond the material form. As a result, the emergence of polarization in the construction industry is understandable: the massive centralized production for the infill and structures with certain standards on one hand, and the diverse demassified institutes or workshops as intermediaries connecting the original products and final customers' particular customer's requirements on the other.

Bypassing the characteristics of buildings such as longevity, aesthetics, and expense, dwellings can be compared to something very familiar in daily life such as computers. Although the process of transmitting data from one part to another is complicated, the truth that a computer is composed of three parts (i.e., external components such as case, screen, and keyboard; internal components such as hard disk, motherboard and memory; and software such as operating system and various programs) is easy to understand. When a computer is bought, what is actually purchased is the permission to use the software, and the ability to avail of periodical maintenance checks and upgrading which can essentially satisfy buyers. Nowadays, the manufacturing of the hardware is centralized to several big companies following the international standards. However, the development of the software is dispersed around the world with specific responsibilities which can involve only 5 or 6 people in each group. For what reason then do we choose one computer rather than another? It is the differences in service and promises between the systems and programs with similar functions. This choice becomes freer since the DIY concept has become a part of popular culture. And almost all the programs are designed with more space self-creation and a wide range of options for its users. In short, no two computers are the same.

The rapid development of the computer industry gives us a good lesson on one tendency of Open Building. With regards the dilemma of housing, the utilization of advantage technology helps less than we expect in improving the entire construction system toward becoming more sustainable. One of the reasons might be the asynchronous development of the service, which falls behind not only with technology but also with the main social culture. This brings to mind what Kendall says about mass housing not being able to provide any appropriate mechanism for the industrialization of the housing industry (Kendall & Teicher, 2000, p. 11).

A similar example in the Netherlands is the Matura Infill System and its patented products: the Base Profile and the Matrix Tiles, and the software program called MaturaCads. This system provides infill design following the matrix grid system, prefabricated products, and installation services. It can be utilized in both new constructions and old buildings. One of the famous projects is the Voorburg Renovation Project near Rotterdam in 1990 (Kendall & Teicher, 2000, pp. 113-114). Nevertheless, the limitation is obvious: as the storage of the prefabricated products is limited, the system can only be utilized in some small projects. Since all the products are fixed on the Matrix Tiles, the design should follow MaturaCads and the main structure should be appropriate to the system, both of which limit the system's utilization.

Public participation and control

Another characteristic of the post-industrial society is public participation in every aspect. This is expected to occur in the construction industry. Increasing public participation influences the role of the architect in the industry. From being a designer or an authority, the architect becomes a consultant or the person balancing the profit of all the stakeholders involved in the project, or even an assistant helping the users understand and master the system. The responsibilities go beyond architectural design and now include compiling the ideas or requirements from potential users or owners and achieving consistency through repetitive communication. On this aspect, a typical example is the Maya High-Rise Residential Building project in Chongqing, China. Completed in June 2008, its distinctive façade demonstrates that these two towers underwent different courses of architectural design and construction processes (Fig. 3).

Figure 3: *Maya Project in China*

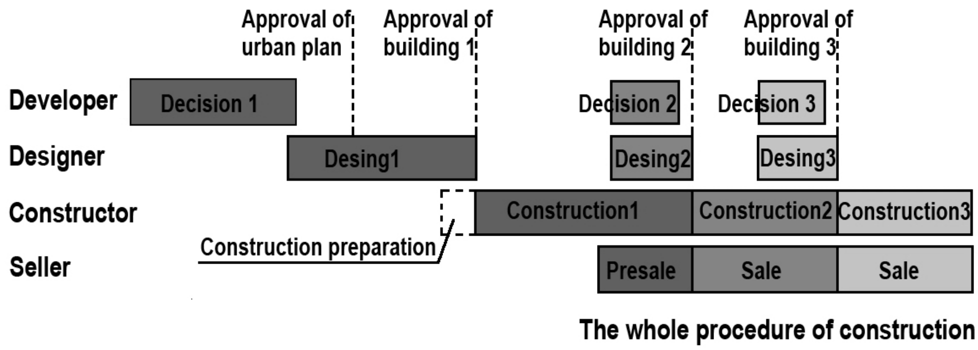

Figure 4: *The whole procedure of decision-making, design, construction and sale*

Figure 5: *Changes of the flat type proportion*

Source (3, 4 & 5): *Li, H., & Ren, Z. (2008). Control And Appearance of Architecture Design--Maya High-rise Residential Building Design. Urabn and Architecture(10), 45-47.*

The two towers of this project used a rectangle plan with 6.9 m×6.9 m column network and two core tubes for the vertical transport in order to carry various flat types, in which 15 basic flat types come out from the smallest (occupying a half column network) to the largest consisting of a total of two column networks. All the drainage, pipes and outdoor parts for air conditioning are arranged in the public corridors, external walls, or the facility floors. After completing the podium, the first pre-selling round turned out well. The developer collected the feedbacks and other related information from the buyers and submitted to the architects for modifications on the proportions among the different flat types. The two tower buildings were built following the new design and consequently, the units were sold out to the first round customers. The second pre-selling round began when the floors up to the 22nd were constructed. The architects redesigned the rest of the parts following the same procedure (Fig. 4). The external walls of the different flat types are painted with different colors, which can be easily recognized from the outside (Li & Ren, 2008).

The Maya project shows a model of public participation in the construction process. The entire project was clearly divided into two parts: one that was handled by designers including the design conception for the entire project, the podium part, the main support structure, and the vertical transport parts. The other part followed the real needs of the consumers, such as the flat type. The potential residents were fixed by the pre-sale, while a survey on which flat types they required most was undertaken. The architects redesigned the plans following the result of the feedbacks, thereby ensuring that the customers could get the flats with their requirements, while ensuring that all flats will be sold. As exemplified by the differences in the two towers' façades, the plans of the towers were decided indirectly by the customers rather than by authorities outside of the project. However, the data analysis on the project illustrates that the final flat type proportion is not exactly the same as the feedbacks showed. Obviously architects made adjustments to integrate flats into a whole (Fig. 5). Here, the role of the architects has not been limited to designing but also included balancing the relationship among the requirements of the building design, the individual customers, and the developers.

Unfortunately, this valuable architectural design model did not go further. Like almost all the other residential buildings, the architects withdrew from the project after the completion and sale. The project only focused on the requirement of the residents at the beginning stage but ignored the future evolution of the project. Any changes in the residents or their family structures will make the previous design model meaningless. In other words, the project was designed for a given group of people and cannot adjust to any more changes that could be brought in by future users. Therefore, future complaints may be expected just as in any other project.

Communal society and the NEXT 21 Complex House project

Temporary public participation in the Maya project indicates that it is not enough for the self-evolution of the residential buildings which lasts in the whole process of use. A more appropriate way is to establish long-term connections between participation and buildings. By far, the NEXT 21 Complex House project (Fig. 6) in Osaka City, Japan, is a relatively successful model of this long-term participation. As a part of natural resource saving and effective-energy use, the concept of support-infill system was included in the entire experimental system. Three experiment phases were scheduled from 1994 to 2011 after the project was opened to the public in 1993. The phases include high-efficiency energy utilization and greening for changes in future lifestyle in the first two phases, the flexible housing remodeling system in the third phase, and an experiment for establishing an urban community among residents along with all the three phases ("Osaka Gas Experimental Housing: NEXT 21," 2007).

In the concept of flexible “support-infill” system, all the construction components, except the basic skeleton, in NEXT 21 are standardized, pre-fabricated, and modularly designed including partition walls, floors, ceiling, façade, and wire and piping systems (Fig. 7). All the 18 flats in five floors are varied and can be adjusted in accordance with the residents’ requirements. When the residents moved in, they were provided with “Rule Books” and keys. The books describe in detail how to use the building in every aspect. These books will enable the residents to use the building for 100 years without involving the original architects and builders ("Osaka Gas Experimental Housing: NEXT 21," 2007, p. 4). Apart from providing rule books, a public infill system test laboratory was established on the ground floor. It was opened to all the residents for testing and mastering various types of infill components in the different positions of the house. As a result, the residents can update their knowledge and get what they need in tune with the newest technology. On the other hand, the residents were given the idea that the NEXT 21 project is more than a residential building but a small urban community unit. The purpose-designed three-dimensional street system and the public communication room on the first floor enhance the connection in three levels: between the local town and the NEXT 21, between the community and individual residents, and among all the individuals. The communal living rules were established in order to clarify the rights and responsibilities of each resident within the community.

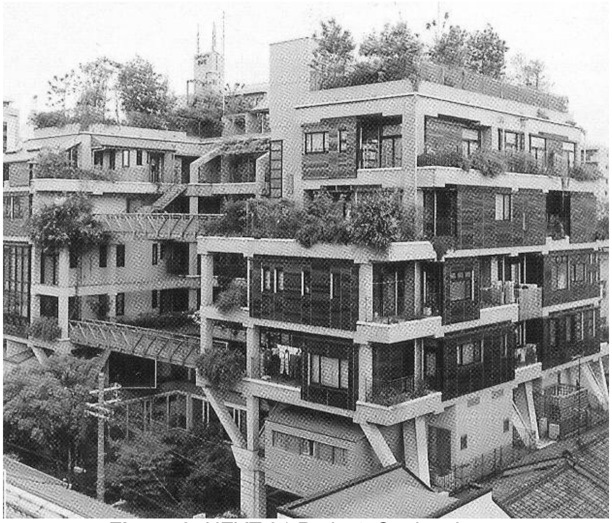

Figure 6: *NEXT 21 Project, Osaka, Japan*

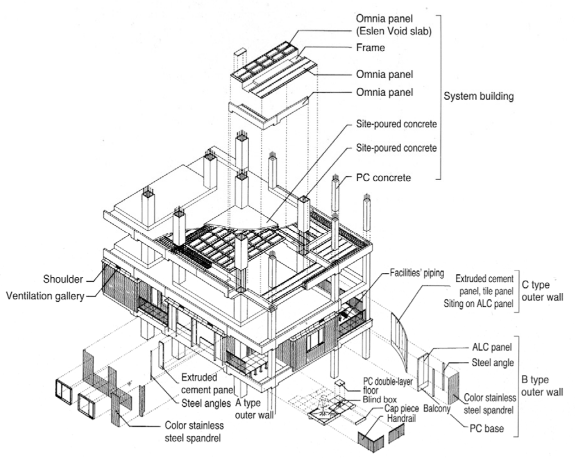

Figure 7: *Support-infill structure of NEXT 21*
Source: *Osaka Gas Experimental Housing: NEXT 21 (2007). In L. Osaka Gas Co. (Ed.), NEXT21, Planning & Development Team, Residential Market Development Department. Osaka: Osaka Gas Co., Ltd.*

All the people involved in the project’s construction wished to participate in the process of decision-making, just as Bell has explained that the people have the influence to control their life (Bell, 1973, p. 157). Public participation in the NEXT 21 project can be classified into two levels: individual participation and communal participation. The former was realized because the relative knowledge and technology were well transmitted to the residents. This became a continuous process which also meant that the service from the developer will continue after the project’s completion. In reality, several dwellings were remodeled according to the changes of family situation even at the early stages of the first phase. The remodeling was implied as participatory in nature, where the roles that architects and builders played relatively declined. Synchronously, the community or “communal society” was established on the basis of communal participation of culturally diverse people who must share the same rights at present and in the future. The community appears as integrated when addressing public issues such as cleaning work in the public area and the greening of the entire building (Fig. 8). As a result, it can be assumed that the residents will actively and spontaneously participate in improving their residential environment as well as the building ("Osaka Gas Experimental Housing: NEXT 21," 2007, p. 22).

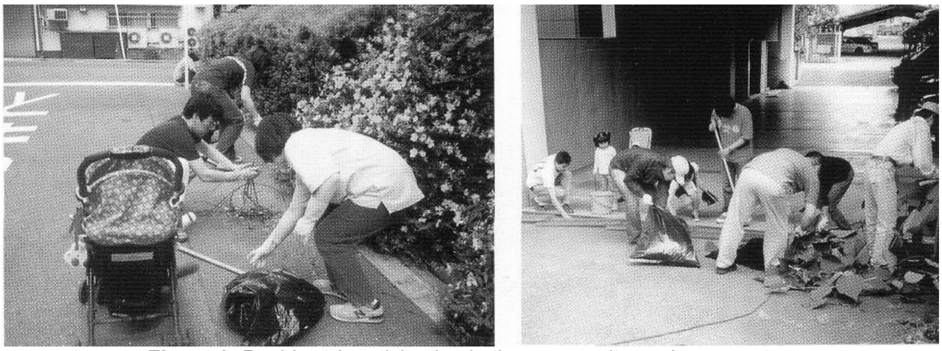

***Figure 8**: Residents' participation in the community work.*
***Source:** Osaka Gas Experimental Housing: NEXT 21 (2007). In L. Osaka Gas Co. (Ed.), NEXT21, Planning & Development Team, Residential Market Development Department. Osaka: Osaka Gas Co., Ltd.*

CONCLUSION

When the term "flexibility" is repeatedly discussed as a way leading to a sustainable construction pattern, it is often considered as a matter of technology. The Open Building concept takes the first step for breaking this brassbound tradition and tries to find various methods to make buildings flexible. For years, it has been proven that the power of technology is not enough to meet the demands of societal development. The transformation from the industrial society to the post-industrial society inspires a new perspective on the issue from dematerialized aspects—the relationship among people: service, participation, and control.

The service providing system gives a model that separates material production from final infill construction and adds an intermediary agency. This agency is in charge not only of design but of recycling the infill materials and components for different customers. This model can be realized in the house leasing market conceived by Yashiro and his colleagues. Maya high-rise residential project provides a pattern as to how public participation and control are carried out in the process of construction. A deeper thinking of the case reveals that this temporary participation and design comprise a kind of sales strategy to attract customers but one that could also lead to rigescent formalism compared to the Open Building concept. Certainly, this should be avoided. The NEXT 21 project, although still in the experimental stage, can be considered as a rudiment of the post-industrial residential building, as it effectively connects the evolution of the building with the development of its users in a long-term scale and converts the building to a mirror reflecting the relationship among men. However, whether or not this model will work in communities with extant residential buildings and distinctive social ideologies should be looked into in the future. However, there must be some prominent projects of Open Building that has not been covered by this paper. Further work should be done to address this limitation.

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MODULAR ECOTECHNOLOGICAL ARCHITECTURE: A RESPONSE TO THE DEMANDS OF THE 21ST CENTURY

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ABSTRACT

Constant change in current market and social conditions has triggered the demand for a more adaptable building stock. The capacity to assume and accommodate change has thus become a new requirement for buildings. At the same time, there is a growing demand for more environmentally conscious buildings. New protocols, building codes, and certification systems are becoming stricter regarding buildings' CO_2 emissions, energy efficiency, and other environmental aspects. The current building industry fails to satisfy these two demands; conventional buildings rarely enable change, unless undergoing complex renovations, and rarely consider environmental features beyond mandatory legislation. In this context, this paper proposes Modular Ecotechnological Architecture as a response to both demands. The basis is an integrated design that looks at energy, water, and materials' efficiency altogether, combined with a modular industrialized building system. The system allows buildings to grow or reduce in size according to their needs, with little impact for their inhabitants, enabling versatility for a variety of uses within the same space and over time. This paper presents the concept of this new building system together with the technical, building code-related, and economic challenges encountered throughout recent experimental projects.

Keywords: ecotechnology, green architecture, sustainable building, modular building, industrialized building

INTRODUCTION: THE CONTEXT FOR CHANGE

A growing demand for more adaptable buildings

The adaptation of buildings once designed for a specific use in a specific time to a different use in a different time, is not new. The European urban landscape of the end of the 20^{th} century holds numerous examples of an industrial, merchant, and military age which, having fallen into disuse, have become available architectures that have adapted to the most unlikely projects, lending themselves readily for modification (Bordage 2002). Industrial, commercial, and military buildings are now cultural centers, concert halls, and museums, among others. The Reina Sofia Museum, in Madrid, is an example of a former military hospital converted into a museum. In Bilbao, a 1600s baroque church now hosts a popular concert hall, Bilborock. While the natural lighting and acoustics may make these types of buildings ideal for certain activities, it is the great structures and absence of partitions what enables a physical polyvalence to host a variety of uses.

Besides singular buildings, the demand for adaptability has reached the wider building stock, triggered by constant change in market and social conditions. The most widespread need today for adaptability is either within or between residential and tertiary uses. For instance, large dwelling units are being split and turned into smaller units, as the average household size has decreased and smaller units result more marketable due to high real estate values. At the same time, many municipalities in the Basque Country are currently modifying their bylaws to allow residential uses in street-level floors formerly planned for tertiary uses, mainly office and commercial. Again, a combination of new market and social demands, as these spaces, under their former land use designation, remain undeveloped. This situation has its opposite in many residential buildings, in which dwelling units are often used as offices for a certain period of time. The capacity to assume and accommodate change has thus become a new requirement for buildings, which must adapt to different uses and situations throughout their lifespan.

The current building industry fails to achieve such goal. Most buildings in the Basque Country are built with post and beam concrete structures, where interior partitions have no significant structural role, and could therefore allow for change in the floor plan layout. However, the extended use of brick for interior partitions makes adaptation a complex process that involves time and user discomfort, as well as a significant generation of waste material. The recent use of lighter solutions for interior partitions, such as plaster boards or dry walls, contributes to adaptability. According to Pladur, the most popular plaster board company in Spain, their system has been used for over 20 years in over 250.000 dwellings and hundreds of office, hospital, hotel, cultural buildings, etc.

The need for a more environmentally conscious building industry

Buildings have a significant impact in the environment, both as great consumers of resources (e.g. energy, water, materials) and as generators of waste (e.g. CO_2, waste materials).

Energy consumption

In Europe, buildings (represented by the housing-services sector) are the greatest consumers of energy (41%), ahead of industry (28%) and transportation (31%) (European Communities 2008). In Spain the impact of buildings in the total energy consumption is somewhat lower (27%). The Basque Country presents a different picture, with a housing-services sector energy consumption share of 19%, behind those of industry and transportation (46% and 33%, respectively). However, while transportation consumption has dropped in the last year by 5%, housing has increased by 10% and services by 8%, positioning the housing-services sector as the fastest growing one per year in terms of energy consumption (EVE 2009).

Water consumption

Buildings in the Basque Country, again represented by the housing and services sector, are by far the highest water consumers. They represent almost 70% of the urban demand, and 45% of the region's total water consumption demand (Ihobe 2009). Within the sector, domestic consumption is 5 times greater than the services one, making residential buildings a key player to reduce the region's overall water consumption.

Waste generation

Buildings directly generate waste materials during the building phase, renovation, and demolition. In this sense, the building sector in the Basque Country generates around 1.8 million tons of waste per year, representing 15% of the region's total waste (Ihobe 2009).

Building codes and certification standards

The negative impact of the current buildings stock in the environment has generated a trend of environmental consciousness in both the public and the private realms. In Spain, the new recent building code (Código Técnico de la Edificación, CTE) includes specific energy consumption considerations, as well as the use of energy efficient utilities and renewable energy production in buildings. Apart from legislation, the government has set up the incentive-based Spanish Energy Efficiency Saving Plan, which in the Basque Country is carried out by EVE (Ente Vasco de la Energía). On the other hand, the private sector is slowly beginning to specifically include environmental benefits in its projects, as "green" becomes trendy for the market. Certification systems and standards, such as Passivehaus, LEED, BREEM, etc. are still underway in both Spain and the Basque Country. LEED is perhaps one of the most popular ones, applied in few specific outstanding buildings, such as the Iberdrola Tower in Bilbao. There are around 15 buildings in process of LEED certification in Spain, and up to now, none are residential developments.

Perhaps the flaw in current public efforts is putting all the eggs in the energy basket. That is, concentrating most of the new legislation and incentives towards saving energy and cutting down emissions, leaving buildings' responsibility on water and materials aside. Bioclimatic and ecological practices and certification standards such as LEED, Living Building Challenge, HQE, provide a more holistic approach towards sustainability and buildings' environmental performance.

The context for change

Either market, socially, or environmentally - driven, there is a growing demand for an adaptable and more environmentally conscious building stock. These concerns, related to the way buildings perform over time, are generating a context in which a substantial change in the building industry is needed. At the same time, the economic crisis, while it is significantly affecting both the Spanish and Basque building sectors, represents an opportunity for innovation in new building models. Increased efficiency in terms of time, labor, and material consumption are key to reduce cost guaranteeing, and even improving, quality. It is worth mentioning that, in order to accomplish significant change, these new models should look beyond new construction and over to existing buildings.

THE CONCEPT OF MODULAR ECOTECHNOLOGICAL ARCHITECTURE

This paper proposes the concept of modular ecotechnological architecture as a response to the demands for adaptability and environmental friendliness in buildings. The basis is an integrated design that looks at energy, water, and materials' efficiency altogether, combined with a modular industrialized building system.

Integrating design and technology to enhance environmental performance

Ecotechnological architecture is understood by this paper's authors as the integration of design and technology to significantly improve buildings' environmental performance. The concept considers three key areas due to buildings' high impact on them: energy, water, and materials. The first two are mainly related to consumption, while the latter to waste generation. These three areas of buildings' impact represent a starting point, acknowledging there are other ones within environmental sustainability to be considered (e.g. site, biodiversity, air quality).

In order to significantly improve a building's environmental performance, this paper proposes three ambitious goals, based on the application of the concept of zero energy buildings, beyond energy, and on to water and materials.

Zero energy goal

Although the term "zero energy building" (ZEB) has recently become quite popular, there is a lack of a common definition and understanding of what it means. There are different variants, such as net-zero site energy, net-zero source energy, net-zero energy costs, or net-zero energy emissions. Defining the zero energy goal affects design choices and whether one can claim success (Torcellini et al, 2006).

In this context, this paper uses the net zero site energy goal, which can be easily verified through on-site measurements. A site ZEB produces as much energy as it uses, when accounted for at the site (Torcellini et al, 2006). In order to achieve this goal, design and technology come together to first, reduce the building's energy demand, second, maximize the efficiency of its utilities, and third, generate the energy it needs.

Zero water goal

This goal applies the zero energy site concept to water (again, to provide a simple way to measure performance). The concept of net zero water, defined by the Living Building Challenge, proposes 100% of occupants' water use must come from captured precipitation or closed loop water systems that account for downstream ecosystem impacts and that are appropriately purified without the use of chemicals (International Living Building Institute, 2009). As in energy, the first step towards achieving the goal is minimizing demand, through low consumption devices, and secondly capturing rain water and treating grey water.

At the site level, it is also important to achieve zero storm water runoff generation. That is, taking care the building's site run off within it. This maintains the site's original hydrological balance, contributing to overall water and waterways' quality, reducing flood risk and the need for expansion of municipal infrastructure.

Zero waste goal

This paper proposes the zero waste goal applying the cradle to cradle concept to building materials: To eliminate the concept of waste means to design things from the very beginning on the understanding that waste does not exist (McDonough and Braungart, 2002). The aim is to use building materials wisely; not only to reduce resource consumption during the construction phase, but mostly to guarantee their recuperation, either for reuse or for recycling, when the building's useful life is over, reducing waste by demolition. Ideally, no building materials should end up in landfills.

Modularity and industrialization, a consequence of environmental consciousness

The "modular" in modular ecotechnological architecture is a consequence from the concern to reduce consumption of building materials and generation of waste (materials) throughout a building's lifespan; during construction, renovation, and deconstruction processes. On the one hand, industry and thus industrialized systems have always been more material-efficient than the construction industry. On the other hand, reducing waste in renovation and demolition basically entails the use of "dry" systems that can be recuperated at a certain point in time. Traditional use of concrete and brick on-site would therefore not meet the goal, as the materials used are not able to be recuperated, ending up in landfills.

Modularity and industrialization through open building systems are ideal to accomplish the zero waste goal. These systems are constituted by elements or components from different precedence; are able to be collocated in different types of buildings (industrialized or not) and in different contexts; usually make use of pretentiously universal joints, delimited modular ranges, offering an almost total project flexibility (Salas 2008). According to J. Salas, the development of these systems, particularly between 1990 and 2000, has been the germ for a new building philosophy, a term he has coined as "subtle industrialization".

Research findings indicate significant construction waste can be cut down through open building manufacturing techniques: Reductions of 100% of waste can be achieved in plastering; from 74% to 87% for timber formwork; from 50% to 60% for concrete, and from 35% to 55% for reinforcement bars (Tam and Tam, 2007).

Enabling adaptability and, hence, contributing to sustainability

The use of off-site industrialized systems, either from different precedence or having been assembled in one specific off-site location, allows buildings to grow or reduce in size according to their needs, with little impact for their inhabitants. At a smaller scale, the "subtle industrialization" of open building systems entails an elasticity of construction solutions based on components which has made possible the compliance of new energy saving legislation and responses to demands for other types of architecture (Salas 2008). Modularity in these components facilitates the design and construction / assembly process (and thus, time and money), while at the same time offers a vast range of end-user solutions.

Within the different structural solutions of open building systems, those with less structural elements in plan provide the maximum adaptability to different user-activities. Providing a clear plan with few master partitions enables versatility for a variety of uses (e.g. residential, office, educational), within the same space and over time. This is a critical aspect for adaptability and flexibility of use.

A word on adaptability and sustainability

Modular ecotechnological architecture intends to enhance adaptability and environmental performance through the integration of design and technology, using modular open building industrialized systems. The concept is intrinsically sustainable, as it contributes socially, environmentally, and economically. Socially, it responds to changing social demands (e.g. smaller household size, related to need for space, and housing size, related to affordability). Environmentally, it reduces buildings' energy, water, and material consumption and waste generation. Last, economically, it responds to changing market conditions, enabling different economic activities, and reducing cost (through increased time, labor, and materials efficiency).

CASE STUDY: EXPERIMENTAL PROJECT FOR SINGLE FAMILY HOUSING

The following case study is an experimental project for single family housing applying the concept of modular ecotechnological architecture. The south-facing rectangular site is located in a rural environment in the Basque Country, on a relatively steep East-West slope, with views down to the valley on the East.

From the beginning, the project program required adaptability of use over time. The program is proposed for a household of four (2 adults and 2 children), with an annex for hobbies, guests, or the children as they grow up. However, in the first years, the annex would be used by a close relative, as an independent apartment (Figure 1). The annex thus required a specific distribution in the short term that could at one point become one single open space. At the same time, the overall program required independence between the two units, and spatial coherence as well, as, in the end, it is one single dwelling. At one point a new adaptability requirement came up, due to affordability reasons: the possibility to build the house in phases (the main unit first and the annex later).

The client was interested in modular ecotechnological architecture for several reasons: program adaptability, shorter building time, lower overall cost, and a strong belief in ecological friendliness and technological innovation.

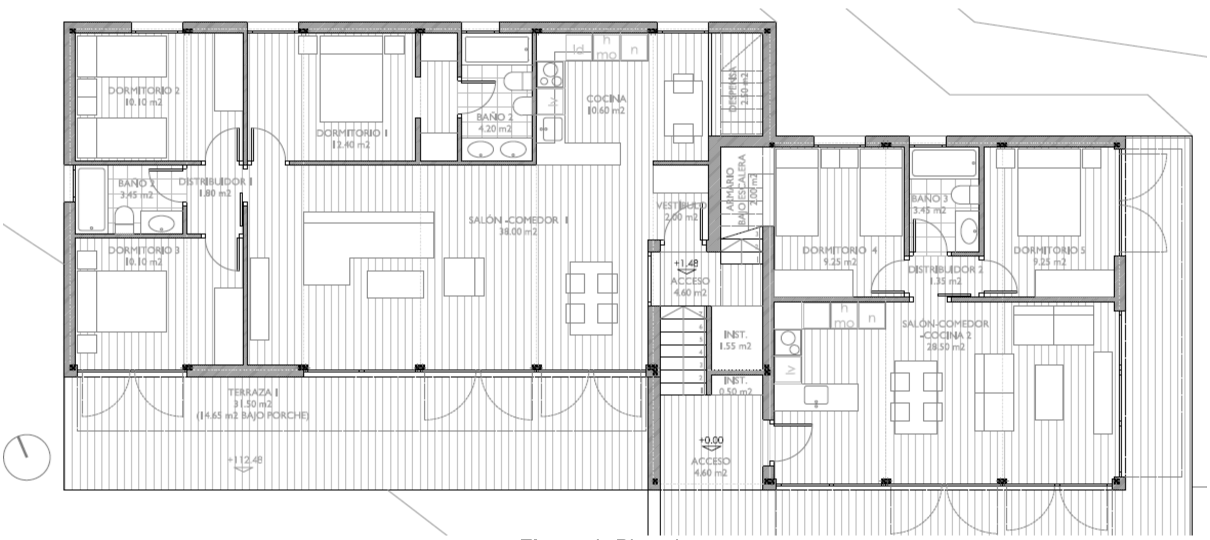

Figure 1: *Plan view.*

Technical aspects and challenges encountered

Below is a compilation of the technical aspects and challenges encountered throughout the project, divided into four key areas: structure, envelopes, interior partitions, and utilities.

Structural system

The structural system consists of 9 rectangular tridimensional modules. Each one is made up of four tubular steel posts and a prefabricated concrete slab. Modules attach to one another through a joint specifically designed for this structural system. The system and choice of materials responds to the zero waste goal, in that the building can be taken apart into its modules, and the modules can be taken apart into their components, ready for reuse or recycling.

The choice of modules only consisting of the minimum number of pillars is the cornerstone to provide an adaptable space. The combination of modules positioned contiguously on their long side provides a clear open plan (Figure 2).

Module dimensions are 2.5 m wide, 7.5 m long and 3.1 m high. One of the first challenges encountered in the design were dimensional and weight limitations. The modules were to be built off-site, so transportation and on-site assembly capacity were key aspects.

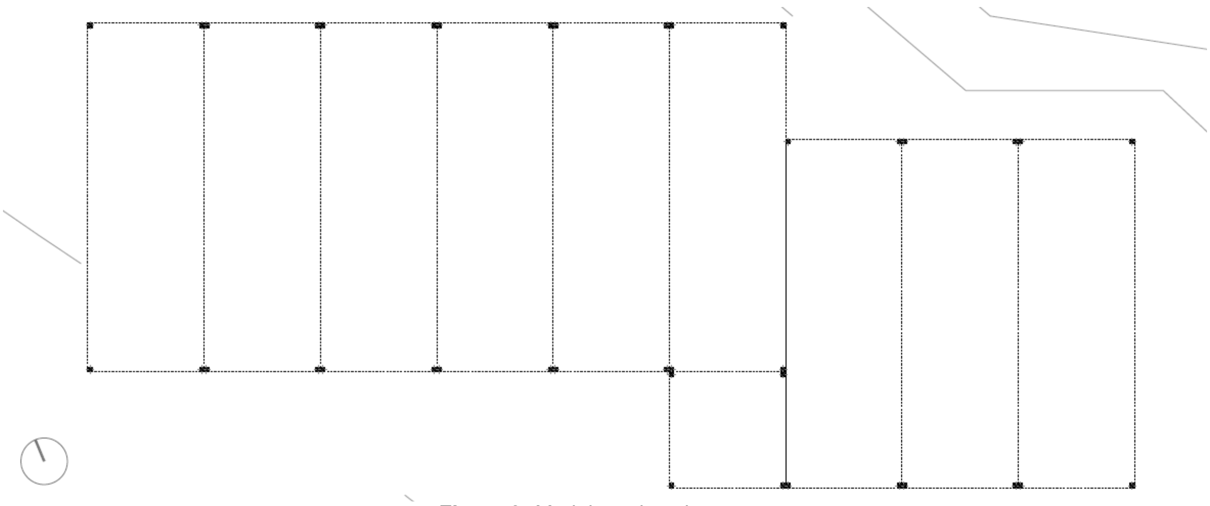

Figure 2: *Modules, plan view.*

Building envelopes

Building façades respond to site attributes, such as valley views, and orientation, to optimize solar gain and reduce energy demand. The building is mainly open to the South, with glazing and solar protection (Figure 3). To the North and West, prefabricated wood panel ventilated façades with few openings and extra insulation, as the North West winds are the coldest in the area. Openings on opposite façades allow for cross ventilation. Façade panels and openings respond to the modular system (Figures 1 and 3).

Green roofs provide a horizontal garden for the dwelling; an outdoors usable space in a site with a steep slope. The roofs include a shallow water deposit that covers the whole roof. The system not only reduces heat gain in the summertime, but also retains rain water in periods of heavy rain, and most importantly stores water for toilet use. Thermal panels on the roof provide energy for heating and domestic hot water use.

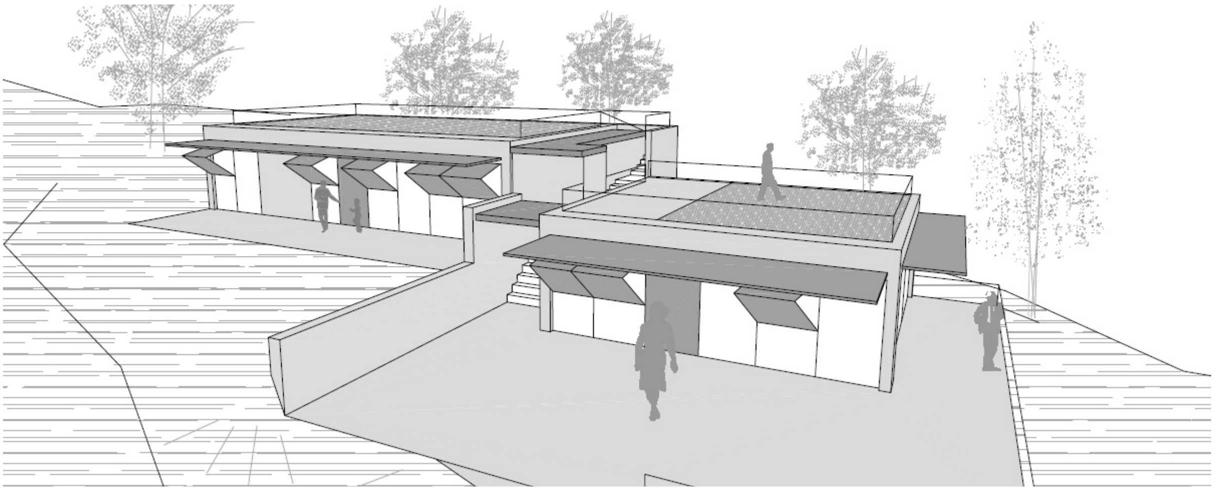

Figure 3: *South-facing view.*

Interior partitions

Interior partitions are made up of industrialized plaster boards that offer a simple assembly and are able to be taken entirely apart. This is relevant for the waste goal as well as for the adaptability demand. The modular system allows flexibility of plan distribution (Figures 1 and 4), although partitions do have to follow the modules to a certain degree. This can be considered a design limitation.

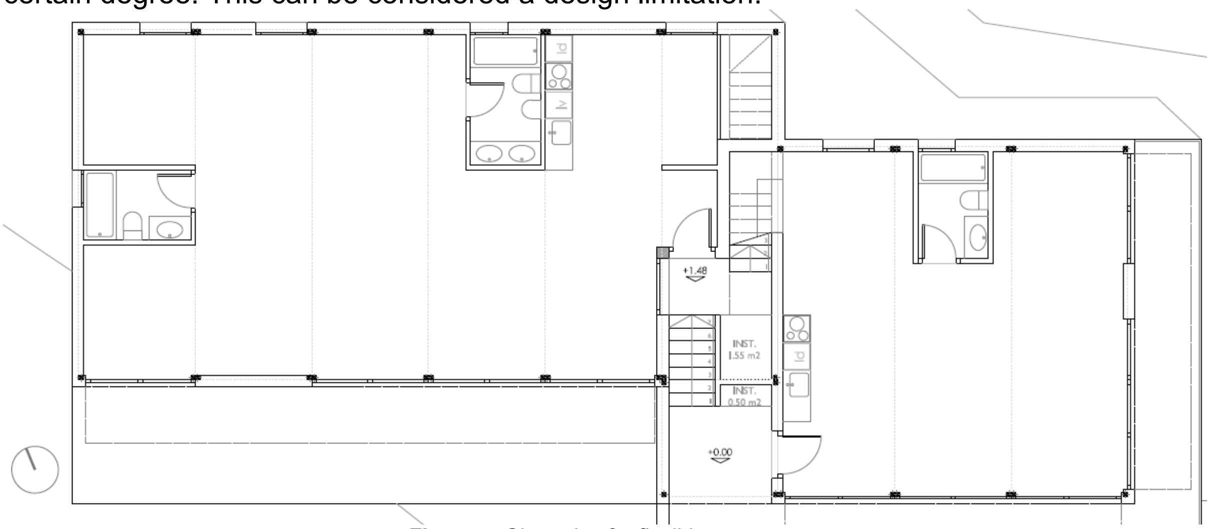

Figure 4: *Clear plan for flexible use.*

Utilities

As mentioned, the building contains thermal panels for heating (radiant floor) and hot water production. Default energy supply is natural gas. Lighting is through low consumption light bulbs and LEDs. Bathroom elements, taps with air pressure devices, and the roof deposit for toilet use, minimize the buildings' water consumption towards the zero water goal.

The main challenge in this sense is technological innovation, and the cost related to it. Some of the proposed systems are out there on the market, although not quite meeting all the project requirements (e.g. few radiant floors meet the zero waste goal). Others are just not there, either in development or yet to be developed. Another challenge encountered is the modular system requires bathrooms to be included within a single module (Figure 4). This poses a certain design limitation, as, once built, these elements prevail throughout the different plan distributions.

Normative aspects and challenges encountered

As with many technological innovations, the challenge with legislation is either it directly does not consider certain systems, or it penalizes others. For instance, the new Spanish building code (CTE) does not include open building manufacturing, and the new stricter acoustics section makes design with light interior partitions relatively difficult to comply. At the same time, Spain requires a 10-year structural responsibility for the developer, for which a technical control office must approve the project. These offices have little knowledge on open building systems, and require specific certifications (DITE) to give their ok.

Economic aspects and challenges encountered

The project is currently on standby for reasons beyond the project's control, so the real economics are based on a forecast. According to the manufacturers consulted, the building could be completed within 4 to 6 months, whereas the average time in conventional building would be 18 months. Indirectly, this means cost reduction. On the other hand, the project budget resulted in 10% below a previous project for a similar dwelling. The biggest challenge, nevertheless, was the cost of specific ecotechnologies in order to meet a cost objective to fit the market. Finally, although this project was not the case, there is a generalized market perception that prefab is low cost and low quality, and it applies to modular industrialized systems. This is a major challenge.

CONCLUSIONS

The concept of modular ecotechnological architecture intends to respond to recent demands for adaptability and improved environmental performance in buildings, contributing to the expansion of the Sustainable Open Building knowledge. The concept sets ambitious goals in the areas where buildings significantly impact the environment: energy, water, and waste. Such goals are meant to be objectives towards which to work and be able to measure performance and (hopefully) progress. Lessons learned from the case study presented suggest key elements to provide adaptability are modularity, structural system, and interior partitions. For environmental performance, envelopes and utilities are key for the energy and water goals, while structure, envelopes, and interior partitions are key for the waste goal. Ultimately, modular ecotechnological architecture is based on the integration of design and technology, and requires substantial imagination and innovation in order to meet the proposed goals and overcome the diverse design, technical, technological, normative, and economic challenges.

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OPEN SYSTEM PLATFORM FOR OPEN BUILDING MANUFACTURING

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ABSTRACT

This paper describes the OMSP-Open Manubuild System Platform designed in the Manubuild Project. ManuBuild is a 6th FPM project that focus on creating an Open Building Manufacturing System, a new paradigm for building production by combining an open system for products and components offering diversity of supply and building component configuration (on demand) opportunities in the open market, and value driven, innovative, efficient and safe manufacturing and assembly in factories and construction sites.

The OMSP has been designed to support all the generic construction process, including different roles and phases. The OMSP is conceived as the support and integration of the *Information and Communications Technologies* (ICT) tools and services that are required to support activities for open building manufacturing: design for manufacturing, offsite manufacturing and logistics and assembly planning. The OMSP is designed as the sum of ICT tools that share a common data model and provide services that make it feasible to perform the identified demonstration scenarios.

Keywords: Open building manufacturing, open platform, ICT.

INTRODUCTION

One of the fundamental problems that the construction industry has failed to address in past decades is in relation to its processes. As a result, the construction industry is very slow to innovate and unable to develop or even effectively implement new technologies particularly those cascading from technologically more advanced industries. It is necessary a deeper knowledge and control over the construction process to reach radical and sustainable changes in performance and competitiveness. *ManuBuild-Open Building Manufacturing* project objective is to achieve significant impacts to solve this problem through the development and implementation of a new ambient and ultra-efficient manufacturing based paradigm.

ManuBuild is a 6th FPM project that focus on creating an Open Building Manufacturing System by combining an open system for products and components offering diversity of supply and building component configuration (on demand) opportunities in the open market, and value driven, innovative, efficient and safe manufacturing and assembly in factories and construction sites.

ManuBuild project targets the construction of affordable, customised and flexible buildings improving the quality of life and providing better value to the customer by the manufacturing of the building process. This objective involves open manufacturing in construction, ambient and scalable manufacturing methods, and value driven business processes appropriately supported by Information and Communications Technologies (ICT).

A new model for a generic construction process has been defined to include all these concepts. One of the characteristics of the construction sector is the collaboration of many stakeholders who work together for limited periods of time. The complexity and long life cycle of products is other key characteristic. Several roles (designers, developer, suppliers,…) and phases have been identified in the model to integrate all activities and agents involved. One of the main roles in the process is the end user, as the whole process is defined to involve him/her from the early stages to the operation phase in the open building process. Main phases identified are Pre-activities (requirements setting), Design, Off-site manufacturing, On-site manufacturing and Operation and Services.

This complexity justifies the necessity of achieving holistic ICT support covering the project life cycle. A platform has been designed to support all the generic construction process, including different roles and phases. The OMSP- Open ManuBuild System Platform is conceived as the support and integration of the Information Communications Technologies (ICT) tools and services that are required to support activities for open building manufacturing: design for manufacturing, offsite manufacturing and logistics and assembly planning.

The OMSP is designed as the sum of ICT tools that share a common data model and provide services that make it feasible to perform the identified demonstration scenarios. The common data model has been defined based on the analysis of a general scenario for information requirements and the actual data models of integrated ICT tools, in order to facilitate sharing and reuse of information to facilitate open manufacturing. This platform paves the way for an open system for the construction industry open, modular, holistic, pluggable and expandable in the future. Research and developments concerning OMSP in Manubuild are described in next paragraphs.

MANUBUILD PROJECT

The goal of the ManuBuild project is to create an Open Building Manufacturing System. The project targets a radical paradigm shift to create a new European *"open building manufacturing"* industry transforming and improving the construction industry by fundamentally re-engineering the whole construction lifecycle process for buildings and integrating with it ambient production methods supporting scalable manufacturing and plug and fix component assembly (and production) on site as per user customisation demand.

Manubuild proposes a transition from a heavily craft and resource-based industry to a knowledge-based manufacturing industry using ambient and scalable manufacturing and "plug-and-fix" components from the open market and assembling them efficiently on site into customised buildings. The proposal of ManuBuild targets radical changes in the current ways of working of the industry.

The key elements addressed by ManuBuild Open Building Manufacturing System include open building concepts (lifecycle guides, key products, connections); business processes (value Management, process models); production technologies (fixed factories, mobile factories, site production); ICT support (open ICT system, critical ICT tools); and are supported in terms of implementation through training & education and standards.

Concerning ICT support, research in the project focus the definition an ICT architecture and tools and standard interfaces towards an open ICT system.

Processes supported by ICT tools in Manubuild

The general process for ManuBuild is defined including the activities for every actor. This can not be considered as unique as different organisations may have their own process according with their internal protocols. The proposed process has been identified as a model that could be adapted or modified to different situations. This general process has been developed based on discussion by several stakeholders involved in the building process and was considered as a model for a more general case, then the actors and processes for the building creation to be supported by ICT tools of ManuBuild have been identified. The main processes are the following:

- Managing catalogue objects (components)
- Managing templates
- Configuration of buildings based on component catalogue
- Customisation of dwelling design based on customer preferences
- Management of building production
- Management of supply and assembly

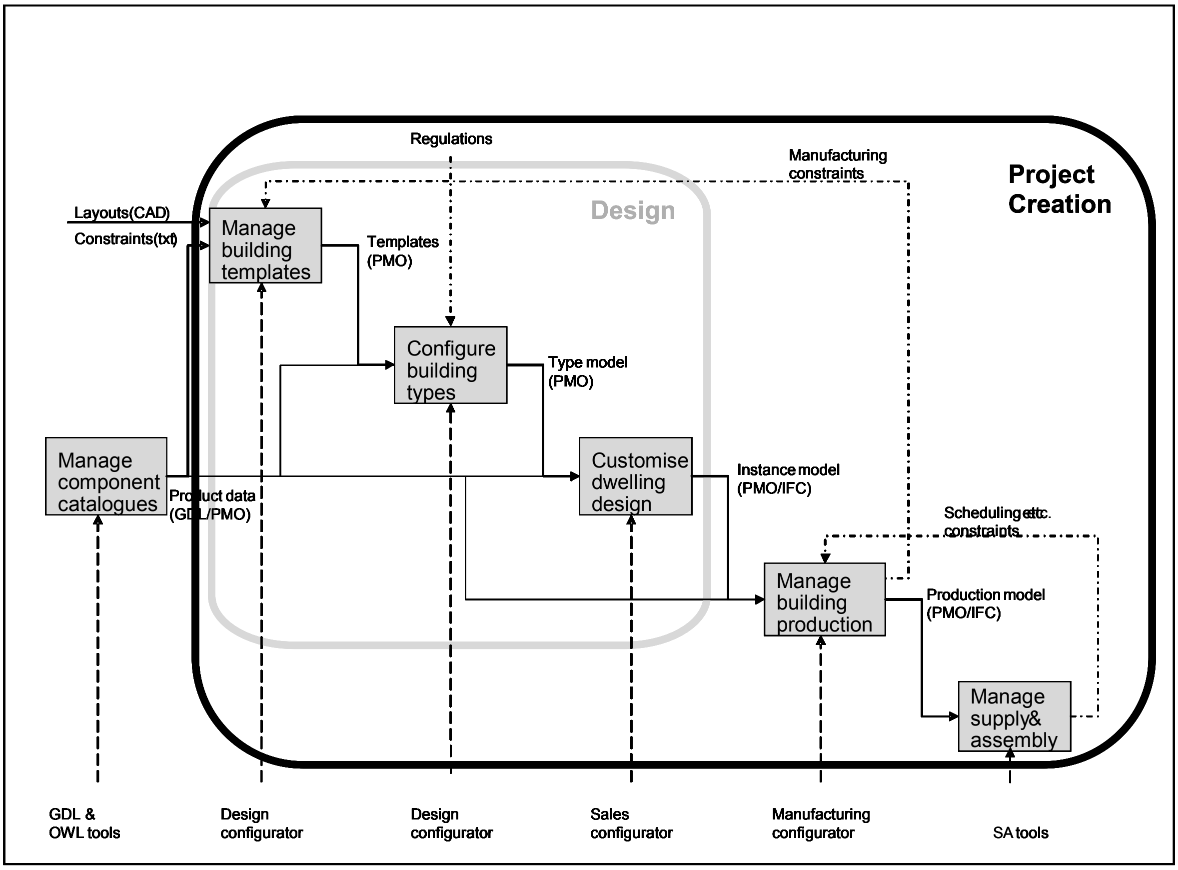

Figure 1: *Processes supported by ICT tools.*

The diagram shows the identified processes to be supported by ICT tools for the template generation and building project creation. The ICT tools that are integrated in the platform that are in charge of each process are also shown: GDL&OWL tools, design configurator, sales configurator, manufacturing configurator and logistic and assembly planning tools. These processes are broken down into activities in the ManuBuild process maps.

OPEN MANUBUILD SYSTEM PLATFORM

OMSP concept

The Open ManuBuild System Platform (OMSP) is defined to support the Information Communications Technologies (ICT) tools and services that are required to support the following activities:

- Design for manufacture,
- Offsite manufacturing, and
- Logistics and assembly planning.

The OMSP is conceived as the integration of ICT tools that share a common data model and provide services that make it feasible to perform the general scenarios identified in the project. The OMSP identifies the required exchange requirements by tools, based on the analysis of the different data models of the tools developed in order to facilitate sharing and reuse of information.

The OMSP involves the use of open methods and tools to design and implement ICT architectures that are expandable in both capacity and features. Such a platform supports flexibility in the use of hardware and software. Future feature expansion of the platform would be easier as the industry steps towards open systems and the distinction between industry tools would be changed.

As an open system, the platform supports and facilitate an integrated, streamlined construction process and collaborative business models. The ideal is a construction process that is receptive to innovation with:

- All the various phases thoroughly integrated,
- Consistent and timely information to the construction site,
- Non-adversarial, partnering agreement among all stakeholders in the construction process, and
- Integrated ICT tools that link all capabilities across all phases of the process from conception to operation.

The OMSP enables free and/or commercial services to everyone involved within the construction processes customers, stakeholders, architects, suppliers, manufacturers, producers etc. by using the tools integrated in OMSP.

OMSP functionality

The OMSP functionality comes from the integration of the various ICT tools and services. The platform enables the ICT tools and BIM applications to effectively share information and enable other new applications to successfully share and use the IFC, PMO, and XML information that the OMSP data model is built upon. The OMSP provides the means to enable such tools to effectively communicate with each other. The OMSP enables software tools or users to interact and share with the information that is needed to enable design, manufacturing and logistics and assembly planning

The OMSP can be considered as the integration of the ICT tools that share common data and provide services that make feasible to perform the building creation scenarios.

The next figure shows OMSP functionality schema from integration of tools and services.

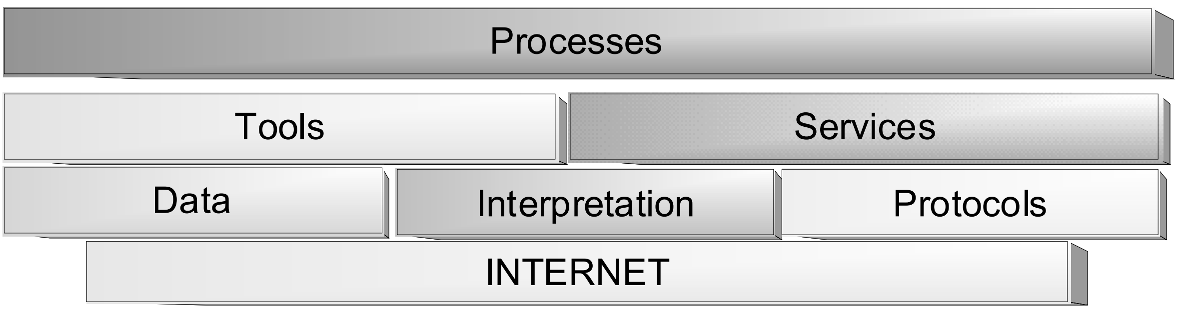

Figure 2: *OMSP.Tools and services integration.*

OMSP COMMON DATA MODEL

The Open ManuBuild System Platform (OMSP) provides the common data model to support the tools interacting. It is not a sharing of individual files but a common understanding of the meaning of the information in a file must be agreed and documented to capture the Exchange Requirements between that various processes. The information is defined using the Information Delivery Manual (IDM), which has been developed by BuildingSMART and will be published as an ISO international standard.

By having a common understanding of the information it enables the various ICT tools and BIM applications to effectively share information and enable other new applications to successfully share and use the Product Modelling Ontology (PMO) information that the OMSP is built upon. Therefore, it is a specification that will enable ICT tools to communicate to enable the ManuBuild System to be supported.

A general process map has been designed to describe the flow of activities within ManuBuild business process. It defines the sequence and the actors in the process, as well as references to the information that is required to be exchanged and/or shared by the various ICT components within the OMSP (and actors) that are described through Exchange Requirements (ER) that define the common data model. The information is shared through the Catalogue Server, which is an information platform that provides services to other tools.

The overall integrated process in Manubuild is a complex process that is decomposed in several sub-processes. Most of the activities are supported by the ICT tools developed in the project, while others not. Activities related with finance and tender processes are performed in parallel with all the process but are not treated by ManuBuild ICT tools.

The supported activities are the following ones in the housing development:

- Strategic design
- Design
- Manufacturing
- Assembly

The next figure shows the process map diagram for building model creation sub-process from a high level perspective. This process is performed in the design phase and it is previous to the sales process. Exchange Requirements for generic building template and basic building model are defined for sharing information.

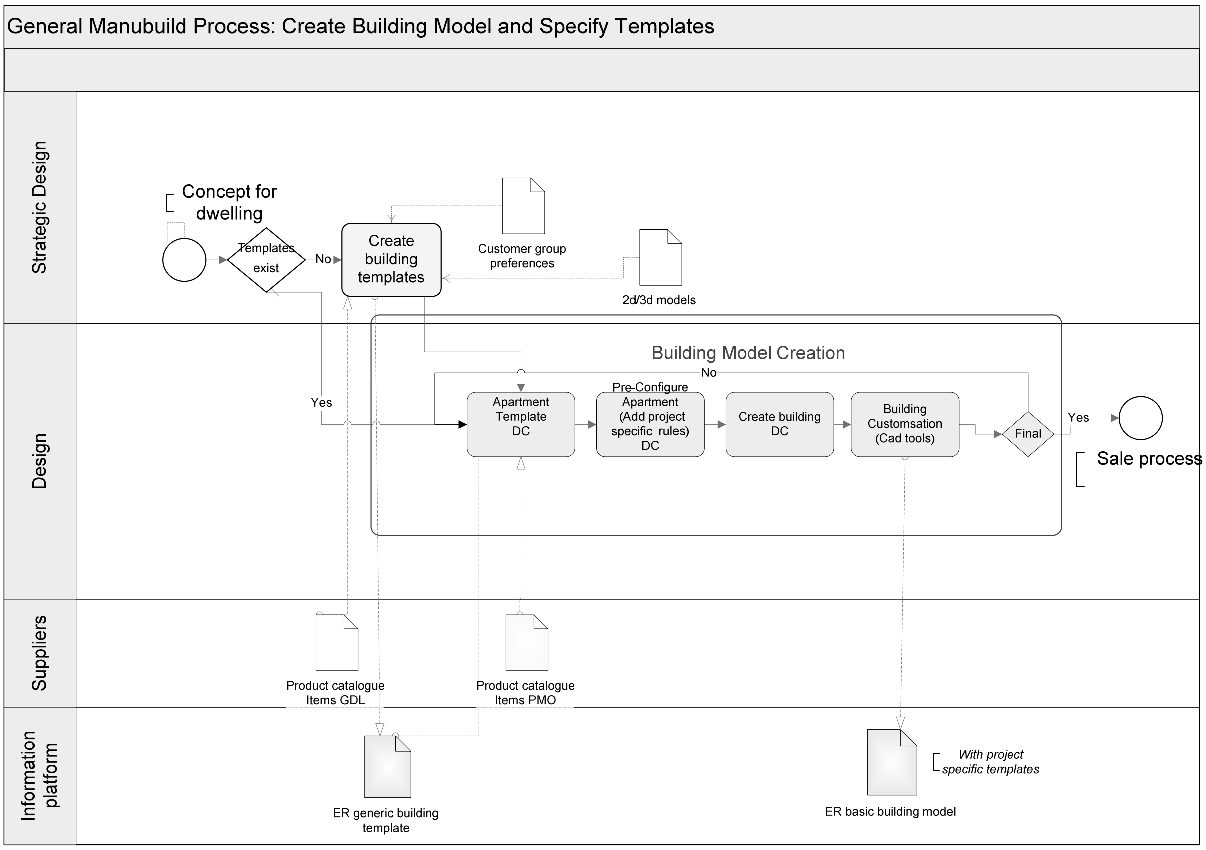

Figure 3: *Process map: Building model creation.*

CONCLUSIONS

OMSP- Open Manubuild System Platform has been designed to support all the generic construction process, including different roles and phases. The OMSP- is conceived as the support and integration of the Information and Communications Technologies (ICT) tools and services that are required to support activities for open building manufacturing: design for manufacturing, offsite manufacturing and logistics and assembly planning.

ICT tools in OMSP share a common data model and provide services that make it feasible to perform the identified generic scenarios. The common data model has been defined based on the analysis of a general scenario for information requirements and the actual data models of integrated ICT tools, in order to facilitate sharing and reuse of information to facilitate open manufacturing.

The common data model has been defined based on the analysis of a general scenario for information requirements and the actual data models of integrated ICT tools, in order to facilitate sharing and reuse of information to facilitate open manufacturing. The OMSP defines the exchange requirements that support the seamless access to all the ICT tools and services that have been developed:

- Intelligent Catalogues
- Design, Sales and Manufacturing configurators
- Logistics Management and Assembly Planning

OMSP involves the use of open methods and tools to design and implement an ICT System Architectures that is expandable in both capacity and features The platform paves the way for an open system for the construction industry open, modular, holistic, pluggable and expandable as the industry steps towards open systems and the nature of competition and distinction between industry tools would be changed.

ACKNOWLEDGEMENTS

We would like to express our sincere thanks to Manubuild team. The development of the Open Manubuild System Platform has been performed as a result of collaboration with partners involved in all workpackages in the project.

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OPEN BUILDING FOR A KALEIDOSCOPE OF CARE: A NEW CONCEPTUAL APPROACH TO OPEN SCENARIO PLANNING

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ABSTRACT

Open scenario planning, in a market such as healthcare infrastructure where change at every scale is inevitable, provides a significant opportunity. Healthcare, which comprises a complex mix of people, technology, buildings and other forms of infrastructure, is facing huge pressures. As such healthcare trusts are looking to make better use of resources; decrease carbon emissions; and re-think how they can act in a more sustainable and integrated way. Within the UK National Health Service, “taking care closer to home” and “saving carbon, improving health” are two of a number of Department of Health (DH) initiatives to improve healthcare and respond to the need for sustainable, accessible, efficient and effective services. Furthermore these are also the drivers for integration between health, social care, local authority, independent and third sector providers which is creating blurring between spatial scales and roles. Against this backdrop it is not surprising that the effective life span of buildings is continuing to shorten, which is significant in a sector that has infrastructure that is one of the most expensive to operate, maintain and replace. As such the notion of “change ready” is key. This paper through a state-of-the-art literature review introduces and explores the potential and conceptual linkage between infrastructure, capacity and scalability within open building and planning extending (Astley, 2009; Kendall, 2009). The authors’ collaborative and action research has contributed to the development of a new approach and this research has identified the need for a flexible, dynamic and scenario based approach to planning that goes beyond estates strategy and beyond master planning and which precedes open building. The diversity of care pathways across a changing healthcare planning environments is demonstrated using a case study review, which raises the importance of a hierarchy of decision making, principles and process within an open planning approach. This paper further provides a review of existing business case development processes and capacity planning tools that are prevalent in healthcare strategic planning and operations management, but not so in adaptability research. Scalability as a concept that can bridge the healthcare and estates infrastructure domains is also introduced.

Keywords: Care Model, Health, Open, Planning, Scenario,.

INTRODUCTION

Adaptability for growth and change in healthcare design of the twentieth century has a long history; specifically in the organisation of functional relationships between hospital departments and principles of standardised space. However, an Open Scenario Planning (OPS) approach is being proposed to respond to new thinking in service delivery and for a flexible, optimised, use of facilities in healthcare and across the spectrum of care (Astley, 2009). All too often schemes can gain momentum and develop, be designed or constructed at scales that are outmoded and inappropriate, when judged against existing healthcare demand, innovation and distribution. The authors are working to devise a more strategic and integrated approach to OPS, addressing the need for better description of scales, typologies and 'rules of thumb' for an estates response that fits with a health Trust's business objective and inform strategic board decision making and aids the development of integrated and sustainable healthcare solutions that appropriately distribute expertise and technology to deliver the highest quality care.

This principle of organising healthcare services for large areas according to distance, scale and level of specialism is an issue that has not been discussed in open building, however it has been described as part of office developments. Nor has the need for integrating care service, estates and transport infrastructure expertise into the planning process to ensure the delivery of sustainable, accessible and world class healthcare services been given enough of a priority. As such, this paper argues that open building (that relates to the spatial and technical building), must be proceeded with strategic, open, dynamic and scenario based organisational and programme discussions about business functioning, location and distribution that will inform project level "base build" specifications and design briefing. It also highlights the need to consider open-building stakeholder decision-making levels and processes in more sector and organisation specific terms. Traditionally within the healthcare sector, the focus on adaptability and flexibility has been on technical building qualities and procurement, rather than on the integration of stakeholder infrastructure perspectives to deliver an optimum whole system solution. This work starts to outline this need and the shape of the authors' ongoing work based on the following existing flexibility and healthcare concepts:

- **Open Building**. An emerging and ongoing dynamic and systematic approach to organising decision making and construction that technically and spatially separates building levels. Designing open buildings is the creation of a loose fit relationship between the base architecture and its changing fit-out according to Kendall (2007); in a way that supports stability, change and constant environmental transformation (Kendall, 2009).
- **Care Model**. A care model is an evidence-based, safe and efficient procedure made up of care elements, pathways and protocols that structure a patient journey (DH, 2010). As such it defines the scale, distribution and quality of the infrastructure that supports integrated health and social care and defines workforce roles, technologies, IT, finance, information and estates (DH, 2010).
- **Capacity**. Is a whole system healthcare planning approach that involves regulators, commissioners and providers coming to an agreement on how resources should be distributed and capital invested in expensive equipment and built infrastructure (in terms of bed numbers, floor area or a service specification).

In addition to these concepts, this paper aims to raise the importance of the following concepts alongside open building in a healthcare context:

- **Healthcare Infrastructure**. The basic, physical underlying structure of productive healthcare operations. It is a high cost investment or asset that supports and sustains functioning at various scales in order that they can be effective and efficient.

Infrastructure coincides with regulator, commissioner and provider organisations/partners that have systems of care, estates, transport, technology and staff.

- **Open Infrastructure**. Building planning and design is nested within a broader system of infrastructure. Taking health as an example this system integrates technologies, workforce and transport systems that can all have a significant impact on the changing roles and functions of buildings.
- **Open Scenario Planning**. A dynamic multi-stakeholder and multi-level planning approach to integrating care, estates and transport infrastructure systems through a robust process of gathering data, modelling and value review. This approach defines and integrates systems and scales to achieve flexible, scaleable, efficient and productive healthcare infrastructure.
- **Scalability**. Is a desirable property of a infrastructure system, a network or process whereby infrastructure can be adapted by adding resources and growing or shrinking capacity while concurrently improving quality and performance

Figure 1. combines these concepts and demonstrates the focus of this paper on developing an integrated approach to open infrastructure planning which the authors have termed (Open Scenario Planning or OSP) that aligns with the existing healthcare business case development process. Further it demonstrates the need for Open Building to emerge out of a broader planning framework than the present state-of-the-art would suggest. Figure 1. further positions three of the concepts of OSP, two of which this paper explores. These include the importance of gathering baseline capacity and modelling various scenarios to understand infrastructure scalability and to evaluate value from various stakeholder perspectives and against different value criteria. The later is a subject that is discussed by the authors in other publications.

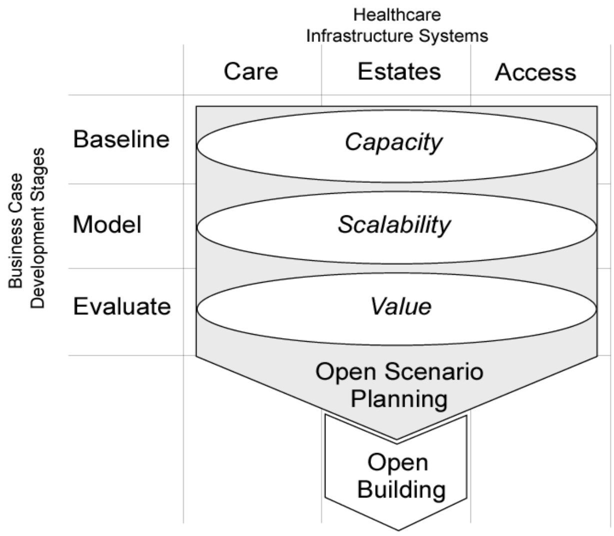

Figure 1. *Open Scenario Planning Framework*

THE NHS KALEIDOSCOPE OF CARE

This section describes the dynamic nature of healthcare planning and design and the problem that "open building" must address. It also identifies the need for a new approach to open scenario planning and raises the importance of scalability as an importance adaptability strategy. The phrase Kaleidoscope of care was first coined by Kember and Macpherson (1994) to explain the shifting structure, movement of funding, changing market and re-organisation that has contributed to: changes in the NHS from centralised to de-centralised and back; and the need for increased infrastructure adaptability and evidence to address the impacts of policy, technology, economy and environment on healthcare outcomes.

Regional care systems all over the country have been affected by changes in population, demographics, healthcare needs, politics (national and local), public and clinical pressure and the development of medical science, education, diagnostics and disease treatment and management. The increasing ability of doctors to treat illnesses has increased the demand for and capacity of services and led to an escalation in whole system cost. The development of specialisation has led to scales of advanced treatment and care delivered at various scales from treatment centres to hospital departments – while technologies distributed these into community scales. According to Rivett (1986) advances in bacteriology, biochemistry, physiology and radiology created the need for laboratory accommodation and service departments, so that hospitals no longer consisted merely of an operating theatre and a series of wards. Furthermore, "sub-specialisation ultimately meant that services had to be organised on a regional basis and the reputation of clinicians determined demand". A situation that still persist today. Thinking about the systematic organisation and optimisation of care for a given population at a regional or district scale, has a long history. Dawson (1969) suggested a hierarchical system for planning with simple and complex scales that would require new patterns of medical administration, to ensure "unity of purpose at all levels". According to Rivett (1986) organising hospital services on a district basis should be accredited to Dawson, who identified the importance of planning against a population need – an issue that has not been strongly articulated in adaptable building literature today. What is needed is a framework that defines how capacity can meet demand (given the number of cases, speciality of treatment and size of the catchment population).

In recent years a number of DH policies and initiatives have strongly emphasised the need to shift healthcare towards local community settings, closer to patients' homes DH (2006); Darzi (2007) and Darzi (2008) and prioritises specific care pathways. In 2006, a series of 30 demonstration sites were selected in six specialties: Dermatology, Ear Nose and Throat (ENT), General Surgery, Gynaecology, Orthopaedics and Urology (Leese, Michele Bohan et al. 2007). Care models for these six are being further explored in the UK (DH 2010). Table 1. shows the diversity in location of care across exemplar trusts for these six speciality areas. The implications of this is that open building must accommodate these changing service locations and scales if they are to optimise flexibility, adaptability and capacity.

	Dermatology	ENT	General Surgery	Gynaecology	Orthopaedics	Urology
Specialist		Ipswich, Epsom	Newcastle, Hartlepool	Camden	Middlesbrough	
Community	Middlesbroug, Camden, Leeds	Bradford, Cornwell, Rotherham	Leicestershire	Manchester, Newcastle, Norwich	Oldham, Southampton	Essex, Bradford, Edgware
Health and Social	Hull and East Yorkshire, Leicestershire		Cornwell		Kingston	
Home		Ipswich	Newcastle, Winchester, Hartlepool			Nottingham, Newcastle

***Table 1**. Diversity of Care Pathway Locations Across 30 NHS Demonstration Site*

LITERATURE ON OPEN BUILDING AND ADAPTABILITY

Kendall (2007) positions open building as a new emerging research area within healthcare construction and identifies the need in this field for new theory that goes beyond technical building methods. The central premise of Kendall (2007) is the need for a loose-fit relationship between the base architecture and its changing fit-out, which he demonstrates using a three tier system and design team separation as an approach. Further Kendall (2007) defines the need for scenario planning at a building scale. However does not highlight the need for scenario planning at a higher fabric or infrastructure scale. Cuperus(2001) identified the conceptual relationship between open building and lean construction which are both to deliver value and reduce waste. Cuperus(2001) further defines a number of levels of decision making and urban scales. However has not taken a sector specific view of how infrastructures are shaped by organisations. This paper introduces infrastructure open scenario planning and scalability as important concepts alongside open building.

Chefurka and Nesdoly(2009) describes the need for the consideration of hospital flexibility throughout planning, design, construction and post-occupancy phases. Within these Chefurka and Nesdoly (2009) highlight strategic planning, master planning and functional programming amongst others. Within this framework, functional programming (which includes equipment choices, service consolidation, standardisation and modularisation) is similar to traditional views of flexibility. Whilst master planning, which includes for Chefurka and Nesdoly (2009) the planning horizon, building and site size and type and service growth and change is most closely related to the approach presented in this paper. However as Astley (2009) discusses there is a need to go beyond this to develop new integrated infrastructure scenario planning approaches and tools that go beyond traditional prescriptive master planning and which generates a plan that ‘plugs’ into existing infrastructure at appropriate levels and allows any future building ‘module’ to be tested for a range of options and a prioritised range of different scenarios of use. A technique to facilitate a dynamic business model (Astley, 2009).

Within the adaptability literature, the term scalability includes extendable, expandable, upgradeable, elasticity, redundancy and shrinkable according to Schmidt, Eguchi; et al. (2009). Of the authors they cite, Blakstad (2001) has perhaps the most relevancy to this work. Blakstad(2001) takes a strategic approach to adaptability looking at the user and building interface and identifies "extendibility" along side "partitionable" and "multi-functional". Further the importance of value in relation to future adaptation versus the cost of adaptation is also raised. Related to scalability is the concept of capacity which is not prominent within the adaptability literature, which is particularly significant in the healthcare field. Capacity within open building relates to the measure of quality in the base build to accommodate a range of variations in floor plan and use within the constraints of the given base build, or the degree of freedom provided by a higher or lower level of system separation. This definition of capacity is expanded within this article to include the discussion of regional or whole-system capacity, outside of that defined by a building and across infrastructure.

METHOD

This paper is a part of ongoing research into healthcare open scenario planning, strategic asset management and master planning. These areas were highlight as significantly important by healthcare sector practitioners during three initial steering group workshops with industry as part of the Health and Care Research and Innovation Centre (HaCIRIC) EPSRC funding programme. The first was a DH Estates and Facilities strategic direction meeting (n=12), where “n” is the number of participants, and the second and third were peer review processes (n=15) and (n=9), that included representatives from industry a policy think tank and academia. Once the direction for the work was established a collaborative initiative and programme of workshops was delivered that included the Department of Health, The Prince’s Foundation, HaCIRIC, MARU and HUDU. This paper draws on multi-stakeholder decision making process and tool reviews that were completed as part of this work and a series of five workshops with an expert sample of DH, NHS and other institutional and academic representatives. Attendance at workshops varied between (n=5) and (n=20). These workshops led to the development of a new approach to Planning Healthcare Infrastructure that aimed to integrate care, estates and transport planning through a process of gathering baseline data, modeling scenarios and reviewing the value of proposals. This method has subsequently been tested in two live case studies and compared to observations carried out in a third, however this work is not described here. This paper combines these applied research and development workshops with a broad and shallow literature review of open building, adaptability and healthcare service and capacity planning. However, a deeper and more detailed literature review is required to rigorously confirm the findings and gaps in the literature and theory of open building.

THE EXISTING HEALTHCARE PLANNING PROCESS

If OSP and Open Building are to be successful within the healthcare sector it must be understood alongside existing infrastructure business case development and change and innovation processes. These processes have been mapped in Table 2. against the planning healthcare infrastructure process (top line) developed by the authors (and also shown in Figure 1).

<table>
<tr><td colspan="4">Baseline Case for Change</td><td colspan="4">Model Scenarios</td><td colspan="2">Review Proposals</td><td>(PHI 2009)</td></tr>
<tr><td colspan="2">Priorities Need</td><td colspan="2">Plan</td><td colspan="2">Review Current State</td><td colspan="2">Design Future State</td><td>Implement Service Change</td><td>Transition and Monitor</td><td>(DH 2009)</td></tr>
<tr><td>Baseline Information</td><td colspan="2">Fitness for Purpose</td><td>Finan ce</td><td colspan="4"></td><td colspan="2"></td><td>(CHP CIAMS 2009)</td></tr>
<tr><td colspan="4">Strategic Context: Make A Case For Change</td><td colspan="4">Outline Business Case: identify (a range of scenario) Options</td><td colspan="2">Full Business Case: Assess and Plan the preferred Options in Detail</td><td>(NHS Executive 1994)</td></tr>
<tr><td colspan="4">Baseline</td><td>Query and Analysis</td><td colspan="2">Analytical Modelling</td><td>Forecast-ing</td><td colspan="2"></td><td>(HUDU 2006)</td></tr>
<tr><td colspan="4">Understand and Reframe</td><td colspan="4">Develop Concepts</td><td>Test and Learn</td><td>Design and Delivery</td><td>(NHSIII 2010)</td></tr>
</table>

Table 2: *NHS Infrastructure Business Case Development Processes*

Healthcare infrastructure planning is by nature a complex interaction of factors that determine the distribution of resources. These factors in the planning process are interrelated and interdependent and as such the delivery of an efficient and effective proposal is often dependent on an iterative and multi-stakeholder information and coordination decision making process that emerges at the correct level of generality. As such, the definition of demand and capacity is problematic and locality specific demographic need, divergent care pathways and different infrastructure (technologies, workforce and buildings) are difficult to account for in Open Building. What is more the power and influence of various healthcare regulator, commissioner, provider and customer stakeholders is unequal and changing during the business case planning and building design process (Mills, Price et al. 2009). In order to deal with this complexity, Trusts often employee external healthcare planners who can assume a responsibility for gathering baseline data and generating options. However, there are few fully integrated infrastructure planning approaches to do this. Some will employ both estates healthcare planners and care service planners; however, few Trusts will employ transport specialists, rather hoping that local authorities will assume these roles. As such, approaches and starting points to healthcare planning vary hugely as well as the level of specialist and technical detail used to address the infrastructure planning process. Thus, what is needed for all healthcare planners and decision makers is a common multi-disciplinary workshop driven by common integrating principles.

THE EXISTING HEALTHCARE CAPACITY PLANNING TOOLS

Capacity planning is well understood as a crucial component of health care governance that is used by most countries. It often involves central, regional and legal authorities, with tiered responsibility and approval mechanisms. The outcome of capacity planning is often a capital investment strategy that identifies expensive equipment, number of developments, bed capacity and a service specification (Ettelt, Nolte; et al. 2008). However how these broad capacity figures are translated into building design is less well understood, not alone used to plan or design for adaptability. This paper raises the importance of developing methods and tools that link capacity and strategic open scenario planning. What is needed is a more integrated approach with estates planning actively informing new service re-design, rather than what often happens which is responsive and retrospective fitting service capacity into existing and new buildings, with staff having to make do, rather than customising infrastructure systems to be truly fit for purpose. Capacity planning is used to determine the demand of services along with the required capital investment planning (for healthcare facilities and technologies) and adequate staffing requirements. However this is often a complex and dynamic process where site specific characteristics such as patient management profiles, structural, political, geographical and organisational environments can play a large role (Nguyen, Six et al. 2005). Capacity Planning consists of: modelling the demand for services along with changing care pathways, modelling the available capacity, identifying appropriate settings for healthcare delivery, determining activities and the sourcing requirements along with the affordability of the services (Green, 2004; Huddy and Jon, 2002; Nguyen, Six et al. 2005; Nguyen, Six et al. 2007; Exadaktylos et al. 2008a; Exadaktylos et al 2008b). Table 3. describes some of the existing care, estates and access infrastructure capacity planning tools and where they are applied in the business case development process defined by the authors (as in Figure 1. and Table 2.).

Table 3. *Healthcare Capacity Planning Approaches*

	Structural Infrastructure Content			**Business Case Development Stage**			**Method Description**
Tool	A Care	B Estates	C Trans	1 Base Data	2 Model	3 Review	
HUDU Model	1			1		1	A web based benchmarking tool to aid planning. It presents predicted bed and area capacity against future housing, population and demographic needs that allow for comparison between Trusts on healthcare demand.
SHAPE	1	1	1	1			Web based benchmarking tool that combines cost, hospital episode/activity, ERIC, Estates KPIs, demographics, prevalence and GIS time travel data. This tool does not include any definition of bed, room or building capacity.
Dr Foster	1		1	1		1	Web based benchmarking tool that contains clinical data. It provides data on avoidable admissions and provides benchmark data on local demographics, health needs, prevalence and geographical referrals.
Systems Dynamics (e.g. Simul8)	1	1	1		1		A non-sector specific software that aids in the design of care pathways and is used to demonstrate capacity, bottle necks and schedule resources.
Scenario Generator	1			1	1		A web based and care pathway design tool that is supported by clinical activity data. It aids demand and capacity planning through the demonstration of changing population, prevalence, flow, delays and waits across the whole care system
GIS			1		1		This approach is web based and a specialist programme. It can be used to spatially map population and healthcare distribution at various scales and demonstrate how capacity is responding to demand, accessibility and equitability parameters.
CIAMS		1		1			An approach and process to collecting benchmark data on trust estates quality, use, location, cost and its potential to meet existing and future demand.

Estates Capacity Planning		1		1			Site specific activity data or service specifications are translated into building departments, spaces or number of beds and costed. More advanced approaches translate this activity into utilisation targets and space use timetables.
EstatesCODE		1		1			An approach to establishing a buildings physical condition, functional suitability, quality and space utilisation. Its concentration is on establishing existing building use data, is not directly related to clinical specialist areas, nor does it take a future scenario based look at technological and clinical change.
Strategic Service Development Plan (SSDP)	1	1		1			A principle and business case document that sets out the link between health and social outcomes and infrastructure development. It aims to sit across the range of services and settings, however is often a service specification for a specific site. It sets out the expected 10 year demand for services based on demographic, technology and clinical changes. Prescriptive specification rather than scenario based.
Open Scenario Planning	1	1	1	1	1	1	A dynamic multi-stakeholder and multi-level planning approach to integrating care, estates and transport systems through a robust process of gathering data, modelling and value review. This approach defines and integrates systems and scales to achieve flexible, scaleable, efficient and productive healthcare infrastructure.

Traditional estates capacity planning approaches see the translation of activity data (Hospital Episode Statistics HES in the NHS) into building departments, spaces or number of beds. More advanced approaches translate this activity into utilisation targets and room use timetables. However, estates capacity planning approaches are often only as good as the care activity models that support them. These types of approaches can cover up a number of assumptions about where and how diagnostic, treatment and rehabilitation is carried out in the building and the actual care pathway that patients take within and between buildings and rooms. Further estates planning tools may not allow on their own open planning – they must be integrated with other clinical and transport based approaches.

Table 3. shows that capacity planning tools often take a single perspective and do not incorporate all aspects of a structural infrastructure change (HUDU, Scenario Generator, CIAMS, EstatesCODE, and Estates Capacity Planning). Further that some approaches do not facilitate a broad strategic and open discussion of how data is modelled or evaluated, while others provide no data at all and rely on the experience and skills of practitioners. OSP aims to address this need for an approach that integrates all structural changes (starting with care model design) through a process of data capture, scenario development and review. Existing capacity planning tools have little definition of scale and as such often measure capacity within a healthcare sub-system, without reference to what impact a capacity change will have on another part of that same system. This work raises the importance of defining change scenarios that are supported by data and can be evaluated from the perspective of the whole system, so that broader impacts can be understood. Further, existing capacity planning approaches can sometimes require disproportionate input of resources for the clinical benefits received. From a care service redesign perspective there are wasted clinical visits for tests results not yet back, operation deferral, missed appointments, overlapping treatments, incorrect referral or inappropriate system entry and step down. From an estates perspective these will result in poor space utilisation and space redundancy, lack of sharing and space duplication. What is needed is a scenario based approach to planning that occurs before the building is commissioned or designed. This approach to

capacity planning will require a more radical look at the care system that will provide for a more strategic and regional approach to open and change ready infrastructure. In so doing these new capacity planning tools must be built around: 1) Prevention, 2) Supported self-care, 3) Lean pathways, 4) A choice of low carbon treatment alternatives, 5) A distributed care supply model to meet patient needs and demands, 6) Innovative technologies that support remote and distributed care, 7) Efficient and effective out-patient and day-case referral management and patient experience. Ensuring patients get access to the correct care first time is critical in ensuring quality, and 8) Efficient and effective step-up and step-down management and patient experience (Health and Sustainability Network and Climate and Health Council, 2010).

An interesting concept that is starting to emerge in the technology, IT and innovation diffusion domain is scalability. This is further explored here as a potential concept that both adaptability and healthcare planning academics and practitioners can support. Systems of healthcare infrastructure are never static, and as such scalability (as a measure of how a system can be changed) is an important factor. Scalability as a concept in building design is an issue that has not been researched, but it has fundamental implications for whole system demand and capacity planning. It is how an infrastructure or infrastructures (care, estates, transport), or a part of can handle growing or shrinking capacity, increasing or decreasing demand or can be readily enlarged or shrunk without impacting the performance or value of that system. It can refer to the capability of a system to increase total throughput under an increased pressure when resources are added or removed, but more specifically a scaleable system improves performance in line or proportionately with an increase in resources or capacity over the whole system. Further, if the performance or quality of a system is reduced or fails, then the improvement is not sufficiently scaleable. The term is also used in a commercial context when a company’s underlying business model offers the potential for economic growth. Its importance is that it could lead to: 1) Optimisation of capacity within and between layers of the system, against various resource scales and overhead minimisation, 2) Greater infrastructure utilisation (building, technology and staff), 3) Improved whole system capacity planning and increased resilience and adaptability, 4) Integration and less complication within and between scales, and 5) Fewer network complications, delays, expenses. However these scalability benefits require further testing.

DISCUSSION

The introduction and position of the terms infrastructure, capacity, scalability and open scenario planning has been discussed within this paper. Brand (1995) and Kendall (2007) detail the importance of scenario planning at the building scale, however scenario planning on a regional and neighbourhood fabric scale, across infrastructure is not addressed. Astley (2009) first discussed the use of a flexible scenario based approach, which is expanded by this paper. The introduction of OSP will be explored buy the authors so that changes in clinical care service or logistics, that have a direct impact on a buildings and business function, can be more clearly expressed within or alongside the theory of open building. This paper expands Cuperus (2001) and Kendall (2007) definitions of open building and decision making through its introduction of “infrastructure”, which might in open building be referred to as the ‘grain’. As such it is hoped that this work will broaden the defining system of open building from that of the building to a wider consideration of the urban fabric, workforce, technologies and other systems, networks and processes that make up a complex sector such as healthcare. This paper references the work of the authors in establishing a decision making framework and definition of nested scales that allow system separation across healthcare infrastructure. This paper and the future work of the authors will describe the critical concepts and approach taken in healthcare infrastructure planning.

The use of capacity as a term is limited to the building scale within existing approaches to open building, this paper has expanded the consideration of capacity across a whole healthcare system, and the importance of redefining approaches to capacity analysis in open infrastructure planning through national, regional, city, community and building scales. Future research by the authors will need to investigate the influence and freedom that such an approach will have on open building and open buildings impact back on the whole healthcare system (including care, estates and transport). There are a number of capacity planning tools (based on target ratios and scenario based predictive modelling and simulation) that need to be introduced and integrated with estates business case development and strategic decision making to evaluate complex health systems along with testing various care models. This paper has demonstrated this need through a desk based review that will require further validation with industry. The OSP approach is a marked difference to existing open building and capacity planning approaches and breaks away from estates strategy adherence to legislative and process procedures, technocracy and comprehensiveness, fixed land-use zoning, and land development control. The traditional design approach is manifest in rigid (master) plans, unresponsive to market drivers and expensive for Trusts in preparation and implementation (Astley, 2009). In short, current economic conditions of reduced capital spend, changes in commissioning patterns and insufficient analytical tools are require new techniques for Trusts and their partners to appraise both the legacy of their existing estate and explore options for their delivery of services in a different way. The OSP is starting to address the limitations of existing approaches by allowing stakeholders to facilitate a more integrated and flexible approach to planning that creates a map of uncertainty and a broad visible understanding of the driving forces for change to ensure that the strategic objectives of healthcare providers, commissioners and regulators are achieved.

CONCLUSIONS AND RECOMMENDATIONS

This paper has highlighted the importance of a number of new theoretical concepts in open building, specifically the importance of infrastructure open scenario planning and scalability. Furthermore, it has explored the linkages between these concepts and introduced opportunities for ongoing research to develop and test a new approach to OSP. It has opened up a new line of thinking in open and scalable capacity planning that may be looked at favourably by estates and service healthcare planners alike and proposes the need to develop more aligned scenario planning approach that can integrate healthcare planners from various different disciplines in health and social care system design.

The authors' collaborative and action research has identified the need for a flexible, dynamic and a scenario based approach to planning, which precedes open building. Further the diversity of care pathways across a changing healthcare planning environment is also demonstrated using a case study review. Further review will investigate new techniques that seek to inform flexible services and estates design. In addition further action and conceptual development research is needed to validate the claims made about existing capacity planning and business case development tools. However, the experience of the authors has demonstrated that existing estates planning approaches are unable to keep pace with shifting service patterns, organisational structure changes or health and social care re-configuration strategy development. The ultimate aim of the authors is to increase the life span of buildings and extend the notion of “future-proofing”, “change ready”, “open building” into healthcare planning.

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RESEARCH OF THE DESIGN OF FUTURE AGED-CARE LIVING HOUSE: SUITABLE TO CHINA

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ABSTRACT

With the economies’ high speed development, China is growing into an aged society. Most old people will choose living in their own homes rather than in aged-care facilities as old life style. At the same time although the first generation of the only child, result of the birth-control policy, have become to be parents, they still depend on their own parents. This dependency requires the houses suitable for the lives of two or even three generations. The requirement is strong, but the houses now in the market are exiguous. Therefore customers can only use the ordinary houses passively to adapt them to new lives. As a result, these houses have the same shortcomings as contrary of privacy and integration, lack of design for old people living and no space design for sustainable development. In view of the above, under the theory of open building, this paper presents designs as adding southing bedroom and bathroom, creating part integration and making the open housing styles which can be either comparted and combined, and pushes forward the development of the houses suitable for generations together.

Keywords: Aged-care living house, two-generation living together, open building.

INTRODUCTION

For years, the per-capita living space in Chinese cities has been grown gradually and the constitution of families is becoming nuclear obviously. Some young people are likely to live individually, but they are hard to dealing with some living problems when they leave their parents and make up a new family. Especially, when they have a child, they have more trouble in both taking care of the child and going to work. Then nuclear family is not their best choice. At the same time high-speed development of the Chinese economy has pushed the society becoming aged fastly. How the aged people can live better has become a social problem. If they live alone, they will feel lonely and often worry about that nobody can take care of them if they are ill. The model of two-generation living together just satisfies such requirement. The aim is that all the old and the young have their dependency in one home. Two-generation living together is that two nuclear families, as one is father and mother and the other is son (or daughter) and daughter-in-law (or son-in-law) and their child. The two families above have natural relations, are relatively independent and can take care of each other in life. On the market there have some houses whose style passively meet the requirement of two-generation living together, but there are some problems in convenience and flexibility. So the theory of open building provides a new approach to solve these. And also it can provide an approach to make a house suitable for one or two generations, sometimes even more, living together inside.

WHY THE OLD AND THE YOUNG LIVE TOGETHER

According to statistics data, houses meeting the demand of two-generation living together are highly required in the large cities in China. There are two reasons about this.

Aged People Like Spending Their Lives in Their Own Houses

In China now aging of population is greatly. For example, to 2025 the aged in Shanghai will reach nearly 4 millions, 28% of the cities' whole population. And, under the Chinese custom, most of the aged people will choose living in their own houses as the way of spending their lives. In order to take daily care of their parents and help them if necessary, most young couples need live with the old together or closely. On the other hand, the aged also tend to live with their sons or daughters, communicate with them easily and thus dissipate the loneliness in their retirement lives.

Problem of the Only Child's Living

In large cities in China it is popular that in a family young couples are all working. The members of most couples now are the only child under the policy of birth control carried out about 30 years' ago. For a lot of only child, they cannot break away the dependency on their parents even though they are married. Living with parents together can relieve their burden. And also, when they have their own child, their parents can help them take care of their child conveniently.

ANALYSIS OF PROBLEMS IN THE AGED-CARE LIVING HOUSE

Although the way of two-generation living together has its great demand in China now, the houses on the market developed to satisfy the demand above can not be seen anywhere. Most people have to, relying on existing house, live together passively. Actually, the houses suitable for the aged-care living must solve several problems:

Conflict between the Privacy and Harmony

As there are difference of age and experience, the two generations living together must have different living custom. If the communication of the two generations inside the house is too frequent, the differences are able to be sharpened and new contradiction will break out (Figure 1). On the other hand, in order to satisfy the two generations' lives and emotion necessary, fusion area inside the house is needed, in which the two generations can live harmoniously. The first problem to be solved is to change the space style of the houses now to make it either keep relatively privacy or provide the two generations fusion lives harmoniously.

Comfortable Design to the Aged

The old people have less social activities and stay in houses most time. So, their bedroom must face south to provide them health condition. Besides, the other rooms for the old people should also be different as at daylighting, ventilation and bathroom apparatus from ordinary houses. All these require special designs.

Space Design for Sustainable Development

Each family has its life cycle, just as everyone will experience birth, grow, becoming old and death. A changing family requires changing house. The houses now have stable constructions and are difficult to be divided again, which cannot meet the new space demand by the changing of the family. So, the open building for the aged-care living house must be flexible and sustainable during its whole life.

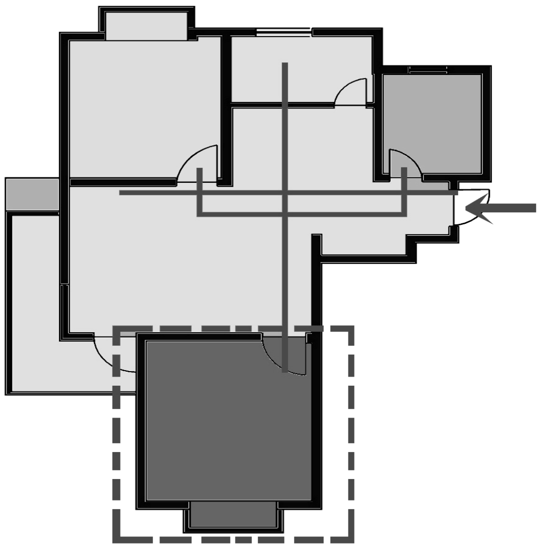

Figure 1: *Activity route is interchange frequently*

DESIGN STRATEGY OF THE AGED-CARE LIVING HOUSE

In the design of the aged-care living house, we can use the theory of open building to classify buildings into support and fillout. The different levels of support and fillout have disparity in useful life, so that the building can be sustainability.

In Support

To adapt flexible house design

In order to changing with the family cycle, the space design of the house should also be adjusted. The partition inside the house should be flexible and can be changed if necessary to re-locate the space resource. In this design the conditional design of shear wall is abandoned and replaced by frame construction, thus the space can be re-divided flexibly (Figure 2).

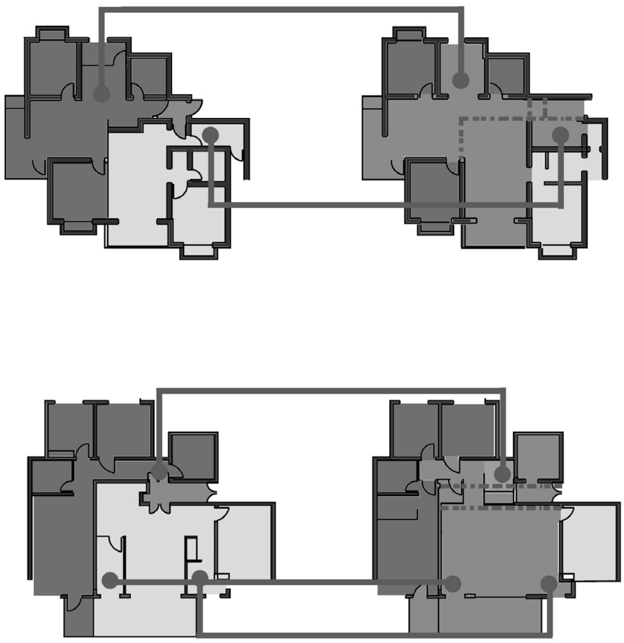

Figure2: *Flexible Style of the house*

To increase southing bedrooms and another supply for bathroom
An ordinary flat must have the below construction if it meet the demand of two-generation living together: it has two or above southing bedrooms and two or above bathrooms.

In fillout

To design new neighbour-style houses

For a long time there has no initiative design for two-generations living. The neighbour-style houses using now are all combined by two separate flats bought individually. These houses provide the two generations more privacy but less fusion space for communication harmoniously. Now, we can combine some space of the two houses, since the support has provide the possibility of the combination. For examples, we can combine the two vestibules of the houses (Figure 3), and also the sitting room and the dinner room (figure 4).

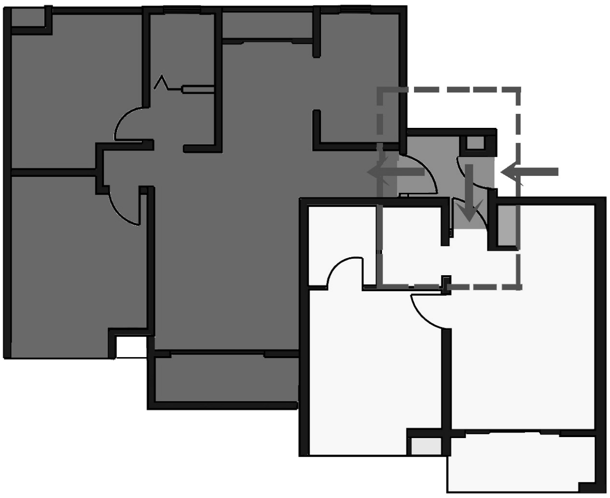

Figure 3: *Combination of the two vestibules*

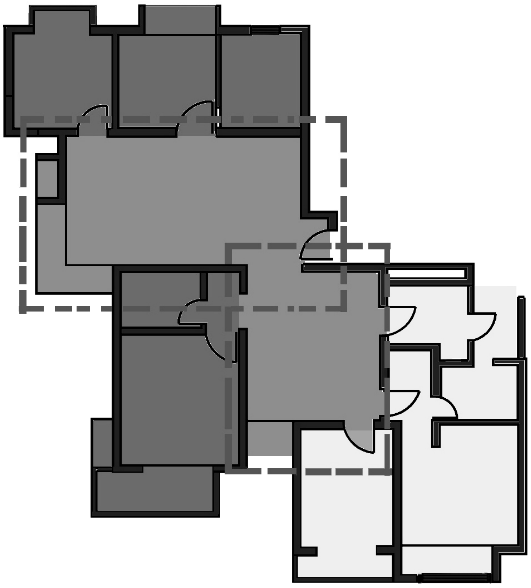

Figure 4: *Combination of one sitting room and the other dinner room*

To design flexible house

We can design flexible aged-care living house by moving the internal wall, changable furniture or other movable partition walls to make the house changing according to the number living inside (figure 5).

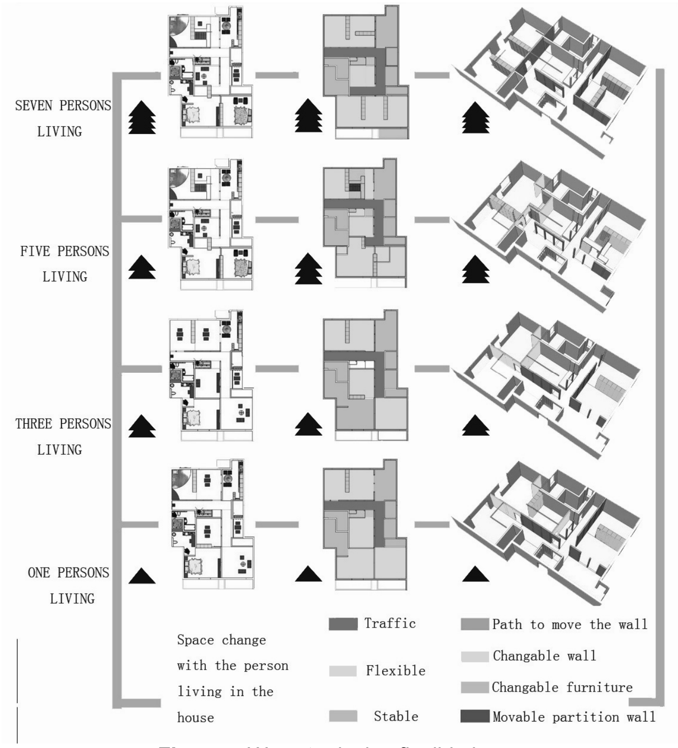

Figure5: *Ways to design flexible house*

ANALYSIS OF THE AGED-CARE LIVING HOUSHOUSE STYLE

Now, by using the theory of open building, we have several kind of style of aged-care living house:

Living in One House

This is the most popular way for the two generations living together. That is, the old couple and young couple live in a flat, which has two or three bedrooms, one living room and one or two bathrooms (Figure 6). This style has its advantages as that the two generations can have more common spaces and harmonizes with each other highly. Its disadvantage is the lack of privacy.

One house of two floors

The two generations live in such a flat (Picture 7). Although the difference of the time for work and rest is still there, the relatively separate space can provide a degree of privacy and the two generations can relatively keep up their own living ways.

Neighbors in one floor

That is, they are living in two flats. Commonly, the two generations choose two neighbour flats in the same floor (Picture 8). Its disadvantage is, due to they are separate flats, the two generations must pass the pubic space if they communicate, and the privacy is thus low.

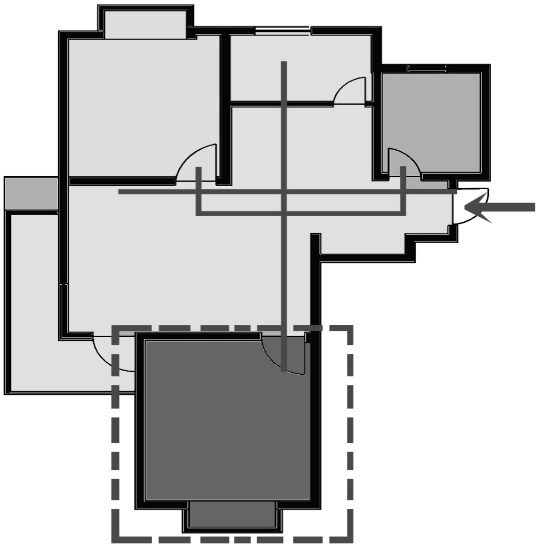

Figure6:*Style of one house*

Figure7: *Style of one house of two floor*

Neighbors in up and down floors

Similar to the style of one house of two floors. That is, choosing the two flats in up and down floors and rebuilding them, usually digging a door in the middle floor, as the two generations houses. It has higher privacy than style 2 and 3. Having no pertinence design, overlaying two separate flats together causes that life harmonies of the two generations is low.

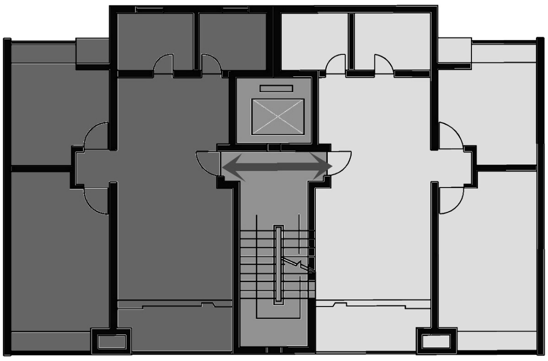

Figure 8: *Style of Neighbours in one floor*

Living in the same building

The two generation lives in different flats, which are in the same building but not next to each other. Compared with style 4, no acoustics disturb in this way and the privacy is high. Its disadvantage is that if communicate the two generations have to pass the out-flat public space and is much inconvenient, especially in winter the great temperature difference between room outside and inside will have much influence on the old and the child(kid of the young couple).

The same community, different buildings

This is a style which has highest privacy. The two generations live in different flats of different buildings, but in the same community. In this style the two generations have less daily communication except for having dinner together. Anyway, the distance is not far, the young family can take care of the old quickly if necessary.

CONCLUSION

Two-generation living together has great influence nowadays in China, which can make the aged spend their lives after retirement in their own houses smoothly and solve many living problems for the only-child couples. The design for the houses two-generation living together is just at the beginning and probing. With the acception of the concept of open architecture, the related polices will provide more beneficial aids to the use and promotion of the houses under the above design.

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ARMENTIA. APARTMENTS FOR ELDERLY PEOPLE IN A BUILDING DESIGNED AS A RETIREMENT HOME

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LKS. Mondragon Corporation

Derio, Spain

ABSTRACT

The building as a model for conceiving a project

The future of the construction industry will be a science of what to do with the built environment rather than the classical problem of what is needed to be built.

The necessary areas for living, working and entertainment are probably already built, but we need to update them to comply with the new codes, the new needs and the new uses of our society.

For this reason we are looking at new ways of addressing our profession:

- Firstly we have to decide whether a new way of living requires a new space or if there is already an existing space available.
- Secondly, we have to adapt the chosen space to the new requirements of society and the new codes and regulations.
- Thirdly, we have to think about the sustainable and energetic needs, in order to update the building to the new efficiency requirements in terms of energy.

Biomimicry

The traditional biomimicry analysis of building construction was to compare it to the nutrition and metabolic functions of a live being.

We want to add a vision of life cycle to a building in terms of changing and updating.

With this vision we are looking for "quality existing buildings" and for a way of designing "versatile frameworks" and layouts allowing for future renovation and refurbishments.

Therefore our research is two pronged:

1.- Identify the best examples of transformable buildings (such as the historic industrial multistory buildings or warehouses for textile, used nowadays for offices or "lofts"

2.- Looking for a design strategy that allows for easy changes of use.

Keywords: Adaptable, Building Energy Efficiency, Universal, Refurbishment, Life Cycle.

INTRODUCTION

In 1999 a building was constructed in Vitoria-Gasteiz for an elderly persons home but there was a problem with permissions and it could not be opened for that use. Ten years later a local fund for social means bought the building with the goal of using it as apartments for elderly people.

In order to obtain planning permission there were not only problems with dimensions and fire strategies which had not been taken into account in the original project but also the need to update the building in compliance with new building codes.

Furthermore, the project needed to implement energy efficiency and sustainable excellence.

There was an additional problem with the building since it was situated in an important place in the city, and could therefore be seen by almost everybody. The problem being that the aesthetic result of the building was probably not that which a citizen of Vitoria-Gasteiz would wish for.

The main objective has been to determine the type of intervention to implement: demolition of the building in order to construct another one or, on the contrary, reutilize it.

According to the analysis of alternatives, focused on functional, economical, and environmental aspects, an ecological readaptation of the building was considered the optimal solution.

The final refurbishment project had four axis for its design:

1.- Adaptation for the new use: instead of an elderly persons home controlled by the owner or developer of the business, a collection of apartments, also giving facilities to the elderly people but with more autonomy in their lives than those of a traditional retirement home.

2.- Compliance of the local and national codes for fire strategies, dimensioning and construction systems which have appeared in the fifteen year gap between the construction and the final development.

3.- Implementing the urban requirements for a proposal that was a problem in its first conceptions and which we aim to turn into a landmark of the city.

4.- Comply with the cost estimate presented by the developer.

Additionally the decision was made to seize the opportunity by:

1.- Analysing sustainabiliy criteria in buildings.:

The buildings consume large amounts of resources. The consumption of energy for services related to the buildings add up to an estimated one third of the EU energy consumption. Therefore an efficient utilisation of the buildings during their lifetime is necessary, which includes an extention of life cycle through rehabilitation, as a way of showing environmental responsibility and social sensitivity, and in that way contribute to achieving the fixed aims of reducing climate change.

2.- Analysing design criteria in buildings that are easily adaptable:

The building suffer permanent changes throughout their lifetime. An approach towards the project seen from the perspective of its life cycle and the building´s capacity of adapting to the change, is fundamental.

DESCRIPTION OF THE BUILDING

The building consists of one single volume with a dimension of 24,30m.x18,00m. developed in 5 levels including to basement, ground floor, first floor, second floor, and attic with a constructed total area of 2.125 m2.

Regarding the construction system the foundation was made of isolated and strip foundation with retaining walls, concrete structure made up of three parallel structural bays forming a 6,00x6,35 m. grid with a 5,75 m. wide, centered bayvoid that has the stairs located in its center. The facades are cavity walls with brick as the external finishing. The single gable roof has been built as a steel profile, supported by the concrete slab of the attic, in which composite panels with insulation and mixed tiles are resting. Internal partitions were made out of brick.

The focus of the contract was to work on a site in the city where a building was erected, which, although constructed within the last two decades, was obsolete.

> OBSOLESCENCE- The condition of being antiquated, old fashioned, or out of date, resulting when there is a change of the requirements or expectations regarding the shelter, comfort, profitability, or other dimension of performance that the building or building subsystem is expected to provide. Obsolescence may occur because of functional, economic, technical or social an cultural change (Iselin and Lemer, 1993)

In accordance with the definition of Nutt and Sears 1971, and Baum 1993, different forms of obsolescence exist, of which the following can be applied to the project as study objects:

- Aesthetic (or visual) obsolescence, resulting from outdated appearance.

The building is located in the city´s very important pedestrian axis, and with its strong urban appearance its aesthetics are questionable.

- Functional obsolescence, changes in occupiers' requirements.

The purpose of the building is modified from being a geriatric residence to supervised apartments for the elderly. The supervised apartments correspond to dwellings for elder people with a sufficient level of personal autonomy, being supervised by a private entity and assured conditions of attention and safety similar to those to be found in a nursing home. The aim is that the people who inhabit them remain in their habitual surroundings while keeping their autonomy, supporting its development whenever possible and avoiding the entry into a nursing home. With regard to the capacity of these apartments, 7 individuals and 11 doubles can be assumed.

- Legal obsolescence, resulting from the introduction of new standards. - Social obsolescence, resulting from increasing demands by occupiers, or by society in general, for better environments and improved facilities.

- Structural/physical obsolescence, resulting from technical deterioration that will make the facility increasingly inadequate.

In the initial analysis the options of demolishing or reutilizing the building were considered. The capacity for adaptation of the building with respect to the new purpose was evaluated and each of the alternatives was analyzed economically, not only from the economical point of view but also taking the environment into consideration.

Eventually an adaptative reutilization with a design adequate to the conditions of the building with great potential for serving as accommodation for the intended client. That way the building would enter a new life cycle.

REFLECTION: WHAT TO DO? REFURBISHMENT VS SUBSTITUTION: ANALISYS FOR RE-USE. ADVANTAGES COMPARED FROM THE SUSTAINABILITY PERSPECTIVE. ENERGY CONSUMPTION DURING CONSTRUCTION.

As indicated in the previous point, the first and most important decision which was faced was the option of demolition of the building or on the contrary the adaptative reutilization.

The analyses had to take into consideration the state of the building (remember that the building was built recently), its technical and functional quality, its capacity to adapt to the new program, and on the other hand the costs emerging from either of the actions, both economical and environmental. (fig. ‘1)

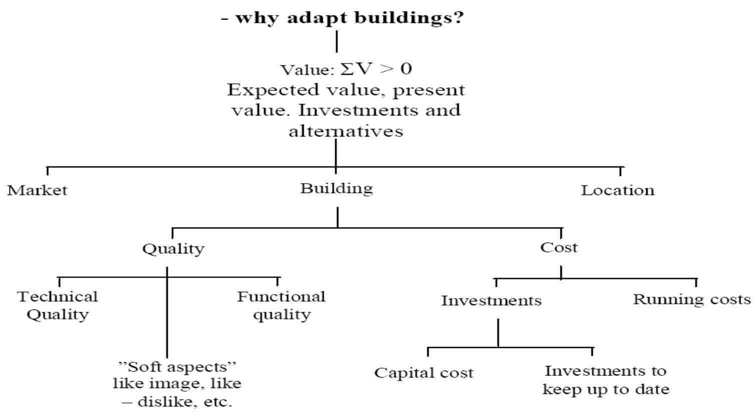


Fig. 1 *Hans de Jonge’s presentation at Workshop Voorburg.*

It was essential to consider a strategy which allowed us to determine if the building could have changes and adaptation. One alternative was to study the building as a complex system composed by different layers with different life expectancies and therefore, different timing for replacement of each one of these elements.

From a building system perspective, several examples can be found within the bibliography (fig. 2), with individual layers that can each represent a different adapting capability of the building.

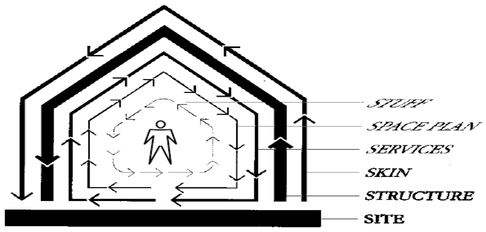


Fig. 2: *Siri Hunnes Blakstad 2001A strategic approach too adaptability based on Stewart Brand drawing*

Each layer has a different function, life-span, control, and distinct technical qualities. Therefore, the different layers form a hierarchical building system. “Open Building” theory, defined three layers: tissue, support, and infill, as described by the OBOM (Open Building Ontwikkelings Model) group in their presentation folder:

> “the concept of levels is the central idea of Open Building. Three levels of decision-making are distinguished, being tissue, support and infill. They are separated, yet co-ordinated.(…) The concept of levels can be explained by looking at the doorframe, the door and the doorknob. We can replace the door without affecting the doorframe, however it will replace the doorknob too. Three levels and their relationships can be distinguished. The doorframe is of a higher level than de door, because it is not affected by changing the door. The door is of a lower level than the doorframe, because if the doorframe is replaced, the door needs to be replaced too. The hinges represent the co-ordination between the levels of decision-making. This co-ordination problem can be simplified by looking at the hinges as an intermediate system between two levels”. Quote information folder, OBOM Group, Delft, the Netherlands, 1998.

Load bearing structure is usually the layer with the largest life span. It is complicated and expensive to alter, which results in a lack of changes or simple partial interventions within its life. Considering Worthington classification, structure has four elements which influence the building adaptability:

- Floor to floor height, which will influence affect the services layout and the building’s capability to house certain activities or uses.

- The shape and layout of the building affects its depth and how the different parts are linked together. This determines the way in which the building can be used and subdivided.

- Different floor depths allow for different space layout options. Floor depth will also have an impact on daylight and access to an external view.

- The building’s structural grid defines both the services layout and the internal partitions alternatives.

The external envelope, whose function is protecting from the weather, regulates temperature and the external (aesthetic) image of the building is a second layer, which determines its adaptability. It also defines the amount of daylight let into the building and alternative ventilation strategies. Nowadays, innovations within the external envelope are directly related to its importance for energy consumption of buildings. Therefore, there is a development from an aesthetic response to an energetic response.

Services are a third layer that includes several systems, with different characteristics and life-spans. The services which add adaptability to the building in a more significant manner are:

- Inlet (main entry)

- Main arteries

Both of them are more difficult to alter and will also have longer life-spans technically and functionally than inner services. As technology develops very quickly, new demands may require the entire system to be replaced. Buildings with highly integrated services within other layers may risk demolition because they are too difficult to adapt. The coordination of services with other construction elements is one of the main subjects in terms of improvement for the building's capability to accommodate change.

Finally, space plan (internal layout, walls, ceilings, floors, doors, etc) has the lowest influence in the adaptability.

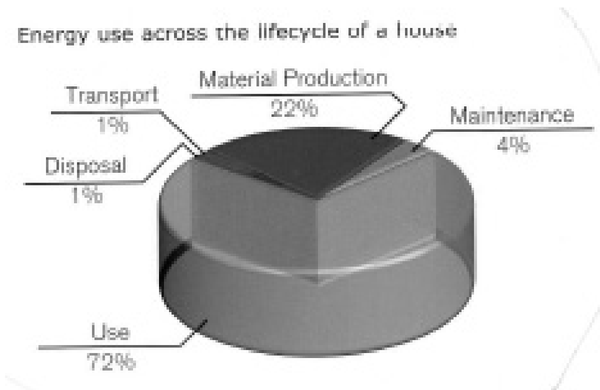
Looking at the different issues, in terms of the capability of adaptability of the building for new uses, different scenarios were taken into account, looking at the advantages to the brief established by the developer.

In every scenario, the existing building could adopt a similar use while maintaining the structure and part of the facade.

Therefore, the decision was to opt for the re-use of the existing building carrying out the necessary changes. The existing building was suitable for its new use it being a more valuable option than the alternative of substitution, at the same time at a lower cost.

So, in our design, the following layers were identified to be maintained with an increasing level of intervention: load bearing structure, external envelope, new openings, additional external insulated cladding (estimated to maintain at least 50% of the façade brickwork) and finally the urban services (inlet), the remaining elements were modified.

In reference to the environmental perspective, the energy used for production of construction materials is approximately 22% of the total energy consumed during the buildings life cycle, which makes it secondary to the utilization corresponding to 72%. (fig. 3)



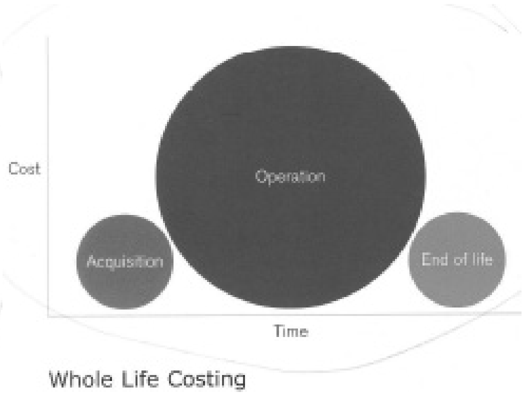


Fig. 3: *Mardaras et Cepeda 2004* *Cei-Bois 2006 Tackle climate change: use wood*

Furthermore, the energy cost of fabrication is directly proportional to durability: a durability twice as high reduces its annual incidence to half.

Therefore, with the alternative of reutilization we meet directly above the life cycle of the building when extending it. An action such as the demolition would increase the energy cost in an unsustainable way, as it would triple its incidence in the estimated life cycle of the original project (in case of assumption that it has had a purpose).

As we have said in the proposal of reutilization, we were planning to maintain the structure and at least 50% of the façade brickwork, as well as the urban services while modifying the other elements. This strategy would allow for a saving cost in relation to a new building (excluding the demolition of the existing building) of 40 % (structure), 0,5 x 20 % (brickwork), with a total of approximately 50 %. (fig. 4) Furthermore, the refurbishment would improve the efficiency of the original building as well as the compliment of the new more strict regulations.

Manufacturing cost proportions per budget chapter	
Structure	43%
Brick/blockwork	24%
Windows and doors	11%
others	22%

Fig. 4: *Mardaras et Cepeda 2004*

The energy cost for the fabrication of structure and the other element to be maintained are approximately 50 % of the total cost. The demolishment of the original building in order to erect a new one would mean the loss of half of the energy cost, excluding the energy cost during its life span. When the demolishment cost is added, the waste transport, and hopefully its recycling, the comparative advance from an environmental point of view, the need for re-utilization of the building becomes clear.

Manufacture/lifespan +use+demolition/ lifespan

50 % energy cost saving in the construction process represents 11 % of the total energy used during the building life span.

In other types of buildings, for example office blocks (fig. 5), where glazing has a larger repercussion, the embodied energy of the different elements alters noticeably the share between construction and use energy consumption (excluding structure).

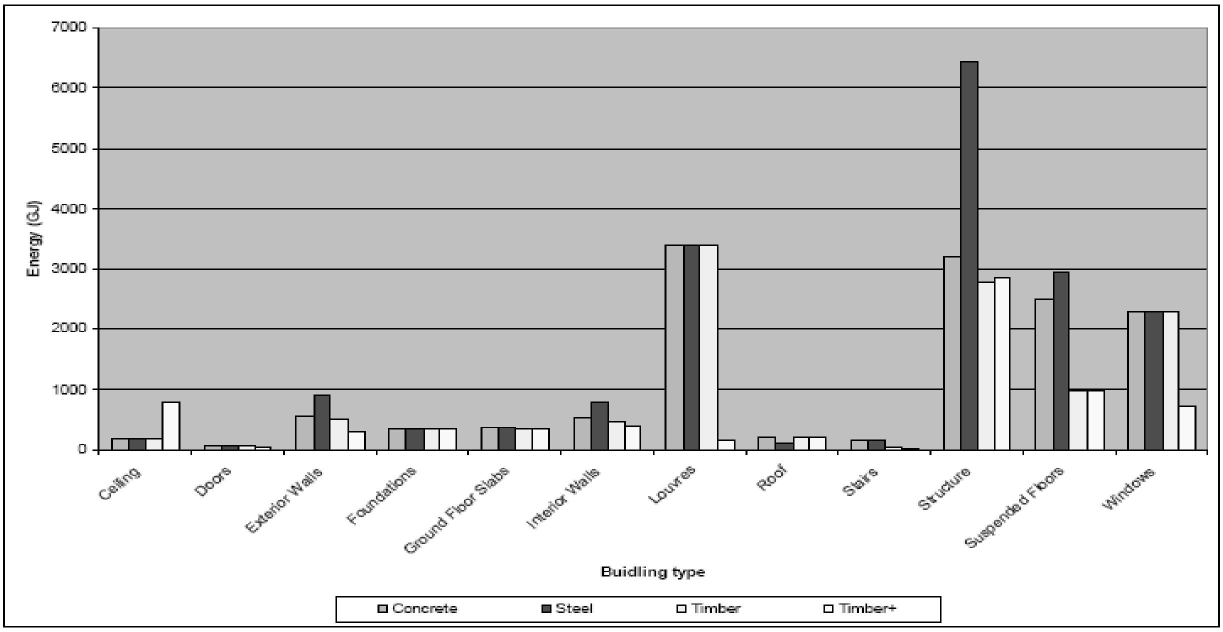


***Fig. 5:** Stephen John, Barbara Nebel, Nicolas Perez & Andy Buchanan 2009 Total embodied energy (GJ) for each building component, compared between building types. Environmental Impacts of Multi-Storey Buildings Using Different Construction Materials.*

Accordingly, re-utilization was a more sustainable approach than any type of new building.

WHAT WE DID/WHAT WAS DONE: ECOFRIENDLY DESIGN. ENERGY CONSUMPTION DURING BUILDING USE. FUTURE RE-USE.

The project includes an intervention on an existing building with a proposal for a change in use. Its original volume is not altered; however, the site layout is revisited in order to respond to planning regulations. The existing building will become housing for the elderly, with an underground level, three storey height and a further level above set back from the main façade. It is a dense volume (set within the limits of planning regulations) with an external space to the south east of the site for residents.

The main intervention evolves from the idea of a new elevation composition, which will integrate the different elements by setting three areas defined by use and location. There is aluminum solar shading on the North and South elevations outside the residential areas. These are set back from the façade, being supported by an exposed vertical structure. Communal areas are located within in a glass plinth. The upper element is cladded in a steel sheet, which works as a ventilated façade and as a roofing material, wrapping the volume and guarantying the layout and continuity of materials.

The clotheslines are protected with aluminum shading. Sideways these are protected with planar glass containing white butyral up to a height of 1,1 m, which will protect them from an external view.

Behind this shading, as well as on the east and west facade, the external material is a white resin mortar over an insulating system.

The opaque elements on ground floor have steel cladding as on the upper level, creating a dialogue between the two of them.

Internally, the existing elements are maintained, including the structure, staircase and lift location. The new apartments are arranged around the central staircase. Lighting and natural ventilation of the staircase are guaranteed by a skylight which complies with local regulations.

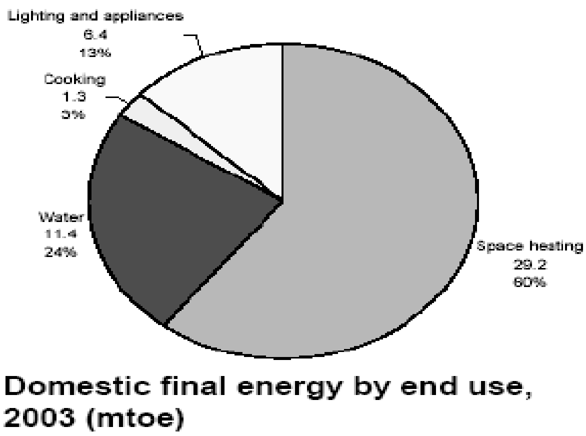
There is a parking area on the South facade (entrance) and another one on the North façade, which can be accessed through a ramp located to the West of the site. There is a landscaped area to the South east of the site for residents. The landscaped area has deciduous trees in order to provide shadow in the summer. There is also a concrete paved area where urban furniture is located.

The parking and walkways are paved in concrete. Opposite the South façade, there is a large enough pavement with deciduous trees for people to rest.

However, during the design process and in relation to its building life span, three priorities were established:

1.- Diminish the energy consumption during the building life span by using bioclimatic strategies (both active and passive) and by improving the efficiency of services.

In order to achieve this, energy consumption in buildings of similar use was analyzed. (fig. 6).



BUILDING	
Heating	70% thermal
cooling	
hot water	
lighting	30% electrical
electrical appliances	
communications	

IDAE 2009

Fig. 6: *Final energy consumption by end use in housing buildings*

As the graphic shows, the main consumption in this type of building is related to thermal services. It was therefore decided to respond to this issue in order to minimize demand.

The external envelope is essential in order to minimize the thermal impact. The insulation was enlarged by the addition of a new layer. In the ground and fourth floor, there is a ventilated façade, whereas the intermediate level has a continuous EPS insulation system. With this intervention, cold bridges disappear and the external envelope becomes more durable. U values were reduced by approximately 50 %.

There is an insulated superimposed roofing layer.

The external envelope, with passive means, has a triple function:

a.- To improve the hygrothermal behaviour with considerable energy savings during the use of the building.

b.- By improving construction elements, their life span increases.

c.- The composition of the building is adequate to its new use, location and current architectural language.

A list of the analised environmental issues studied is attached (fig. 7). It must have been said that some of them were finally implemented due to budget reasons.

Operation and maintenance
Passive strategies: reduction of U values below CTE standards, through increased insulation levels
South facing wintergardens with brise soleil for summer radiation
double glazed windows (Climalit) with additional low e layer on north facing glazing
facades and roofing: light coloured to encourage reflection
natural cross ventilation in certain areas of the housing
thermal blinds with interior insulation
aluminium window frames with thermal breaks
Active strategies: electr. Low energy lighting in common areas
electr. Lighting fitted with high frequency ballasts in common areas
electr. Lighting with motion detectors in common

Operation and maintenance
areas
electr. Independent lighting circuits in common areas and staircases
electr. Natural lighting at flat entrances by means of skylight.
electr. Exterior lighting powered by pvs
htg + dhw. Centralized heating and hot water system
htg + dhw. Gas condensing boilers
htg. Individual energy metering
htg. Independent flat thermostats
dhw. Pre heating using solar collectors
dhw. Thermostatic taps
dhw. Preinstalled bithermic electrical appliances
water management: rainwater harvesting and storage for irrigation reuse
low consumption taps
low consumption cisterns with double flush
atmospheric emissions:gas condensing boilers

Fig. 7: *Environmental issues studied*

2. The decision of adapting an existing building instead of constructing a new one and the passive solutions adopted such as an energy efficient external envelope, increases its durability, with its energy cost reducing drastically and therefore minimizing its percentage of energy consumption within its lifespan.

3. The use of strategies which encourage future changes to the building.

When a building is designed, the general approach is to establish a linear process, where the infrastructure is developed with private initiative up to demolition stage. On the way, different stages take place, including feasibility studies, concept and detail design, construction and use, each one of them with their own repercussions from a point of view regarding energetic cost. As mentioned earlier, the energetic cost in construction is 22 % of the total life cycle cost.

Lately, there has been a lot of attention given to the reuse of buildings as a way of keeping the built heritage. This has concluded in proposals for re-use, which results on a second life cycle for the building. Therefore, if the life cycle is considered (even a second life cycle) during the design process, and the possible changes within an uncertain future regarding use and a technology in constant development are taken into account, a adaptable design can be proposed, a circular model can be adopted. (fig. 8)

When it comes to designing a building, the importance of the adaptability of each one of its elements must be taken into account, in order to achieve a building that will allow for change and therefore increasing its life span in a substantial manner.

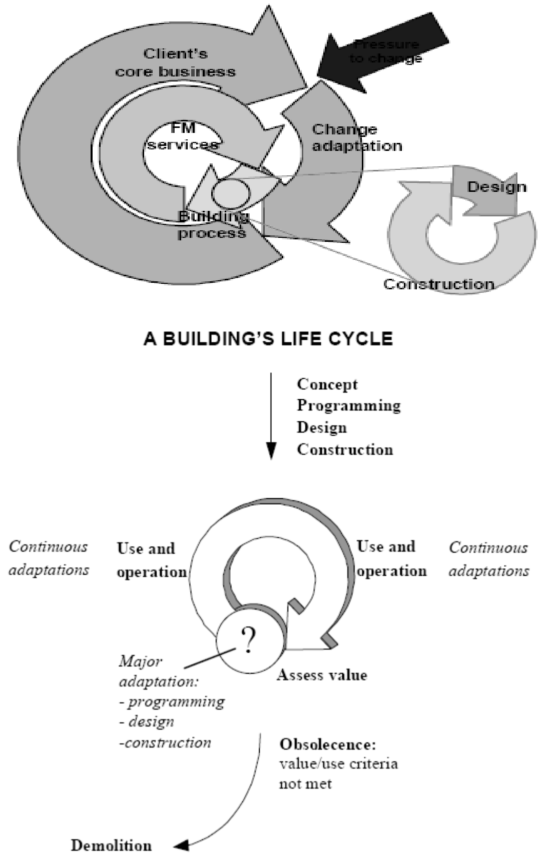


Fig. 8: *Kiviniemi 2000 Building research institute VTT Vera project*

Changes are not common in residential or similar uses, refurbishment or maintenance aside. However, research in office buildings has shown that the cost during its life span varies dramatically. The investment on easily replaceable elements is larger than on those which are a fundamental part of construction, such as structure. In a fifty year life span, the cost of changes within the building may raise up to three times the original price. This shows the developing changes in buildings. When the building adaptation capability can be guaranteed its life span will increase and the danger it will not become obsolete.

Finally, in terms of Flexibility/Adaptability we tend to think about designing flexible buildings, foreseeing future changes that often do not arrive. If flexibility is understood as a method of providing technical solutions (move, change or replace elements within the building envelope) it could be an inefficient approach. However, adaptability considers all these issues.

Therefore, the following characteristics could be described for each alternative (fig. 9).

Adaptability	Flexibility
Capacity to answer to unexpected changes	Possibility of chance within a limited set of alternatives
Approaches the problem form “the top”: Openness, possibilities and constrains	Approaches the problem from “the bottom”: Solutions
Creating manoeuvring room, space to change, both in the building and in the process	To move and adjust according to a predefined set of possibilities

Invest in generosity and robustness	Invest in systems – will they be used?
Usually low level of specification	Usually high level of specification

Fig. 9: *Siri Hunnes Blakstad 2001 A strategic approach too adaptability in office buildings*

Regarding the current project and following the Open Building System terminology in respect to the structure and fabric layers, there was no strategy for the existing elements at the time of the intervention as it was seen that they did not affect the adaptability (in fact the project states that these elements permit future changes). However, there were established criteria in regards to the coordination of services with other construction elements being one of the main issues in terms of improving the building's capability to accommodate change.

For this reason all the services pass through the common areas where they have easy access, without being integrated in other constructive elements which would mean their demolition at the moment of future alterations.

Flexible solutions for the common area finishes were looked for (registered suspended ceilings, over dimensioned service ducts, etc) which allow interconnections between all spaces permitting new service layouts for future technological necessities.

Finally the organization of the different spaces and the relation between them helps answer unseen changes for future needs.

TABLE PRICE/M2 (INVESTMENT) COMPARED WITH OTHER DEVELOPMENTS

	18 apartemets for elderly people. RE-USE		45 flats and parking. Vitoria NEW BUILDING	
	Apartments 2.125 m² Ratio €/m²	Urban Layout 1.507 m² Ratio €/m²	Dwellings 6.102 m² Ratio €/m²	Urban Layout 580 m² Ratio €/m²
1 Initial groundwork	68,88	0,00	0,00	0,00
2 Earth movements	14,98	0,00	26,66	0,00
3 Foundations and floor slabs	0,00	11,71	51,46	0,00
4 Structures	19,20	0,00	115,69	0,00
5 Roofing	10,88	0,00	11,43	0,00
6 Facades	67,02	0,00	106,20	0,00
7 Windows and doors	77,07	0,00	84,97	0,00
8 Internal block/brickwork	88,77	0,00	77,42	0,00
9 Vertical and horizontal finishes	89,90	11,88	69,79	0,00
10 Insulation and waterproofing	0,00	0,00	0,00	0,00
11 Drainage	9,47	6,63	5,33	0,00
12 Elevators	0,00	0,00	13,20	0,00
13 Electricity MT	0,00	0,00	0,00	0,00
14 Electricity LT	39,61	0,00	37,60	0,00
15 Security, intrusion and CCTV	0,00	0,00	0,00	0,00
16 Telecommunications	7,22	0,00	4,56	0,00
17 Other installations	0,00	0,00	9,45	0,00
18 Fire protection	0,61	0,00	0,91	0,00
19 Air conditioning and ventilation	4,83	0,00	0,00	0,00
20 Solar energy	0,00	0,00	8,89	0,00
21 Centralized management	0,00	0,00	0,00	0,00
22 Gas installation	0,00	0,00	0,00	0,00
23 Plumbing	97,54	0,00	65,14	0,00
24 Refrigeration installation	0,00	0,00	0,00	0,00
25 Industrial installation	0,00	0,00	0,00	0,00
26 Urban layout	0,00	0,00	0,00	111,87
27 Furnishing and fittings	0,00	5,54	0,00	0,00
28 Quality control	2,65	0,00	0,00	0,00
29 Health and safety	9,83	0,00	12,01	0,00
30 Waste management	included	included	included	included
TOTAL	**608,47**	**35,75**	**700,71**	**111,87**

The project has not only environmental benefits but it is also profitable when compared to a similar new build project (15% saving) tendered within the same month.

CONCLUSION

During their lifetime buildings undertake continuous changes, which will vary depending on their use. Tertiary buildings are more likely than housing blocks to suffer variations. Therefore, currently the design process must contemplate the adaptability of the project to future uses.

Re-use is a more sustainable approach than any other manner of newly built, with an estimated saving of a minimum of 50 % energy saving during construction.

Enlarging the life span of the building will result in a dramatic reduction of energy cost during construction.

Even though the starting point and new programme is specific to each building and therefore each case must be analyzed independently, this is generally an advisable strategy from an environmental and economic point of view.

Energy consumption during building use accounts for approximately 74% of its total life span consumption, while the energy used in construction accounts for 22 % of the total. Ecological re-adaptation is therefore the most sustainable option since its advantages include a reduction on the services bills, bigger comfort and a reduction on CO2 emissions. It is important to remember that energy consumed by building related services accounts for approximately a third of the energy consumptions of the EU.

Finally, it is worth including the environmental aspect. Following continuous changes undertaken by buildings and their capability of adaptation, the life cycle of a building becomes a compulsory aspect to consider during the design process.

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THE DESIGN OF ADAPTABLE BUILDING IN JAPAN

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ABSTRACT

This paper looks at adaptability of buildings in Japan from the perspective of six companies, which represent three distinct practice typologies. Two cases were studied from each typology: large general contractors, large architectural design firms, and small design ateliers. The paper begins by contextualizing the situation in Japan by presenting a lineage of initiatives by the Japanese government. Subsequently, we present the findings from exploratory interviews and discuss how they can inform future comparative studies between the UK and Japan. The interviews reveal current innovations, trends, priorities, and obstacles within each practice in relation to adaptability in design, particularly of offices. The importance of certain physical characteristics and current solutions are examined such as storey height, location of services, planning modules, and structural spacing/spans. The interviewees acknowledge the critical relationship adaptability has with the state of the market, the role planning regulations and other laws serve as obstacles towards adaptability, and misconceptions/variations of the role and meaning adaptability has in practice. These issues are examined and the paper concludes by reflecting on the role and the dilemma of the designer, as both an individual actor and as a practice when dealing with adaptability.

Keywords: adaptability, design process, design practice, innovation, office buildings

INTRODUCTION

The majority of buildings are designed and constructed to suit a particular use at a certain time, with relatively little thought for the future. The Adaptable Futures research group is investigating the development of adaptable buildings in the UK that can better accommodate an often uncertain future (Gibb et al 2007, Schmidt et al 2009). The research is a three year multi-disciplinary project that aims to facilitate the development of adaptable buildings in the UK through academic research and real-life application. The project involves academics and researchers from the following sectors; construction, architecture, quantity surveying, business, project management and engineering.

The investigation looks to evince adaptability as a definable design characteristic with a principle consciousness towards “time” and “layers”. Our current definition of adaptability reflects our accrued journey, namely *‘the capacity of a building to accommodate effectively the evolving demands of its users and environment, thus maximizing value through life’* (Schmidt et al 2010). “Time” as a design consideration suggests buildings as dynamic systems that interact with a set of evolving endogenous and exogenous demands requiring a capacity to accommodate *change* (space, function, and componentry) through life. “Layers” indicates a design consideration regarding the organization and interfaces between components of varying life spans and functions.

Japan’s construction industry has operated over the years with a strong scrap and build ethos, resulting in a short life for most office buildings between 20 to 30 years. This approach has begun to shift with changing market conditions and priorities aligning with a more sustainable agenda. In response, the Japanese construction industry has begun to realize the advantages adaptability can provide in reducing environmental impact and increasing cost-effectiveness.

Achieving greater adaptability demands a shift away from the current emphasis on form and function in response to immediate priorities, towards a ‘time-based’ view of design. This part of the research explores the role of the practice in this transition, and the attitudes and mindsets of designers, to understand how current processes/ projects either impede or enable adaptability in their practice. There are clear linkages here with the “distributed control” concept which is one of the central principle of Open Building (Kendall et al 1999). The interviews reveal current innovations, trends, priorities, and obstacles within each practice in relation to adaptability in design, particularly offices. The results of the interviews are used as benchmarks for further research.

THE SETTING: JAPANESE LONG LASTING HOUSING

This section describes the transition of Japanese approaches towards building longevity as a background for understanding the evolution of adaptable buildings in Japan. Historically the life expectancy of Japanese buildings were much shorter than that of western countries. With that in mind, Japanese public sectors have initiated several projects, especially pertaining to housing, to prolong life expectancy and adaptability has been seen as a good solution.

Short-life buildings and lower investment into refurbishment

The life expectancy of Japanese housing is about 30 years which is shorter than western countries (Figure 1). In coordination, the ratio of maintenance and renovation in the total investment is lower than western countries (Figure 2). These charts imply

Japanese buildings are rebuilt within a short period and new construction dominates the market.

From Quantity to Quality

After WWII, the Japanese government initiated projects to deal with the shortage of housing. A severe shortage continued through a period of rapid economic growth because of a high concentration of people moving into major cities, along with shifts in family compositions, and so on. In a 1968 census, the number of total residential units were greater than the total number of households. After this period, Japanese housing policies shifted from quantity to quality (MLIT Japan et al, 2008).

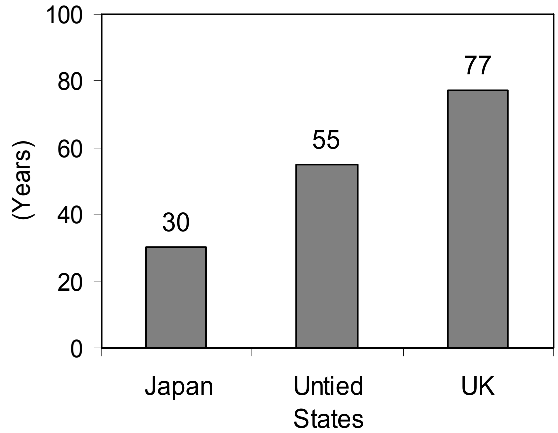

Figure 1 *International comparison of average years elapsed before a house is demolished in around 2000 (Quoted: MLIT Japan et al, 2008, "A Quick Look at Housing in Japan", p48)*

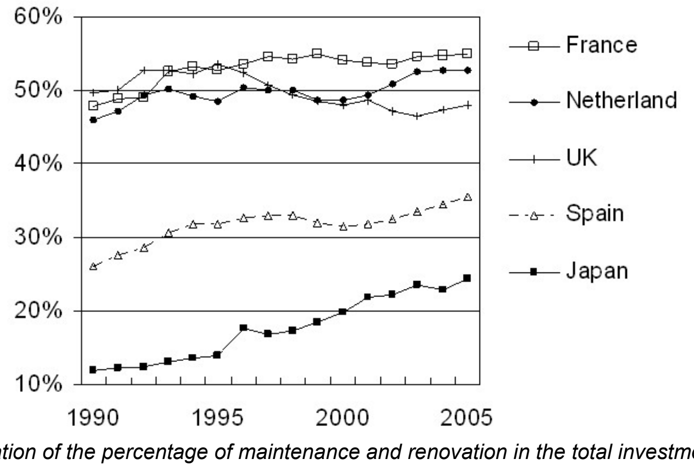

Figure 2 *The transformation of the percentage of maintenance and renovation in the total investment in building activities during 1990-2005. (Sources: Euroconstruct. 1992, 1996, 2000 and 2003 and MLIT Japan 2006)*

KEP: Kodan-Experimental housing Project (1973-)

During the housing shortage period, a large number of reinforced concrete apartment houses were constructed and related technologies developed. Around the 1970s, the Japanese housing industry shifted to respond to the demand of various types of housing and their quality.

KEP is an experimental project conducted by the Japanese Housing Corporation (called Kodan at the time) in order to incorporate flexibility and adaptability into housing from 1973. They categorized the building into structural frame and four subcategories of components - exterior, interior, kitchen & bath and other devices (piping, wiring and etc.). The intention was to identify interface details between each category and facilitate the use of "open" components. During the 1980s and 90s, some projects were designed based on this system.

Century housing system (1980-)

In order to prolong the life expectancy of housing this system proposes to divide the building parts into five categories based on experience and estimated life expectancy; 1) *the main structural members*, which are most difficult to replace lasting 50 to 100 years, 2) *roofs, exterior doors and windows* lasting 25-50 years, 3) *partitions and furniture* lasting 12-25 years, 4) *home appliances, piping and wiring* lasting 6-12 years and 5) *light bulbs and sealants*, which are the easiest to replace lasting 3-6 years. The crux of this system is that buildings need to be designed so that parts with long life spans are not damaged when parts with short life spans are replaced (Utida 2002). This system facilitates the future maintenance and exchange of parts as well as a response to changes in residents' life styles.

SI: Skeleton Infill (1990s-)

This system supplies buildings in two steps; first "S" (skeleton) which signifies the long-lasting part and social property and second "I" (Infill/ fit-out) which represents the short-lasting part and private property (NEXT21 editorial committee 2005). However, in general, most of the Japanese construction industry tends to recognize this system purely as a physical issue, such as "S" means structural frame and "I" means interior and services (Matsumura 2009). This is despite its origins deriving from the "open building" approach by N. John Habraken, which incorporates more of the softer issues such as decision making levels in the management of residential areas (Matsumura 2009). The NEXT 21 project by Osaka Gas (1993) is the most famous project in Japan and both public and private sectors were brought together to develop SI technologies in experimental and practical projects (Kendall et al 1999). In these days, The national government now uses SI in their policies so this word is quite widespread in Japan.

200-year Housing (2006-)

In 2006, the Basic Plan for Housing (National Plan) indicated a transition to a stock-based housing policy leading to the promotion of the "200-year Housing" initiative which aims to extend the useful life of housing (Minami 2009). More specifically, this concept involves the construction of houses that boast excellent durability and are easy to manage and maintain (MLIT Japan et al, 2008).

ADAPTABULE BUILDINGS IN JAPANESE PRACTICES

This section describes the current situation of adaptable buildings, especially about office buildings based on designers' comments from our interviews.

Japanese Architectural Practice Typologies

Japanese architectural design practices fit three distinct typologies: large general contractors, large architectural design firms and small design ateliers. Large general contractors offer a complete package, a one-stop shop, for a complete service ranging from property acquisition, design, construction, maintenance, R&D and so on. According to company profiles as of 2009, the top five companies have more than 2000 licensed architectural designers in house. Large architectural design firms deal mainly with the design stage of relatively large projects (e.g. more than 10,000 m^2 total floor area office buildings). They will also sometimes get involved with Construction Management (CM) and Project Management (PM) businesses as well. The larger companies have about 300-700 licensed architectural designers. Small design ateliers typically consist of a few to a couple of dozen people and deal with relatively small projects, such as private housing. World-famous architects' offices are included in this category. Two practices were interviewed and studied from each typology.

Design trends for adaptable buildings

Currently, clients are not thinking about adaptability, but are becoming more aware of green issues and responsibilities. Therefore, at present, designers and clients share the necessity to consider sustainability, and many carbon reduction technologies have been developed and equipped. This has also led to the demand for more adaptable buildings, as people recognize the correlation between long life buildings and sustainability. However adaptability is not a priority in the consideration of sustainability in Japan, many seeing it as a separate issue.

Current market trends for office building design are moving towards a lower overall height of the building with larger floor space, in comparison to a typical high-rise tower building. Upgrading building services is a big issue driving service space locations which are easy to maintain, such as outside or on the facade of the building (e.g. balcony). Furthermore, a strategy of decentralized services is popular, subdividing as much as possible to respond to each individual tenant's needs (which has parallels to the "distributed control" principle).

Case studies

The following three projects are examples of Japanese adaptable office buildings which the designers were involved in.

Case study A) Mega-floor Office

Constructed in 2004, the total floor area is 33,000m^2 and 7 stories high (see Figures 3-5). The three major concepts of this building are; 1) high efficiency (high quality work place for employees), 2) green building and 3) low cost solution (both initial cost and total life cycle cost). The structural bay is a 10.8m grid for low cost, which is typically used for shopping centers and parking; in contrast to the typical span of office buildings of 16-18m, or even more than 20m. Future change was considered: if in 10 years they wanted to change locations the building could easily expand, contract, or change use into retail or hotel for example.

The design philosophy incorporated into the office layout encompasses a strong sense of openness through a continuous visual connection between floors and spaces (no walls and easy communication) and scattered core items (not centralized but “pack” of core).

Figure 3: *Façade (Source: Interviewee)*

Figure 4: *Interior (Source: Interviewee)*

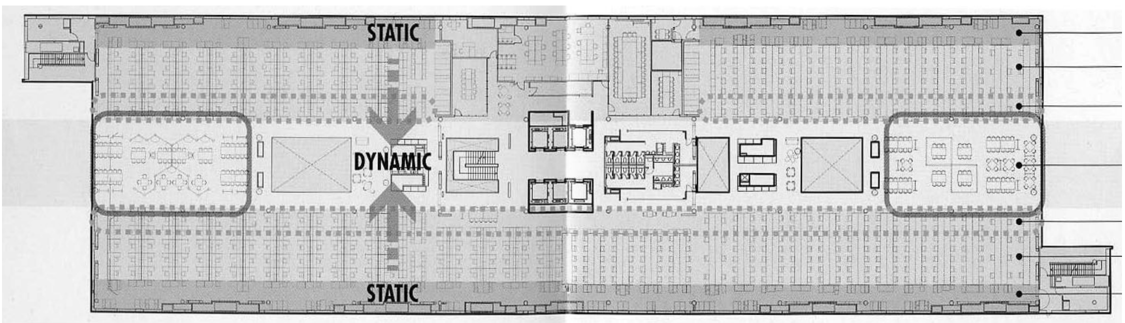

Figure 5: *Plan (Source: Interviewee)*

Case study B) Adaptable system

In this system the core is centralized and the columns surround the perimeter so that they provide a strong resistance to earthquakes and allow the space to be more flexible, such as change of layout (see Figures 6-7). Moreover, it is easy to construct and can reduce the length of construction. Originally this system was developed for residential buildings because of the demand for adaptable housing. Even under construction, the housing market and regional structure, such as population, can be changed. They developed an office permutation adding steel beams. However, this system does not fit the market well at this point, because of its current limitation in floor depth of 14m, while the average office depth is 18m.

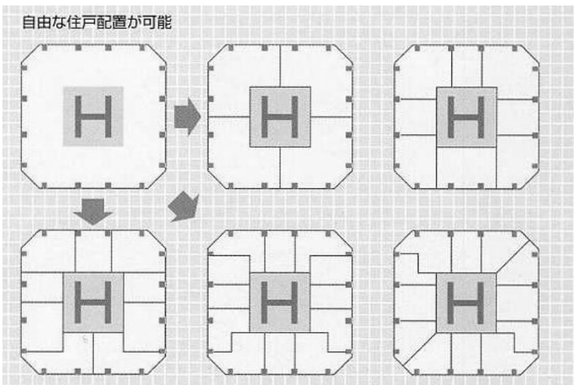

Figure 6: Layout pattern (Sources: Interviewee)

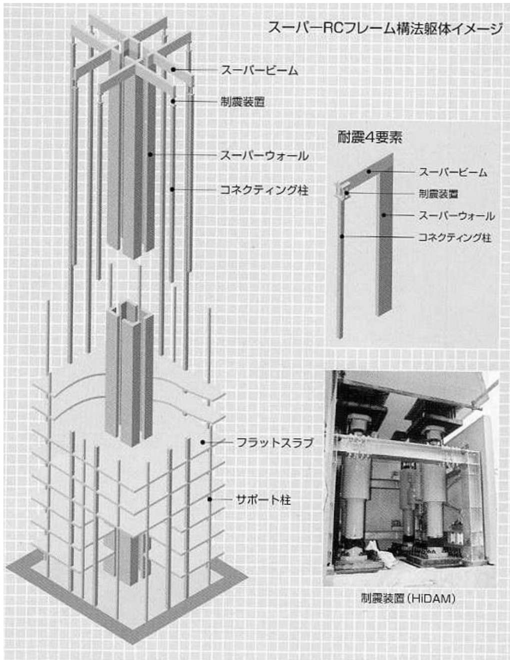

Figure 7: Structural frame (Sources: Interviewee)

Case study C) Adaptable material

In general, there are very strict regulations regarding fire resistance in Japan, so to use predominantly wood as a component in an urbanized area, especially more than three storeys high and non-residential, is extremely rare. This project aims to revive Japanese wooden culture in an urbanized area. Wooden components are used on the façade, interior and some parts of the structure all of which are made by a standard size distributed by the timber market in Japan so that they're easy to replace in the future (Figures 8-9).

Figure 8: *Façade (Source: Interviewee)*

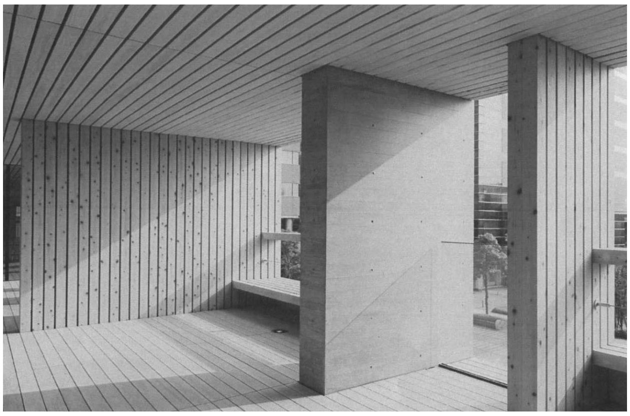

Figure 9: *Interior (Source: Interviewee)*

Design criteria

Through our conversations, the floor to floor height was found to be the most critical design parameter for adaptability. In general, the average floor to floor height is getting higher, from 2.500mm to 2.800mm. With 40 year old offices (built in 1960's) the structural floor height is not large enough for renewal due to the demand for raised flooring to equip the latest service devices. Enlarged personal space has increased the floor module as well from 3m to 3.2-3.6m. Moreover, the current typical span between columns is 6.8m or 7.2m by 16m or 19m.

Obstacles

The clients' mindsets have a huge influence. It is not easy to convince clients when adaptability of the building increases its initial cost, although it is relatively easier with government bodies because they can invest more cost initially and are willing to cooperate to reduce the CO^2 emission for example. Private clients' budget is typically less and they are not completely committed to environmental issues.

At the design stage, obstacles for adaptability are regulations and the mind-set of designers. Designers can adopt adaptability as a concept into their projects to extend the physical longevity; however, they cannot cope with the social longevity reflected in the market and people's demands. On the other hand, one designer said, *"If the building has a good enough structural frame, including large open spaces, there are no obstacles to realize adaptability".*

Innovations in design process

In some cases, designers attempted an innovative approach to realize adaptability within the design stage. To *share motivation within the design team and client*, such as to get an award (i.e. building recognition) helped to unify their organization in producing an innovative solution. In this sort of attempt, designers should make the effects of adaptability clear. If they get an award, this would be an incentive for both designers and client.

Good communication with manufacturers was necessary in another project. One design team used the latest manufacturing technology regarding digital fabrication enabling them to produce components with a unified standard. This allowed the same size of material to be produced readily making it easier to replace the material. The communication between designers and manufacturers throughout the design process was of extreme closeness and critical from the brief stage - which is not typical.

Designers' dilemma: profits and incentives

Commercial buildings tend to be designed to maximize profitable space allowances, locking buildings into specific uses, making conversions more difficult. Moreover, the development of many technologies has a detrimental effect on adaptability. As an example, when a technology for a high-rise building is developed, the more it is used and inevitably evolved to reduce costs, the more specific it becomes leaving less 'space' for future change.

In residential development, the developer can get incentives which enable them to exclude some floors from the floor area ratio calculation (FAR) for a particular use, such as common aisle space, balconies and service spaces which are designed for saving energy. However, in the future the capacity to change those buildings into another use could become a big issue regarding the additional floor space gained, making it impossible sometimes.

Negative mindsets of designers

There are some designers' negative mindsets against adaptability. One designer said that by making something adaptable, there might be a loss of certain characteristics and identity. Another designer said that *"adaptability works as an academic idealism (e.g. Habraken's open building and SI system), but is not practical within the realistic realm.*" Moreover, if buildings last more than 30 years, it might reduce designers' work in Japan.

BRIEF COMPARISON – JAPAN AND UK

This section describes a brief comparison between Japan and UK, using two sources conducted by the research partners of the Adaptable Futures project to understand the UK situation; a questionnaire to potential stakeholders (Reid Architecture 2006) and a conversation in response to the Japan findings with a UK-based designer (Warner 2009).

Similar points are: according to the questionnaire, the most important technical challenges are service and plant space, capital cost and life-cycle cost and story height. From the designer's point of view, floor heights are the most critical and increasingly getting taller creating a huge problem with buildings in the 1960s. Moreover, the minimum floor module for services is critical as well. UK's average module for plan is 3m or 3.6m and 1.2m. On the other hand, society demands new buildings and clients are much more interested in green issues than adaptable issues.

Differing points are: according to the questionnaire, more than 80% of the stakeholders saw a need for adaptable buildings and more than 60% perceived an adaptable building shell as being standard quality (not high like SI in Japan). From the designer's point of view, a bigger problem is the footprint (shape of building). UK policies created a greater awareness of mixed use as a "green" solution; while deconstruction activities in the UK remain incredibly cheap compared to other EU countries.

CONCLUSION – BENCHMARKED BY JAPANESE PRACTICES

How do we design adaptable buildings? What follows is what we've learnt from the Japanese experience as a benchmark for future research in the UK.

Role of design practices

The most difficult issue for designers is to change the mindsets of clients and improving cost effectiveness. Clients tend not to accept adaptable buildings with a higher initial cost. Moreover, the more cost efficient buildings sometimes result in a lower level of adaptability. The balance between cost and adaptability is a critical issue requiring a whole life economics approach. On the other hand, if the building has a suitable structural frame, including large open spaces, there might be few or even no obstacles to realizing adaptability. The other approach towards adaptability is good management of the relationships between stakeholders, to keep their motivation high and sharing benefits between the design team and client and to maintain a good communication between designers and manufacturers. This approach by Japanese practices supports the "distributed control" principle and needs further investigation in terms of adaptability.

Gap between theory and practice

In Japan, SI and sustainability are quite commonly used phrases that help designers to discuss adaptability more easily with their clients and manufacturers. However, designers see the SI system is as an idealized concept rather than as a practical solution. This implies the need for a discussion with industry about the more practical issues.

ACKNOWLEDGEMENTS

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ACHIEVING OPEN BUILDING IN HIGH-RISE, HIGH DENSITY BUILT ENVIRONMENT – FACTS, OBSTACLES AND WAY OUTS

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ABSTRACT

Aging of building stock is emerging. Open Building as a sustainable approach to deal with the aging building stock is seldom applied in the high-rise environment. This paper presents findings from a survey of 495 buildings from ten major housing estates in Hong Kong. Founded on extractions from layouts and floor plans, facts and obstacles of the implementation of the concept of Open Building are unearthed. The opportunities for achieving Open Building in private residential buildings in the territory are discussed.

The layout and structure of private residential buildings in Hong Kong are very much alike. They are in general failed to adapt and so any change in user requirement is not easily accommodated. Implementing Open Building using flexible and green fittings is a feasible way to enable transformation in the existing stock.

Keywords: aging building stock, building layouts, Hong Kong.

INTRODUCTION

Aging of the building stock refers to the transition characterized by falling building mortality and sinking new completions. Inevitably building nowadays will stand longer than before, with old buildings constitute a larger portion of the stock. It has far reaching implications, ranging from built environment decay at macro level and problems in building management and maintenance at micro level. With empirical evidence as the underpinnings, developed regions are undergoing this transition and sooner or later it will occur in those currently emerging regions. For this reason, there are imminent needs to seek measures to tackle the issue in a sustainable way.

As building age, they are inclined to become obsolete. Design and construct buildings for maintainability and adaptability can counteract obsolescence and strengthen building functions. Regardless of the contended benefits, Open Building in high-rise, high density context is under-researched. The goal of this paper is to study the hurdles in implementing Open Building in high-rise and densely populated built environment.

The aim of this paper is twofold, which is to study the constraints and the opportunities for Open Building Implementation in high-rise, high density built environment. The case of Hong Kong will be studied for its predominantly high-rise and densely populated environment. The scope is confined to private residential buildings so as to bridge the gap in former works (e.g. Mahtab-Uz-Zaman and Lau, 2002).

HONG KONG IN FOCUS: THE SITUTATION

Land is as valuable as gold – this expression portrayed the reality in Hong Kong where land is highly scarce. It has an area of 1104 sq km but the terrain is largely mountainous and hilly. Alongside the Victoria Harbour, developments are concentrated in Kowloon and Hong Kong Island. The tall skyline and densely populated area, however, comprised a quarter of the territories only. For the remaining three-quarters, they are mainly countryside that do not fit for or protected from development.

Hong Kong has an enormous and probably the largest public housing system in the world, where 47.1% of the population (i.e. about 3.3 million) is housed (HKHA, 2009). In other words, still more than a half of the population is accommodated in private housing. Their stock, according to RVD (2009), was 1,085,900 units. In accord with other developed regions an aging trend of building stock is shown. It is reflected in the shrinking new completions and demolition. Compare the figure in the 1990s and 2008, annual demolition in the period is almost negligible, ranging from several hundred to about two thousand units; whereas new annual completions dropped significantly from 25,000 units to 8,780 units in 2008 (Table 1). The increase in the estimated mean stock age from 15.2 years in 1996 to 22.7 years in 2008 cross validated the aging argument.

Period	New Annual Completions	Demolition (in units)	Stock at the end of period (in units)
1971-1975	19,283	N.A.	357,480
1976-1980	23,063	N.A.	477,100

Period	New Annual Completions	Demolition (in units)	Stock at the end of period (in units)
1981-1985	26,276	N.A.	592,165
1986-1990	33,767	N.A.	752,846
1991-1995	28,814	2,542	892,800
1996-2000	24,293	1,074	1,025,913
2001-2005	25,414	687	1,053,246
2006-2008	11,943 (8,780 in 2008)	1,097 (1,416 in 2008)	1,085,922
2009-2010*	13,670	N.A.	N.A.

Table 1: *New completions, demolitions and size of private domestic buildings in Hong Kong*

*Source: Rating and Valuation Department (RVD), various issues (*estimated figure for 2009 and 2010).*

OPEN BUILDING IN HIGH-RISE, HIGH DENSITY CONTEXT

Open Building is a broadly shaped idea that encompassed sets of principles leading to a sustainable building stock (Kendall, 1999). These principles, as stated by Habraken, are:

- The built environment is being intervened by Levels – physical elements by human actions;
- The involvement of multi-parties in the design process, with users being able to make decisions; and
- The continually transforming built environment must be recognized, and it is the product of unceasing design process.

In Kendall and Teicher (2002), characteristics that define Open Building are described. A comprehensive account of the approaches to Open Building was given based on earlier works by Tiuri (1998) and Jia (1998) (Table 2). In Tiuri's work, 16 criteria of Open Building and 3 improvements towards Open Building are laid down (Table 3). These criteria depicted the concept of Open Building in application and will form the skeleton of subsequent investigations to interpret the constraints in achieving Open Building in Hong Kong.

Specific Approaches to Open Building
1. Recognizing and organizing work according to environmental levels
2. Distributing decision-making
3. Physically separating support, infill and other environment levels
4. Disentangling building subsystems
5. Structuring professional services in support of household choice
6. Using specific Open Building methodological tools
7. Using specific Support technologies in conjunction with infill systems
8. Using specific infill technologies
9. Using specific Open Building financial instruments

Table 2: *Specific approaches to Open Building by Tiuri (1997) and Jia (1998)*
Source: Kendall and Teicher (2002).

As can be seen in literature, embedding flexibility and capacity to adapt in design, and enabling participation and decision-making of users in the design process are the gist of Open Building. In densely populated built environment where vertical architecture prevails, providing barrier-free access in existing high-rise buildings is an additional requirement for buildings (e.g. Ogawa et al., 2006). When Hong Kong is specifically considered, the essence of the challenges ahead in relation to Open Building are extracted from literature and shown below:

- The dilemma between rehabilitation and redevelopment – those rehabilitated, older stocks may be unable to respond to changes in life styles and technologies, while on the contrary, the replacement approach is environmentally unfriendly;
- Real estates are expensive in Hong Kong. Space optimization through the Open Building process can avoid excess or under purchase of space so that this state of disequilibrium can be eliminated. Neither extra purchasing power is locked in nor unused purchasing power is drained away from the building sector. This is the social and equity issue of Open Building raised by Kendall (1999);
- Hong Kong has been blamed for the enormous amount of Construction and Demolition (C & D) waste produced. As a major contributor, reducing C & D waste resulted from re-decoration works is always on the agenda. Driven by this Jia (2005) evaluated the environmental impact of partition walls with different degree of flexibility and sought possible rooms for using flexible partition walls in Hong Kong; and
- Mahtab-uz-Zaman and Lau (2002) considered the limitations in design in answering the future demand in mass, public housing context, which include 1. changing design parameter 2. tendency to smaller families 3. improving housing standards and 4. rising aspiration of residents. At the same time, the large population of users involved rendered problems to allow for user participation in design process.

User as decision maker		Separation of support and infill systems	
A1	Users decide on the infill or the changes concerning the infill	A5	Open frame structure
A2	Users can participate in decisions concerning the support level	A6	Independent distribution of service systems to each potential spatial units
B1	A few optional floor available to first user	A7	Intermediate floor or installation zones accessible from the apartment
B2	User participation for the first user in the design	A8	Infill systems for services in the apartment
		A9	Infill systems for partitions (demountable partitions)
		A10	Façade infill system
Open spatial structure		**Open Building process**	
A3	Regulations of the distribution of spatial units during construction or later	A11	Distinction of the support and infill levels in decision-making and design
A4	Elements defining floor plan and services inside are on the infill level	A12	Separate procurement and construction for the infill level
B3	Fixed service spaces or equipment but freely divisible floor plan	A13	Functional and spatial design distinguished from technical solutions by using modularization of building parts or performance specification
		A14	User assisted by professionals during decisions concerning floor plan
		A15	Method for immediate calculation of the cost implications of alternative choices made by users
		A16	Visualization of alternatives to users in 3D drawings or full-scale models

Table 3: *Criteria of Open Building laid down in Tiuri (1998)*

RESEARCH METHODOLOGY

It is pivotal that typical designs and layouts of private residential buildings in Hong Kong are included in the sample. Ten major residential estates in Hong Kong are chosen for study. The three biggest local property agencies (i.e. Centaline Property, Midland Realty and Ricacorp Properties) regularly analyse and report the transactions of these ten large-scale estate type residential developments which were completed in late 1970s to early 2000s. From one aspect, the transactions are regarded as indicators of the state of residential property market for the high volume of transactions undertaken. On grounds like building quality and location, these estates are also desirable homes that are welcomed by users. The particulars of the ten estates in the sample are shown in Table 4.

A total of 495 buildings' floor plans are examined. It represents more than 102,000 units, or 9.39% of the private housing stock by the end of 2008. Together with the insights gained in literature review, these solicited plans are analysed using the Open Building criteria laid down in Tiuri (1998). Two key aspects namely open spatial structure and separation of support and infill systems are focused. Remarks on Open Building process and user participation during the design process are added afterwards.

Region		Estate/ Building	No. of Blocks/ Storeys/ Units	Floor Area	Occupation Date	Developer
Ten Major Estates	HK	Taikoo Shing (HK1)	61 Blocks/ 23-30 Storeys/ 12,698 Units	563 sq ft – 1,237 sq ft	12/1976-05/1987	Swire Properties
		Kornhill (HK2)	32 Blocks/ 18-31 Storeys/ 6,648 Units	582 sq ft – 1,064 sq ft	12/1985-06/1987	Hang Lung Properties, New World Development
		South Horizons (HK3)	34 Blocks/ 25-42 Storeys/ 9,812 Units	632 sq ft – about 1,100 sq ft	11/1991-03/1995	Hutchison Whampoa
	KLN	Mei Foo Sun Chuen (KL1)	99 Blocks/ 15-21 Storeys/ about 13,200 Units	616 sq ft – 1,849 sq ft	10/1968-05/1978	Mobil, Galbreath Ruffin Corporation, Turner Construction Co.
		Whampoa Garden (KL2)	88 Blocks/ 14-16 Storeys/ about 15,000 Units	351 sq ft – 1,107 sq ft	12/1985-01/1991	Hutchison Whampoa
		Laguna City (KL3)	38 Blocks/ 25-28 Storeys/ 8,072 Units	517 sq ft – 1,608 sq ft	12/1990-12/1991	Cheung Kong Holdings
	NT	City One Shatin (NT1)	52 Blocks/ 27-34 Storeys/ 10,643 Units	389 sq ft – 1,018 sq ft	06/1981-10/1987	Henderson Land Development, New World Development, Sun Hung Kai Properties, Cheung Kong Holdings
		Kingswood Villas (NT2)	58 Blocks/ 27-39 Storeys/ about 15,800 Units	573 sq ft – 824 sq ft	12/1991-12/1997	Cheung Kong Holdings
		Discovery Park (NT3)	12 Blocks/ 45 Storeys/ 3,360 Units	593 sq ft – 848 sq ft	04/1997-03/1998	Hong Kong Resort Company, New World Development
		Metro City (NT4)	21 Blocks/ 38-43 Storeys/ 6,768 Units	487 sq ft – 1,026 sq ft	12/1996-04/2000	Henderson Land Development

Table 4: *Details of the private domestic buildings (estates) in the sample*

FINDINGS – OPEN SPATIAL STRUCTURE

Not surprisingly, the layouts of the surveyed buildings shared many commonalities. They are typified by the presence of a central core, which is principally the 'support' level of these high-rise residential buildings. Within the central core are elevators, corridors and stairs that form the common passage. Electrical systems and telecommunication systems are distributed through the core as well. Round the central core are load bearing walls and pre-parcelled units. Under most circumstances, the number of units in each floor is 8 (Figure 1 and 2). In addition to the typical layout exemplified in Jia (2005), subject to the location of the kitchen in default layout, the space is divided into living-dining area and bed-washrooms separated by structural walls (Figure 3). Summary of the survey result is shown in Table 5.

As illustrated in Figure 1 and 2, distribution of spatial unit is fixed. Such distribution is bounded by the structural wall sandwiched between the pre-parcelled units and the central core. However, redistribution of space by merging two adjoining units remains a viable option provided that the common party is wall is non-structural (Figure 2). Whampoa Garden and Kornhill, for example, are cases that merging is possible while Metro City (Figure 1) is not. Apart from technical constraints, redistribution of spatial units in existing buildings is legally restricted. Because the common area is delineated in the Deed of Mutual Covenant (DMC), redistribution of spatial units is prohibited unless such instrument is revised.

On top of the fixed spatial unit free configuration of flat layout is not viable. Consider Figure 3, readjusting the layout is not possible because of the presence of the structural walls that separate the living-dining area and the bed-washrooms in both layouts. Furthermore, there are additional restrictions from the gas supply, plumbing and drainage systems whose in-outlet is almost fixed. The chances to relocate the kitchen and the washrooms are further reduced.

SEPARATION OF SUPPORT AND INFILL SYSTEMS

A striking contrast is observed between the support and infill systems in theory and the actual configuration of the sample buildings, that the latter is far from open and showed a high degree of inflexibility. At the support level, the flexibility is due to the gas supply, plumbing and drainage systems running from the external wall. Although they are distributed to individual units separately, restrictions to readjust the floor plan are still imposed. Unlike the gas supply, plumbing and drainage systems which are restrictive, the electrical and telecommunication systems are arranged according to the concept of support. They run in trunkings and distributed to users on each floor via the central core where space for connection and maintenance is provided. In respect of accessibility, elevators are installed in these high-rise domestic buildings. Minor improvements such as providing clear signs and adequate rails are adequate in creating a barrier-free environment up to contemporary standards.

For the infill systems, both the partitions and the façades are conventional ones. It is not until recently the use of prefabricated components (e.g. prefabricated façade) becomes more common in the territory. This move is initiated by the financial incentive offered by the government, that the prefabricated non-structural external walls can now be exempted from Gross Floor Area (GFA) calculations starting from February 2006.

OPEN BUILDING PROCESS

It is beyond question that the surveyed domestic buildings are not Open Building for they are not built to adapt. Thus, Open Building process is not involved.

USER PARTICIPATION AND INVOLVEMENT IN DECISION-MAKING

Perhaps it is improper to tender facts in addition to the survey findings; however, user participation in the design process is extremely rare for private residential buildings in Hong Kong. Like most foreign countries, home buyers and sellers (i.e. developers) meet each other only when the works have almost completed. Not only the ten major estates but nearly all of the private residential buildings are also sold in the same manner in the first market. That is to say, users have no say in both infill and support levels as they are excluded from the design process. Given the irremovable structural walls and inflexible partitions in their units, users can merely decide the interior fittings (i.e. choose finishes and furniture). Alternatives to user participation include optional floor plans and participation of first user, nevertheless, they are also absent completely in Hong Kong. As a remark, further study in user participation and customization is recommended. The authors expect to conduct one by this year to study the current practice and barriers in Hong Kong.

OPPORTUNITIES FOR OPEN BUILDING IMPLEMENTATION

In his own words, W. A. Ward (1921-1994) said, ‘The pessimist complains about the wind; the optimist expects it to change; the realist adjusts the sails.’ Shedding light on Ward’s saying, the mode of ‘adjust the sails’ of private domestic buildings in Hong Kong is to adapt by adjusting the interior fittings.

In the findings, private domestic buildings in Hong Kong are subject to the following constraints:

- Redistribution of spatial units is infeasible. Merging two adjoining units is the only exception, however, keeping in mind the sky high property price in Hong Kong and the difficulties to procure units already in occupation rendered this option impracticable; and
- The variety of layout is limited because of the small space; freedom to readjust is restricted by structural elements.

Making adaptation within pre-parcelled units, therefore, is more practicable. This can be achieved through designing and applying fittings that can change according to user requirements and their lifestyles. Flexibility and environmental sustainability should be introduced into the fittings. The use of flexible partitions is an example that encompasses the aforementioned features (Jia, 2005). Features to save or even space will definitely add merits – not only in Hong Kong but also any places where the demand for space is keen.

CONCLUSION

Aging of building stock is a global issue which demands urgent attention. If buildings are designed and constructed with the ability to adapt, problems arising from the aging stock may be alleviated. With aims to recognize the constraints and seize the opportunities for achieving Open Building in high-rise, high density built environment, layouts of 495 high-rise, private residential buildings from ten major estates in Hong Kong are examined. The survey result indicated the sample buildings are far from Open Building. A high degree of structural similarity is exhibited. Their ability to adapt is limited by structural elements and certain services, resulting in inflexible layouts that fail to meet the requirements of individual users. Meanwhile, neither user nor Open Building process is involved during design and construction of the buildings. To tackle challenges of aging housing stock, transforming within pre-parcelled units are more practicable. An opportunity for units to adapt is to use flexible and green fittings.

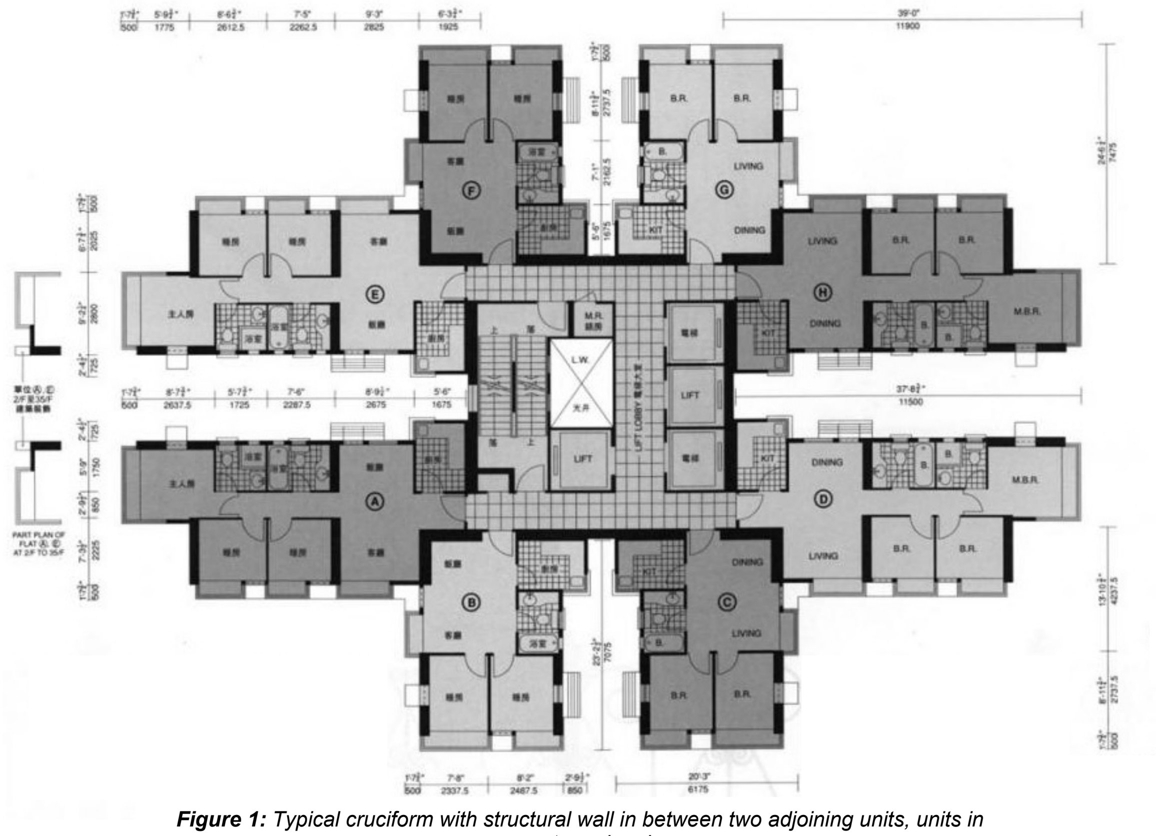

Figure 1: *Typical cruciform with structural wall in between two adjoining units, units in more rectangular shape*

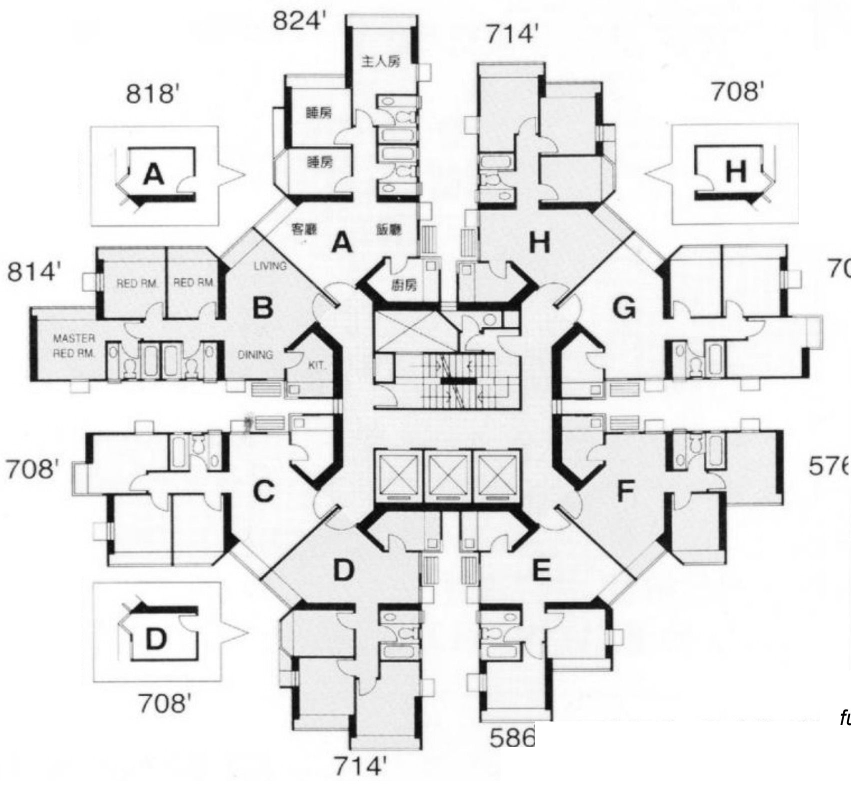

Figure 2: *Typical cruciform without structural wall in between two adjoining units, units in "diamond" shape*

Figure 3: *(above) A typical layout divided into three functional zones by structural walls as suggested in Jia (2005); (below) floor plan configuration limited by structural wall separating living-dining area and bed-washrooms*

Open spatial structure

		HK1	HK2	HK3	KL1	KL2	KL3	NT1	NT2	NT3	NT4
A3	Flexibility in spatial units distribution	N	M	M	N	H	M	N	N	N	N
A4	Freedom to configure floor plan	L	L	N	L	M	L	N	L	L	L
B3	Fixed services but freely divisible floor plan	N	N	N	N	M	N	N	N	N	N

Separation of support and infill systems

A5	Open frame structure	N	L	N	N	M	N	N	N	N	N
A6	Independent distribution of service systems to unit	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A7	Intermediate floor or installation zones	M	M	M	M	M	M	M	M	M	M
A9	Infill systems for partition	N	N	N	N	N	N	N	N	N	N
A10	Façade infill system	N	N	N	N	N	N	N	N	N	N

Open Building process

A11	…	Open Building process is not expected in these buildings for they are not intended to be built as Open Building
A12	…	
A13	…	
A14	…	
A15	…	
A16	…	

User participation and involvement in decision-making

A1	…	No user participation nor involvement in decision making
A2	…	
B1	…	
B2	…	

Key: Y – Yes N – No L – Low M – Medium H – High

Table 5: *Tabulated summary of the characteristics of the sample buildings based on Tiuri (1998)*

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DEVELOPMENT OF FLEXIBLE OPEN SPACES IN HOUSING CONCEPTS FOR YANGON – REGARDING SOCIAL AND CULTURAL CONDITIONS IN MYANMAR

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ABSTRACT

High density built environment developed rapidly in order to fulfill the demand of housing with the growth of population after 1988 in Yangon. Consequently housing facilities were developed by solving the congestion problems of population growth. However, there was given low attention to the life style of residents, the habits of Myanmar people and their culture although Myanmar is a country with still strong culture and habitation. Special regard is given to open flexible spaces of Myanmar traditional housing which is in harmony with Myanmar people's habits. Based on these weaknesses, this paper is intended to support and improve the flexible housing planning in Yangon with respect to local requirements.

Keywords: Yangon housing, Myanmar living habitation, open and flexible space housing.

INTRODUCTION

Yangon is the old capital city of Myanmar. It has the total area of about 598 sqkm. The total population is about 5.5 million in 2009. Due to the development of new satellite town since 1988, the north-wards sprawl of the city has changed to cross pattern housing on east-west axis because there was a change of Government policy from socialist economy to free market economy. 1] Most of the people from rural area migrated to Yangon for their better life because cities enable people to advance socially and economically. They have been trying to live in urban apartments. Due to the development of Yangon, the total population of 2,4 million in 1983 reached to 4,5 million in 2007. With the present population growth rate of 3.4, Yangon population will reach around 10 million in Year 2030. 2]

Under the new economic policy, many projects and actions effecting the housing sectors in urban development were launched. Various methods have been attempted to initiate housing and urban development. Some of them are due to the uncontrolled developments of residential buildings in public or private land known as squatter housing, the housing tasks have been carried out by different strategies: They are: (a) public and rental housing, (b) government's joint housing, (c) site and service schemes, (d) slums and squatter upgrading, (e) programs for individual housing, (f) urban redevelopment projects, (g) area development projects and (h) low cost housing.3] By these different kinds of housing developing strategies, different kinds of housing project were developed. They are: walk-up apartment housing, condominium housing, aerial development housing, single family housing, and garden city housing. 4] Among them, the numbers of walk up apartments are more than other types of housing. The numbers of walk- up apartment of private and public sectors are 85 % of total housing projects in Yangon. 5]

PROBLEMS AND RESEARCH QUESTIONS

Because of the great and fast growing demand for housing and the lack of suitable planning concept, also in order to fulfill the demand of housing, high density built environment are formed urgently. So that, the existing housing facilities are object to critique according to different aspects: insufficient sleeping and living space, unavailability of fresh air due to the housing floor plan design and lack of recreation areas and open space. Moreover, some housing does not harmonize with the Myanmar cultural and social conditions. The housings are designed and planned such that they are not compatible with Myanmar living habit.

Therefore, there are the research questions in order to focus the peoples' needs and used space in urban housing. They are: 1) Are people, living in Yangon housing facilities, satisfied with their functional interior spaces? 2) How can the indoor spaces in housing be improved in order to achieve more well being and quality of life for the residents? 3) What are ways of designing housing concepts, which harmonize with inhabitants' needs?

METHODOLOGY

The selected apartments are analyzed according to the flexible zoning analysis which is compared with flexible Myanmar rural area spaces with the intention of analyzing the relationship between inhabitants' social activities and flexible used space. Moreover, social and cultural performances in Yangon apartments are analyzed by the activities, used time, and spaces, social relationship between residents/ with visitors, and furniture arrangement and activities in order to know urban people's life style and spatial quality of their apartments. The aim of analysis is to install a new thinking of flexible housing design in Yangon which is harmonized with users' requirements.

RESEARCH AREA

The area of research is focused by three factors. They are location of housing, time and type of housing. Most of the housings are located in inner urban ring and outer urban ring in Yangon. Therefore the decision is made to choose the cases in the inner urban ring and outer urban ring. The time in which the cases are placed, ranged from 1988 to 2004. During that time most of the volume of the modern walk-up apartments were built, which give the reason to critical consideration. There are mainly 3 types of apartment, one bed room apartment, two bed room apartment and three bed room apartment, most of the people who migrate from rural area live in walk- up apartment housing. So that, the walk-up apartments in the inner urban ring and outer ring which were constructed from 1988-2004 are selected.

ANALYZING THE QUALITY OF FLEXIBLE AND OPEN SPACES

Zoning Analysis

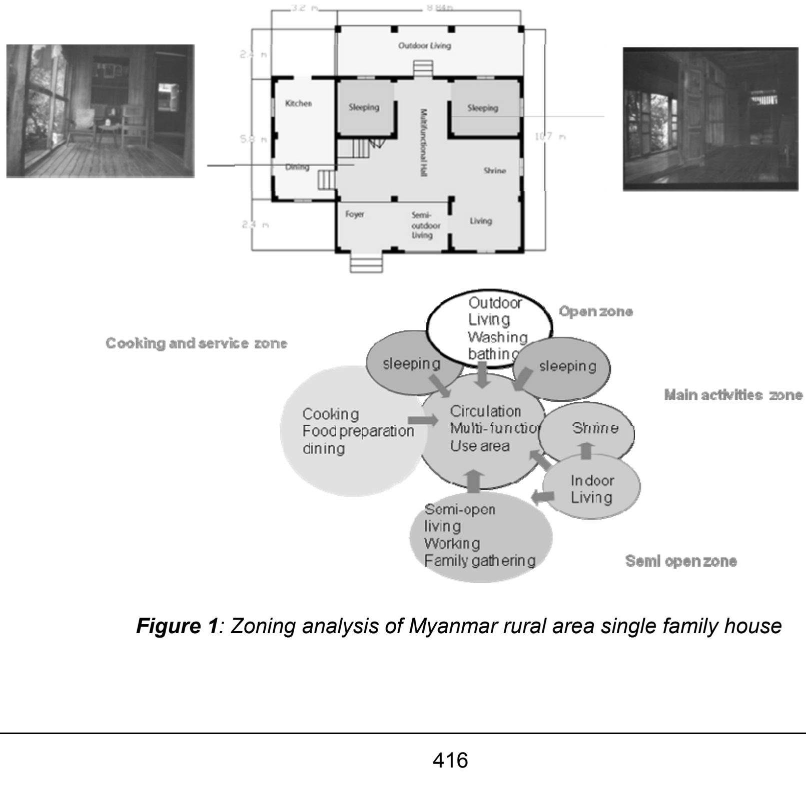


__Figure 1__: Zoning analysis of Myanmar rural area single family house

There is an example of rural area house which has an open space or balcony at the back of the house. In this kind of house, we can see that it has many openings and flexible spaces for each activity even though there is no open courtyard space. The sleeping areas are divided by the curtain which can fold up at the day time. So that, the spaces can be used double functions; one is very flexible and open at the day time and another one has the enclosure function for the private activities at the night time by using flexible and foldable furniture.

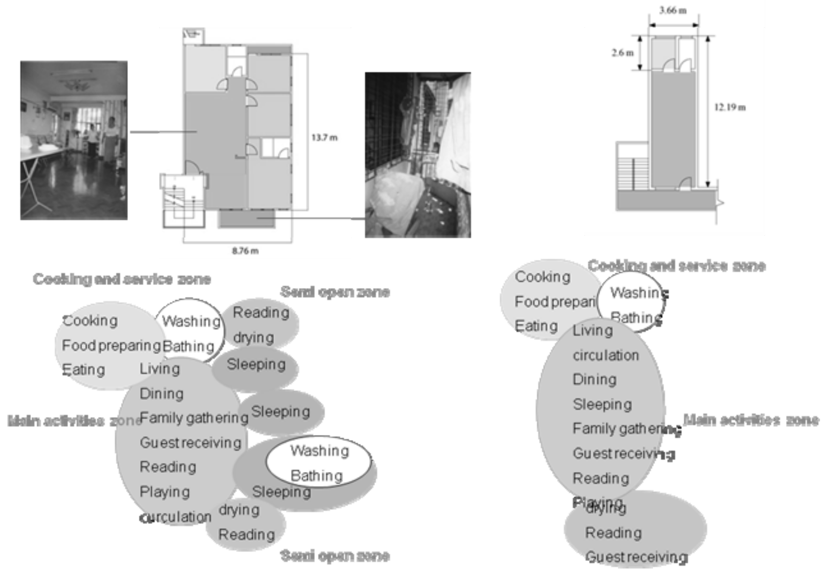


***Figure 2**: Zoning analysis of Yangon apartments*

In the Yangon apartments, there are three main zones: main activities zone, cooking and service zone and semi- open zone. The main activities zone is formed as a living and dining hall and others are bed rooms. In the hall type case, the main activities zone is formed as a hall room for the activities sleeping, living, and dining and so on. Semi-opened zone is formed as a verandah. But the people use this area as cloth drying space or reading, sometimes, guest receiving. In some housing, the people use this area for the shrine. Moreover, it can be also found that some people spend more and more time in tea shops and game centers which originally were placed at the corners of street's junctions. So some people who live in the congested apartments spend most of their time outside. They use to return to their home at the sleeping and dining time. These problems can be found in the very congested urban areas.

DISCUSSION FROM THE ZONING ANALYSIS

In rural area house, the spatial quality of the space is mostly very flexible and comfortable for living. Living space is occurred in interior, exterior and semi-interior in the rural area houses. In tradition, kitchen (or) cooking area is detached (or) attached with the main building. It is intended to separate the public area and private area. Most of the Myanmar traditional houses have multi-functional hall which is mostly very flexible and indoor space with wide doorways. In the interior, exterior and semi-interior of traditional houses, only interior space exists for privacy. By observing the urban apartments, most of the spaces are all interior spaces and verandah space is only semi-exterior space. According to the development of life style and users' requirements, living and dining space (or) dining and cooking space are attached each other. And bed room (or) sleeping area in tradition is developed to the master bed room attached with bath and water closet. By focusing with the spatial quality of traditional houses and urban apartments, the following factors are received. 1) Three types of spaces, interior, exterior and semi-interior space can be found in the rural area houses. 2) The flexible interior spaces provide the residents to be comfortable and flexible conditions. 3) Except for the private space, others provide exterior and semi- interior spatial qualities which are related to the nature and have open flexibility.

ANALYZING THE ACTIVITIES, SPACE AND USED TIME

	cleaning	Hygiene	eating	working	guest receiving	cooking	sleeping	studying	reading	worshiping	bathing	family gathering	children playing	relaxing	cloths drying	Hours/Day (about)
Living			●	●	●		●	●	●	●		●	●	●		14 hours
Dining			●		●			●	●							5 hours
Kitchen			●			●										6 hours
Bed Rooms					●		●	●				●				10 hours
Bath & WC	●	●									●					4 hours
Verandah				●	●			●	●	●		●		●	●	5 hours

Figure 3*: Analysis of people's activities, used space and used time in Yangon apartments*

	cleaning	Hygiene	eating	working	guest receiving	cooking	sleeping	studying	reading	worshiping	bathing	family gathering	children playing	relaxing	cloths drying	Hours/Day (about)
Multi-functinal hall			●		●		●	●	●			●	●	●		19 hours
Living					●				●							10 hours
Outdoor living			●	●	●			●	●				●	●		12 hours
Dining			●					●				●				6 hours
Kitchen					●	●										8 hours
Shrine										●						3 hours
Bed rooms							●		●							10 hours
Open spaces	●			●		●					●		●	●	●	8 hours
Toilet		●														1 hour

Figure 4*: Analysis of people's activities, used space and used time in rural area houses*

This analysis is done by the questionnaires survey to 20 families in both cases including rural area houses, hall type apartments and room type apartments in Yangon. By the analysis of hall type apartment and room type, we could know that hall way or living/ dining hall is mostly used for dominant activities and open verandah is mostly used for alternative activities. Therefore, the living/ dining hall is the most important area in each type of floor plan. To approach the analysis of domestic space use and people's activities, there are two questions, which spaces are used to interact each activities, how many times/ day are used at each space. From this analysis, we could see that in the rural area houses, the multi-functional hall and outdoor living are the most used spaces for the longest time. Also in the urban apartment, we can see that living and dining hall is the spaces for the most activities for the long time per day. But the difference between the rural area houses and urban apartments is that the flexible space or wide space in Myanmar rural area houses is used as common used space (or) social interaction space. In apartments, it is found that living and dining area are the most used area and dominant space for residents' activities. It is needed to be flexible and comfortable for the inhabitants of apartment.

ANALYZING SOCIAL RELATIONSHIP AND USED SPACE

By analyzing social activities and used space, the facts which space is required to be large, which is needed to be reduced and which is required to be combined are emerged. In the walk up apartments, residents can use only living and dining area at the day time and bed room is used for the social interaction space at the night time mostly. Most of the visitors are received and conversant at the living area in urban apartments. When several visitors arrived at the same time, they have to use the dining and bed rooms for receiving guests. The residents use the kitchen and fire escape for the interaction between the residents and neighbors.

Social pattern between residents and with visitors are analyzed. The used spaces are analyzed according the usage of residents in three different times, early morning, afternoon, and night.

Figure 5: *Social Pattern between Residents in One Bed Room Apartments*

Time / Space	Morning	Afternoon	Evening & Night
Living	●	●	●
Dining	●	●	●
Bed room	-	-	●
Kitchen	●	●	●
Verandah		●	●
Bath and Water closet	-	-	-

Figure 6: *Social Pattern between Residents in Two Bed Room Apartments*

Time / Space	Morning	Afternoon	Evening & Night
Living	●	●	●
Dining	●	●	●
Bed room		●	●
Kitchen	●		●
Verandah	●	●	●
Bath and Water closet	-	-	-

Figure 7: *Social Pattern between Residents in Three Bed Room Apartments*

Space \ Time	Morning	Afternoon	Evening & Night
Living	●	●	●
Dining	●	●	●
Bed room		●	●
Kitchen	●		
Verandah		●	●
Bath and Water closet	-	-	-

By questionnaire surveys in each housing type emphasizing on social relationship and used space of residents, the following findings can be carried out.

(1) Living and bed rooms are still used as social space within the family in urban apartments.
(2) Their social interaction time is mostly night time.
(3) The difference of Myanmar house is that flexible space or wide space in Myanmar house is used as common used space (or) social interaction space. In apartments, it is found that living and dining area are the most used area.
(4) When the combination of living, dining and kitchen area is provided, people use these areas for their social interaction and relaxation.
(5) From cultural point of view, it is difficult to meet all member of inhabitant because father usually works out and most of the children have to go schools and tuitions after finishing school time. Therefore, it can be at night time for their social relationship to meet each other.

Figure 8: *Social Pattern between Residents and Visitors in One Bed Room Apartments*

Space \ People	Father	Mother	Son or Daughter
Living	●	●	●
Dining		●	●
Bed room			●
Kitchen		●	
Verandah			●
Bath and Water closet	-	-	-

Figure 9: *Social Pattern between Residents and Visitors in Two Bed Room Apartments*

Space \ People	Father	Mother	Son or Daughter
Living	●	●	●
Dining		●	●
Bed room			●
Kitchen		●	
Verandah	●		●
Bath & W.C	-	-	-

Figure 10: *Social Pattern between Residents and Visitors in Three Bed Room Apartments*

Space \ People	Father	Mother	Son or Daughter
Living	●	●	●
Dining		●	●
Bed room			●
Kitchen		●	
Verandah	●		●
Bath and Water closet	-	-	-

According to the questionnaire surveys on one bed room, two bed room and three bed room apartments, the followings are found. The space which is used for social interaction between residents and visitors is mostly living room. Bed room is sometimes used when many visitors arrive at the same time.

(1) Most of the residents use kitchen and fire escape area for the interaction between the residents and neighbors.
(2) Moreover, most of housewives cannot live in kitchen for the long time except for cooking function because of congestion space and lighting. They mostly use living room.
(3) Therefore, living room is the dominant space for urban residents and it is needed to be large or flexible for urban living.

SHRINE SPACE

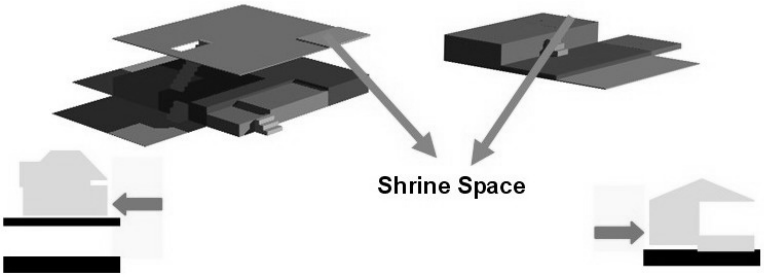


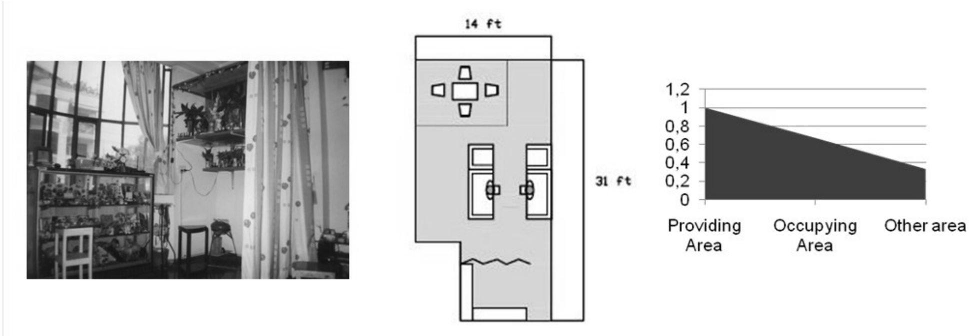
Figure 11: *Religious Space in Myanmar Houses*

Figure 12: *Religious Space in Urban Apartment*

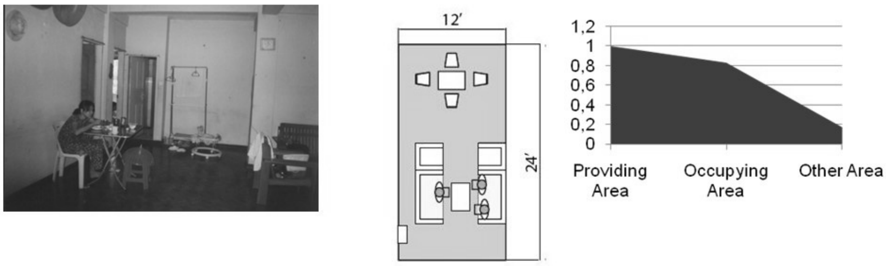
Myanmar people emphasize their beliefs by placing the shrine place (or) altar at the upper storey in two storey building. In one storey building, the residents place the shrine at the higher level. 6] In the walk up apartments, there is no defined space for shrine although there has still strong believes and cultural behavior in Myanmar. In most of the apartments, shrine spaces are found in living area by dividing living space or by placing at one corner of living area or by placing in living area near by entertainment things. If someone in household wants to pray Buddha, there can be disturbance while children are studying, or watching TV in living area. In some apartments, the people use verandah space as their shrine space.

EXISTING FURNITURE ARRANGEMENT AND ACTIVITIES

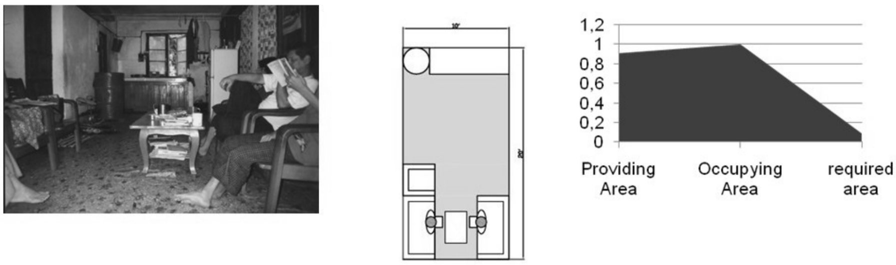
This analysis is presented the existing furniture arrangement, used space and activities of people in the urban housing. By using this way of analysis, it can be found that how the spaces are used according to the furniture arrangement and people's activities. Which space is being used for their activities mostly, which spaces are used for the multi- function and which spaces are needed to be functional for people's activities and their facilities are pointed out from this analysis. The following table shows the used space, activities, furniture arrangement and field photos to analyze furniture arrangement and activities.



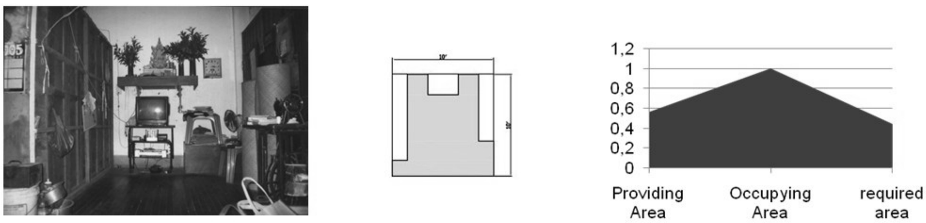
Living+
Dining
+Praying



Living+ Dining / Kitchen

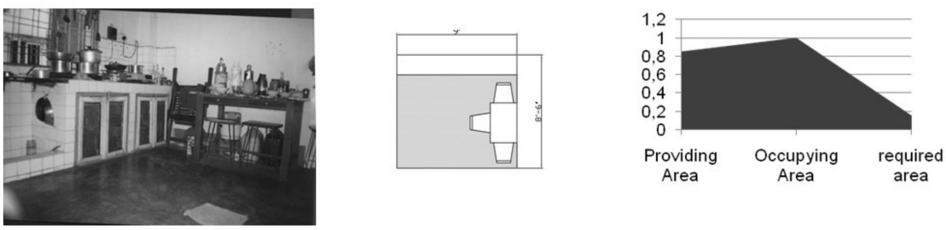


Living + Dining+ Cooking



Living+Praying+

Entertaining



Living / Dining
+ Kitchen

By analyzing the furniture arrangement, providing area and occupying area for activities, it is found that some spaces in some housings are very congested for facilities, furniture and utensils, and some are extra area. Some activities and spaces such as religious function are needed for residents. By looking the shrine area, it is evident that shrine space is also needed in the urban residents and it is needed to be as a separate area.

CONCLUSIONS

According to the analysis of zoning and flexible spaces, there is a common activity zone as a multi-functional hall in the urban apartments. It is formed in living and dining hall. Due to the changes of life style, people's domestic spaces are changed. Therefore, it must be recommended that the relevant spatial quality harmonized with the urban life style should not be disappeared the Myanmar residential effects. The traditional spatial pattern cannot directly adapt to the urban context. It can be transformed to the similar traditional residential spaces as flexible and double functional spaces. Also bed rooms in urban apartments should not be really fixed rooms. It can be constructed with foldable partitions which can be folded at the day time when the people need to use wide more space. On the other hand, it can also support to the flexibility of living and dining hall for the residents' activities and also for the social activities.

According to the analysis of people's activities and used spaces for their social activities, the living and dining hall room is the most used area and it is needed to be flexible and good communication. Master bed rooms and bed rooms are developed due to the development of urban living style. By knowing that, the provided space for the sleeping function should be transformed as double used function. It can also be assumed that the residents in urban conserve their Myanmar cultural value by understanding the place of shrine. They use living area partially for their religious function.

In urban areas, there are now nuclear families consisting of the parents and children. It is different in living style between urban and rural area. By field survey, it is found that the neighbors want to connect each other, although the design arrangement can't save access perfectly. According to their lifestyle and their business type and the required privacy, people usually close their doors.

It is needed to consider whether many bedrooms are required or not in the urban walk up apartments. As Myanmar is a rich country with natural resources, we found in the rural area houses that most of the furniture and household things are made by timber, bamboo and rattan which are very flexible to use and to fold up when we need to have more space. But in the urban apartments, most of the spaces are fixed with concrete walls. There has some mixed used function and spaces because of the fixed spaces. So that, some spaces as bed rooms should be recommended that: it should be double used function according to the day and night time by using foldable curtains or partitions. Also there should be a storage area in the apartment in which we can store furniture and the things easily which will use according to the space function and the time.

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THE MAR VISTA TRACT AS A CASE STUDY - SKELETON AND INFILL AS APPLIED TO HOUSING DEVELOPMENTS

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ABSTRACT

The Mar Vista Tract is a subdivided housing estate of 52 households in the Los Angeles suburbs that was developed in 1948. The architect, Gregory Ain, designed the houses with folding and sliding walls to provide flexibility in the number of bedrooms, ranging from one to three, in response to the changing life cycles of the inhabitants.

Sixty years hence, among these buildings, as many as 51 housing units have been preserved (i.e. only one has been rebuilt), and the Tract has been designated as a Historical Preservation Overlay Zone (HPOZ), or historic district, of the City of Los Angeles. An adjacent subdivided housing development built contemporaneously provides contrast with its chaotic streetscape of two-story houses.

The flexibility of housing unit plans that are adaptive to varying family structures over the inhabitants' life cycle as anticipated by the architect is cited as one of the reasons for their preservation. Through the history of modifications discovered in a survey of 90% of the housing units, this paper identifies those factors that afford the exceptional townscape of the Tract through the preservation of the housing units as the "skeleton" of the housing development, and analyzes this basis through a comparison with the adjacent development.

Keywords: The Mar Vista Tract, stand-alone housing development, alteration/remodeling, townscape

INTRODUCTION

Skeleton and Infill in Stand-alone Housing

The Mar Vista Tract is a subdivided housing estate of 52 housing units developed in 1948 in the suburbs of Southwestern Los Angeles designed and planned by architect Gregory Ain and landscape architect Garrett Eckbo. All 52 units are single-story wood construction with identical plans consisting of three bedrooms, a living/dining room and bathroom, with a total floor area of 1,150 square feet. At the time, the sales cost was $11,000, which was high in comparison to similarly scaled houses in the area. (Figs.1 and 2)

As shown in Figure 3, this development was initially planned for 102 housing units; however, this plan was aborted due to the poor sales of the 52 units of the first phase. The remaining lots were sold to another developer, who altered the road configurations and constructed 57 conventionally designed built-for-sale housing units a year following the Mar Vista Tract development. This housing estate will henceforth be referred to as "the adjacent housing development".

The vast distinction between the flat-roofed exterior and housing plan of the Mar Vista Tract and the conventional built-for-sale salt-box type homes marketed toward the average homeowner is cited as the reason for the poor sales of the Tract units. In their apprehension regarding the sales of the remainder of the lots, the Federal Housing Administration terminated funding, which was the direct cause for the termination of the Tract development.

Sixty years hence, the disunified streetscape of the adjacent housing development provides a starkly contrasting example. On the Tract, only one unit out of the 52 has been rebuilt, while the remaining 51 units have kept their original façades. Moreover, as shown in Figure 4, the landscaped area of the Tract designed by Eckbo has greatly flourished, creating a unified and bucolic townscape. In 2003, the City of Los Angeles designated the Tract as a Historical Preservation Overlay Zone (HPOZ), or historic district. More recently, in addition to its appraisal as an exceptional townscape, the upward trend in attention to postwar Modern architecture and recognition of Ain as a notable architect have driven the real estate value of the Tract units to several times that of the adjacent development.

On the other hand, the adjacent development has followed the course of the average housing district in suburban Los Angeles; along with the rise in living standards after the war, every housing unit has been either rebuilt or extended, and homes with fenced-in front yards have emerged, resulting in a disorderly residential townscape.

This paper defines the factors that maintain the outstanding appearance of the townscape (areas seen as public) of the Mar Vista Tract as "skeleton", and the interior spaces and backyard that have been altered with the passage of time as "infill". In other words, this paper attempts to apply the Open Building concept to a stand-alone housing area.

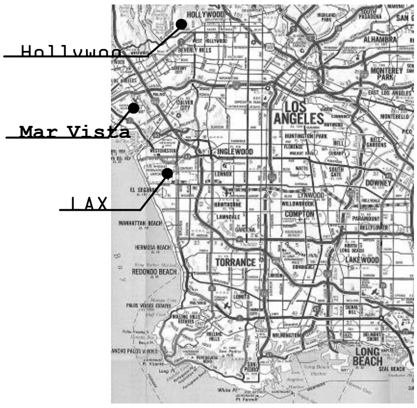

Figure 1: *Site location of Mar Vista Tract*

Figure 2: *Typical housing unit of Mar Vista Tract*

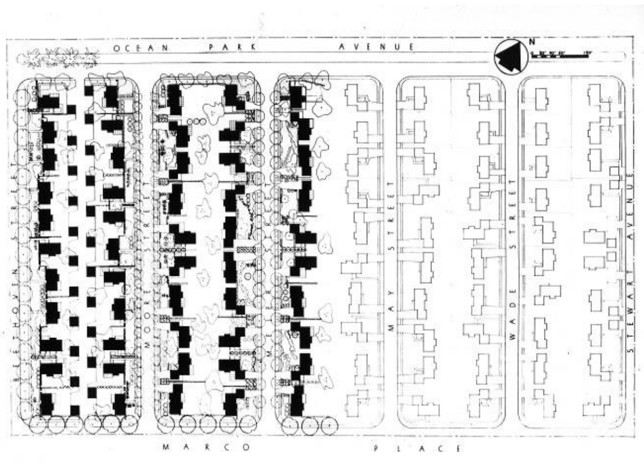

Figure 3: *Initial site plan (Left side: Realized 52 Tract units, Right side: Unrealized area which became the adjacent development)*

Figure 4: *The landscaped area of Mar Vista Tract*

Factors to Improve Residential Townscapes

In Japan, stand-alone housing built for homeowners are the most expensive personal asset for the average citizen. Most homeowners believe that while only the interior of the unit can be altered in collective housing, stand-alone housing affords the freedom to build or plant whatever they please. Yet urban lots for stand-alone housing are constricted with a distance of only 1 to 2 meters between them. If every homeowner were to build their homes without restraint, townscapes would become uneven and disorderly; this is the state of the townscapes of the suburban areas in present-day Japan.

Homes should be able to respond to the temporal changes such as the rise of their inhabitants' living standards as well as to societal changes. Furthermore, because inhabitants themselves change, it is necessary to address diversity in such aspects as family structure, personal interests and values. Interior spaces of the home and private exterior spaces (backyard gardens) correspond to such changes as they arise. The townscape of a residential area in its entirety with its public presence, however, should be something that forms over time with the cooperative contributions of each housing unit within a range of certain standards.

This paper proposes that the compositional elements of the townscape of the Mar Vista Tract provide potential as a skeleton for stand-alone residential areas, and argues this concept while comparing it against a conventional built-for-sale housing development as exemplified in the contemporaneous adjacent housing estate. Five field surveys were conducted on 41 Tract housing units between November 2003 and August 2005 (over a total of 51 days) to compile detailed investigations of the unit interiors and exteriors and to conduct interviews.

OUTLINE OF THE MAR VISTA TRACT

Architect Gregory Ain (Fig. 5) was born in Pittsburg, Pennsylvania, to parents of Polish heritage in 1908(d.1988). After his studies at the University of Southern California, School of Architecture and work at the office of Richard Neutra, in 1935, he established his own practice where he designed a total of 193 houses. Influenced by Neutra and Rudolf Schindler, his architecture is replete with a light Californian Modernist and hygenic sensibility. Ain's socialist ideals sparked his endeavors to make housing accessible to the working- and middle-classes. His also applied efforts to research in low-cost housing and the manufacturing of industrial products in collaboration with Charles Eames. Ain taught at Southern California University from 1953 and served as the Dean of Pennsylvania State University School of Architecture in 1963. As one of his most representative works, the Mar Vista Tract best reflects his philosophical ideals. In 1950, a Mar Vista Tract housing unit was displayed in the garden of the Museum of Modern Art in New York.

Mar Vista's landscape architect, Garrett Eckbo (Fig. 6), was born in New York in 1910(d. 1999). With teaching experience in Japan, his designs were influenced by Japanese landscape design. While Eckbo collaborated with Ain on numerous projects, for the Mar Vista Tract, his contributions extended beyond landscaping into concept development and planning.

Figure 5: *Gregory Ain*

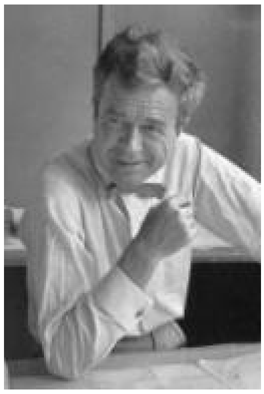

Figure 6: *Garrett Eckbo*

Comparing the Mar Vista Tract with the Adjacent Housing Development

Table displays an outline of comparative data on the Mar Vista Tract and the adjacent housing development. While the average site area of the latter development (540.8 m^2) is slightly more than that of the Mar Vista Tract (637.8 m^2), the average total floor area of both developments were originally approximately the same (95 m^2 and 93 m^2, respectively).

Between the years 1950 and 1980, the scale of the standard American dwelling increased from 800 ft^2 (approx. 72 m^2) to 1,600 ft^2 (approx. 144 m^2).[1] This increase is also reflected in the floor areas of both the Tract and the adjacent development; currently, the average floor area of the Tract housing units is 149.9 m^2 and that of the adjacent development is 163.9 m^2. In terms of rebuilding, only one unit of the Mar Vista Tract has been rebuilt in contrast to ten new structures on the adjacent development. While lower than the average 44-year lifespan of a house in the US[2], this rate is notably higher in comparison to that of the Tract. Likewise, while eight of the units on the adjacent development have been converted to two-story structures, there have been no level conversions made to the Tract units.

Initially, both developments featured a lawn and low hedging in the front yards (Fig. 7). Today, although the housing units of the adjacent development have the same volume of planting in the front yards, there is a difference in the volume of planting in the backyard areas. In comparison to the 47 Tract housing units with trees extending to the roof level, those of the adjacent development are kept low due to the use of the backyard areas as a utility space, and only 18 units (31.6%) have planting up to the window height. As apparent in the aerial photograph of Figure 8, the volume of planting along the streets is greater in the Mar Vista Tract; thus the Tract feels more lush in greenery than the adjacent development.

The average term of occupancy at the Mar Vista Tract is 22.2 years. Regarding occupancy over the past ten years, 16 units in the Mar Vista Tract have changed ownership in contrast to 92 units of the adjacent housing development. This comparison reveals the very low turnover rate of the Tract.

		Mar Vista Tract	Adjacent Housing Development
Conditions at Time of Development	Year of Development	1948	1949
	Total Housing Units	52	57
	Average Total Floor Area	93□	95□
	Garage Area	33□	37□
Current State (As of Aug. 2005)	Average Total Floor Area	149.9□	163.9□
	Average Site Area	637.8□	540.8□
	No. of Rebuilt□ Units	1	10
	No. of Two Story Units	0	8
Turnover units over 10 yr. period		16	92
*Note: The average of the turnover units over the past 10 yrs.			

Table: *Outline of the Mar Vista Tract and the Adjacent Housing Development*

Figure 7: *The Mar Vista Tract and the adjacent housing development (Left hand: The Mar Vista Tract, Meier Street, Right hand: Adjacent development, Westminster Ave.)*

Figure 8: *Aerial Photograph of Current Conditions (Left side: Mar Vista Tract, Right side: Adjacent Housing Development)*

The Basis of the Maintained Excellence of the Mar Vista Townscape
—The Skeleton in Stand-alone Housing

There are five elements of the design of the Mar Vista Tract that serve as the basis for the exceptional maintenance of its townscape: 1) The use of a four-foot module; 2) The flexibility of the unit plan; 3) The connection of the service core to the street; 4) The large-boned "skeleton" of the streetscape design and integration of adjacent outdoor areas; and 5) The pride of the inhabitants and intimacy of the community. The following is a description of these elements.

Use of a Four-Foot Module

Ain's purpose in unifying the design of all Tract housing units was to simplify their construction and reduce building costs. Along the same vein, he applied a four-foot module to each component of the units so that they could be mass-produced, while eliminating waste in material and reducing costs.

Simple extensions to the Tract units are facilitated by the internalizing the four-foot-high sections beneath the eaves and simply disassembling and repositioning the same modular-based exterior fittings. Many of the original Tract inhabitants added extensions to their units in this way, and also used the four-foot module for subsequent extensions. The premise for applying the four-foot module to extensions is the maintenance of the height of the eaves (i.e., the ceiling heights). A townscape of buildings that maintain the heights of the roofs and exterior fittings will likewise maintain the overall appearance even after extensions are made.

The same logic applies to the traditional townscapes of Japan. Traditional Japanese homes are entirely composed of 90-centimeter modules, and the roof configurations that vary according to region are formed from the standardized beam members (i.e., eaves) that connect the columns. Due to the unity of the roof forms and standardized size of the openings below, traditional Japanese townscapes maintain an overall unity despite their composition of independently built houses.

Flexibility of the unit plan

Taking into consideration the growth of the inhabitants' children, Ain separated the rooms with sliding and folding doors that allow a variation of four plans with one to three bedrooms (Fig. 9).

Similar to the traditional houses of Japan, the flexibility of the plans of the Tract units are separated by movable partitions; this concept was applied in response to the increase in the number of children per household and their growth against the historical backdrop of the baby boom ignited by the return of WWII veterans. However, this application of flexibility to the number of bedrooms that corresponded to the growth of children was used only by the original Tract inhabitants. Subsequent inhabitants optimized the flexibility of the unit plans for various other purposes.

Through a series of field investigations, it was found that 31 out of the 41 households surveyed keep the folding walls open to create a space integral with the living area. And in 13 out of 41 units, the sliding walls are kept open to create a single bedroom area, while only six of the 41 units surveyed close them to form two bedrooms, while another six units use the rooms for entirely different functions. At present, there are no Tract residents using the three bedroom configuration, and there are no households with a nuclear family structure with a full-time housewife and husband surrounded by their children as envisioned by Ain at the time of planning.

Not exclusive to the Mar Vista Tract, from the time after WWII up to the present, there has been a trend in diminishing family sizes, aging populations, lifestyle diversification and an increase in the average of residential area. At Mar Vista, the average household family unit is 2.1 people, where consequently the reduced family size allows for more space per person. Although 95 m^2 may appear constrained for the present-day nuclear family, it is ample space for a household unit of 1-2 people. Even in the case of nuclear families, only a maximum of about ten years would be necessary for the use of two children's rooms, and after the growth and independence of the children, only the parents, or one or two inhabitants will remain. Thus, in the design of homes, flexibility is an important factor to allow for an increase in room size in accordance to the decrease in the size of the family unit. The flexibility of the plan in residential design serves toward the changing life styles and diversity of the inhabitants, allowing a family to continue to occupy the same housing unit throughout their life cycle.

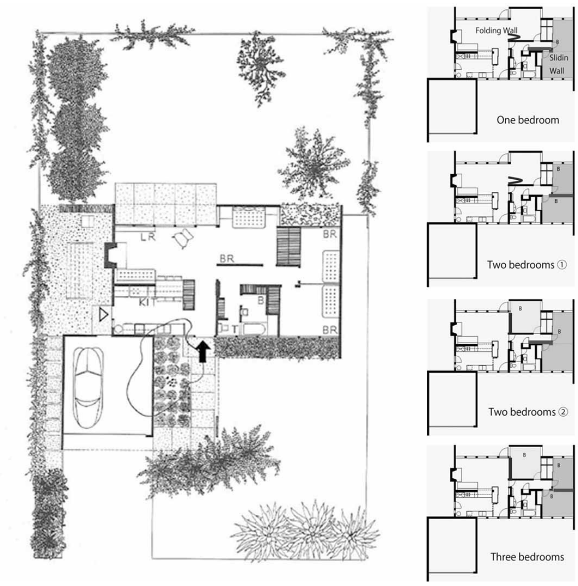

Figure 9: *Typical plan and four types of room configurations*

Connection of the service core to the street

In consideration of improved efficiency of housework for women after the war, Ain positioned the kitchen in the center of the house and close to the entrance. Accordingly, the entire household domain including the front street, foyer, living room and bedrooms could be seen from the kitchen (Fig. 10). Likewise, the bathroom and water-use areas were located alongside the kitchen facing the entry, while the living room was placed facing the backyard. This organization maintained the privacy of the kitchen and as an extension of the living room, the backyard could be used as an outdoor living space.

As shown in Figure11, at the time of the Tract development, in the typical American built-for-sale home, the entrance and living rooms were arranged facing the front yard along the street in front of the house, whereas the kitchens and water-use areas were located against the backyard, and bathrooms were also located the furthest from the entrance. When renovating a building, kitchens and water-use areas are the most costly. Consequently, in the event that changes in life styles necessitated remodeling in a Tract housing unit, since the kitchens and water-use areas faced the entry, extensions were made to other parts of the house. This resulted in few changes to the appearance of the façade, maintaining the original townscape (Fig. 12).

In traditional Japanese cities, in all stand-alone residences, whether machiya (townhouses) or nagaya (tenement houses), the service/utility areas are located in the same part of the house. In the city, not only is it economical from the angle of urban management that service/utility areas of a house (those with strong connections to the urban infrastructure) have fixed locations, there are other advantages, such as the patterns of daily life that reflect the service/utility areas of a home (eg. the relationship of the kitchen to the dining area), establishing a conventionally accepted understanding of its public and private spheres.

Figure 10: *View of Living and Kitchen areas from the backyard*

Figure 11: Typical postwar American built-for-sale housing unit

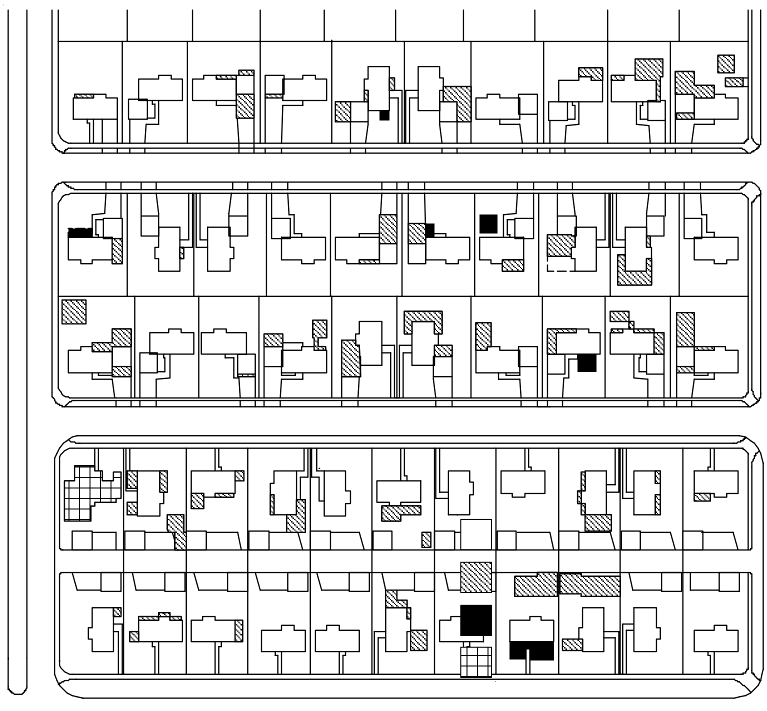

Figure 12: Conditions of Alterations

Original plan

Alterations with no change to unit façade

Alterations that affected the unit façade

Rebuiltion

Large-boned "skeleton" of the streetscape design and integration of adjacent outdoor areas

The housing units of the Mar Vista Tract are dispersed along three 66-foot wide broad streets. Flanking the streets, between the houses and the sidewalks, there is a common green area on which trees with different fragrances are planted in an arrangement of one variety per street. As it can be observed in Figure 13, while at the time of development, these trees were no taller than a dog, at present they are over 20 m and fill the skies above (Fig. 14). Although the townscape envisioned by Eckbo was a bit simpler (Fig. 15), he understood that the large trees would become the features of the street space, and thus one can appreciate that an exterior designer tends to consider the passage of time more than an architect.

As shown in Figure 16, the planting design is integrated and unified between neighboring housing units. In comparison to typical built-for-sale housing units built independent of one another, the integrated front yard spaces produce a coherent residential townscape that, even sixty years hence, other than one unit with a low wall with a flower bed, most units left the exterior space untouched, allowing it to flourish as intended.

Figure 13: *The newly developed Mar Vista Tract*

Figure 14: *The present townscape of Mar Vista Tract*

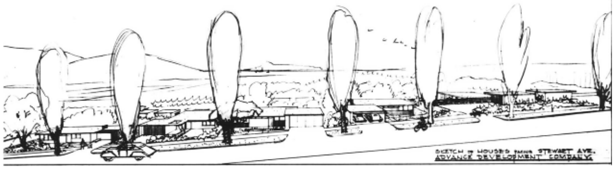

Figure 15: *Photo of Tract under development*

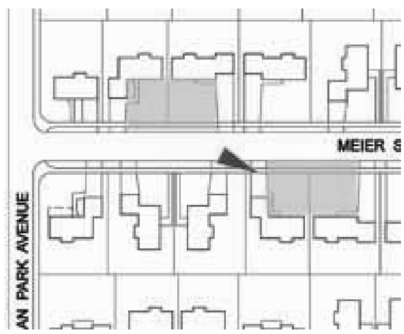

Figure 16: *Front yard lawn area*

Inhabitants' pride and intimacy of the community

At the time of development, since the Mar Vista Tract was not accepted by the mainstream, as it was reflected in the poor sales of its units, its original inhabitants were mostly comprised of intelligentsia who appreciated the value of modern design and Gregory Ain supporters. A majority of the subsequent occupants were either acquaintances or relatives of the former residents. Most of the owners of the Mar Vista Tract units who bought them at present inflated values are those who recognize the excellence of the design and are affiliated with the arts. Stemming from the long term occupancy of the Tract units in comparison to other developments, the resulting hierarchy of the residents serves as the basis for an intimate neighborhood community.

Furthermore, amid the circumstances of the designation of the Tract as an HPOZ, interest has risen from one housing area to another, inciting efforts to restore renovated the Mar Vista Tract units back to their original design.

SUMMARY

Through a comparison to the adjacent housing development, when the following factors become the skeleton for a stand-alone housing development, as in the Mar Vista Tract, they can provide the basis for the formation of an attractive townscape:

1) Housing units designed with a module that applies to all parts of the house.

2) A flexibility in the plan that avoids the use of fixed walls.

3) A fixed location of service/utility spaces in relation to the road and a generous site that allows for extensions and rebuilding without altering the appearance of the streetscape.

4) The pride of the inhabitants for their home and residential area and intimate communities.

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DESIGN OF HIGH-RISE MODULAR OPEN BUILDINGS

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ABSTRACT

Modular construction is widely used for residential buildings of 4 to 8 storeys. In the context of open building systems, modular construction provides a systemised approach to design in which the benefits of prefabrication are maximised. There is pressure to extend this form of construction to more than 12 storeys for residential buildings. This paper presents a review of modular technologies, and describes load tests and analysis on light steel modular walls in compression that are used to justify the use of light steel technology to support higher loads.

However, the effect of installation and geometric inaccuracies must be taken into account in the design of modular buildings. The cumulative out of verticality should not exceed 8mm per module in a vertical group with a maximum of 50mm relative to ground datum. Using these geometric tolerances, the notional horizontal force used to evaluate stability of a group of modules should be taken as a minimum of 1% of the applied vertical load on the modules.

Robustness to accidental load effects is important in all high-rise buildings and it is proposed that the tie force in the connections between modules should be taken as not less than 30% of the total vertical load applied to the module, and not less than 30 kN in both directions.

Keywords: Modular; Structures; Stability; Steel; Tolerances

INTRODUCTION

Modular construction comprises pre-fabricated room-sized volumetric units that are normally fully fitted out in manufacture and are installed on site as load-bearing 'building blocks'. Their primary advantages are:

- Economy of scale in manufacturing of multiple repeated units.
- Speed of installation on site.
- Improved quality and accuracy in manufacture

The current range of applications of modular construction is in cellular-type buildings such as hotels, student residences, military accommodation, and social housing, where the module size is compatible with manufacturing and transportation requirements. The current application of modular construction of all types is reviewed in a recent Steel Construction Institute publication (Lawson). A paper (Lawson, Ogden et al) describes the mixed use of modules, panels and steel frames to create more adaptable building forms.

There are two generic forms of modular construction, which affects directly their range of application:

- Load-bearing modules in which loads are transferred through the side walls of the modules – see 0
- Corner supported modules in which loads are transferred via edge beams to corner posts

In the first case, the compression resistance of the walls (comprising light steel C sections at 300 to 600 mm spacing) is crucial. Current heights of modular buildings of this type are limited to 4 to 8 storeys, depending on the size and spacing of the C sections.

In the second case, the compression resistance of the corner posts is the controlling factor and for this reason, Square Hollow Sections (SHS) are often used due to their high buckling resistance. Building heights are limited only by the size of the SHS that may be used for a given module size (150 × 150 × 12.5 SHS is the maximum sensible size of these posts).

Figure 1 *Partially open sided module with load-bearing walls (courtesy PCKO Architects)*

Resistance to horizontal forces, such as wind loads and robustness to accidental actions, become increasingly important with the scale of the building. The strategies employed to ensure adequate stability of modular assemblies, as a function of the building height, are:

- Diaphragm action of boards or bracing within the walls of the modules – suitable for 4-6 storey buildings
- Separate braced structure using hot rolled steel members located in the lifts and stair area or in the end gables – suitable for 6-10 storeys
- Reinforced concrete or steel plated core – suitable for taller buildings

Modules are tied at their corners so that they act together to transfer wind loads and provide alternative load paths in the event of one module being severely damaged. A recent paper (Lawson, Byfield) reviews the robustness requirements for modular construction based on 'localisation of damage' in which modules are removed individually to assess the ability of the rest of the modular assembly to support the applied loads at the accidental limit state.

For taller buildings, questions of compression resistance and overall stability require a deeper understanding of the behaviour of the light steel C sections in load-bearing walls and of the robust performance of the inter-connection between the modules. A further issue is that of installation and manufacturing tolerances, which cause eccentricities in the compression load path and also lead to additional horizontal forces applied to the modules.

HIGH-RISE BUILDING FORMS USING MODULAR CONSTRUCTION

Modular construction is conventionally used for cellular buildings up to 8 storeys high. However, there is pressure to extend this technology up to 15 storeys or more. One technique is to cluster modules around a core to create high-rise buildings without a separate structure in which the modules are designed to resist compression and the core provides overall stability. This concept has been used on one major project called Paragon in west London, shown in Figure 2, in which the modules were constructed with load-bearing corner posts.

Figure 2 *Modular building stabilised by a concrete core (courtesy Caledonian Building Systems)*

An adaptation of this technology is to design a 'podium' or platform structure on which the modules are placed. In this way, open space is provided for retail or commercial use or car parking. Support beams should align with the walls of the modules and columns are typically arranged on a 6 to 8 m grid (7.2 m is optimum for car parking), as shown in Figure 3.

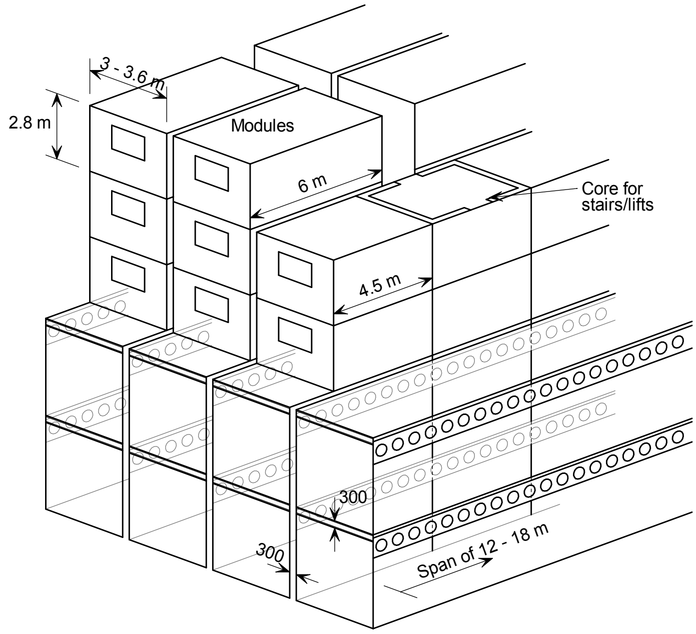


Figure 3 *Modules supported by cellular steel beams acting as a podium*

COMPRESSION RESISTANCE OF MODULAR WALLS

The following tests were carried out to verify the structural action of the load-bearing walls in a typical modular system. Two series of tests were carried out; one on 75 mm deep × 45 mm wide x 1.6 mm thick C sections at the Building Research Establishment (BRE) and one series on 100 mm deep × 42 mm wide x 1.6 mm thick C sections at the University of Surrey. The panels were loaded using a spreader beam, and the test arrangement is illustrated in Figure 4. The sensitivity to eccentricities in loading was also investigated.

Figure 4 *Light steel wall failure by overall buckling*

Orientated strand board (OSB) was attached externally and, in some tests, cement particle board (CPB) was included to assess the difference in restraint provided by the boards. Two layers of 15mm fire resistant plasterboard were used internally, as required for 90 minutes fire resistance. In two of the tests, this plasterboard was omitted.

Additional tests were included on taller walls to examine the influence of slenderness. The boards were fixed using 2 mm diameter air driven nails at 200 mm centres, as used in production of the wall panels. The boards were attached 2 mm short of the web of the top and bottom track so that the boards were not loaded directly.

The walls were first loaded up to around 100 kN to represent serviceability loading before the loading incrementally to failure. The test failure loads are also presented in Table 1. Failure occurred at a vertical displacement of less than 5mm.

Analysis of wall tests

Composite action occurs due to the additional stiffness of the boards attached to both sides, which increases the buckling resistance of the wall. From bending tests on the walls, it was found that the effective inertia is increased by 62% for boards fixed on both sides but by only 2% for OSB board on one side. Calculated compression resistances to BS 5950-5 are presented in Table 1. The strip steel was S350 grade supplied to EN 10327 and measured strengths were in the range of 380 to 405 N/mm^2. The model factor is the ratio of the test failure load to the compression resistance to BS5950-5, based on measured material strengths.

Wall Test Details 75 x 45 x1.6C:	Wall height (m)	Eccentric loading (mm)	Failure load per C section (kN)	Design resistance to BS 5950-5 (kN)	Model Factor
OSB boards on one side	2.45	0	64	48	1.33
Plasterboard on one side, OSB on the other side	2.45	0	97	76 (inc. boards)	1.27
	2.77	0	90	56 (inc. boards)	1.61
	2.45	10	79	56 (inc. boards)	1.41
	2.45	20	62	47 (crushing)	1.31
Plasterboard on one side, CPB on the other side	2.45	0	96	76 (inc. boards)	1.26
	2.45	20	52	47 (crushing)	1.10
100 x 42 x1.6C: Plasterboard on one side	2.30	0	57	51	1.13
CPB on one side	2.30	0	70	61	1.14

Model factor = Failure load/ Design resistance

Table 1 *Failure loads of C section wall studs and comparison with Code design to BS 5950-5*

The stiffening effect of the boards leads to a reduction in slenderness and increase in buckling resistance. Using the measured increase in bending stiffness due to attachment of the OSB and plasterboards, the effective slenderness of the bare C section is reduced by 22%. For a 2.45 m high wall, the slenderness was 79 in the major axis direction, and so the effective slenderness becomes $0.78 \times 79 = 62$, which gives a buckling strength of $p_c = 263$ N/mm^2. The calculated compression resistance was 67 kN, which is 70% of the test result of 97 kN. This suggests that the buckling curve used for cold formed sections is conservative. In addition, local buckling of the flanges of C section may be reduced by the attachment of the boards, which increases the effectiveness of the cross-section.

The eccentricity of load application using a plate below the wall accentuates local crushing, as well as overall buckling. The crushing resistance may be taken into account by considering a reduced compression area, A_{eff}. Because the buckling resistance is approximately 70% of the crushing resistance, it follows that buckling will occur first unless the crushing resistance is reduced by over 30%. A 10 mm eccentricity caused a 19% reduction in load capacity and a 20 mm eccentricity caused a 36% reduction in capacity.

The series of tests on walls using 100 x1.6C sections with boards on one side showed that minor axis buckling is prevented for 1.6mm thick steel, but the increase in compression resistance relative to BS 5950-5 was less than for the 75mm deep sections.

STRUCTURAL ACTION OF GROUPS OF MODULES

The structural behaviour of an assembly of modules is complex because of the influence of the tolerances that are implicit in the installation procedure, the multiple inter-connections between the modules, and the way in which forces are transferred to the stabilising elements such as vertical bracing or core walls. The key factors to be taken into account in the design of high-rise modular buildings are:

- The influence of initial eccentricities and construction tolerances on the additional forces and moments in the walls of the modules.
- Application of the design standard for steelwork to this relatively new technology.
- Second order effects due to sway stability of the group of modules.
- Mechanism of force transfer of horizontal loads to the stabilising system.
- Robustness to accidental actions for modular systems

These aspects are considered as follows:

Influence of constructional tolerances

For structural steel frames, the UK National Structural Steelwork Specification for Building Construction, NSSA (BSCA) presents the maximum out-of-verticality of a single column as $\delta_H \leq$ height/600, but $\leq$ 5 mm per storey. Furthermore, for buildings of more than 10 storeys high, the out-of-verticality over the total height is limited to a maximum of 50 mm.
Eurocode 3-1-1Clause 5.3.2 (EN 1993-1-1) limits the out-of-verticality of a single column to L/200, but this is reduced by a factor of 2/3 when considering the average out-of-verticality over a number of storeys (i.e. $\delta_H \leq$ L/300). The permitted out of verticality of a whole structure is obtained by multiplying this value for a single column by a factor of

$\left[0.5\,(1+\frac{1}{m})\right]^{0.5}$ for m columns in a group horizontally. The result tends to $\delta_H \leq L/420$, which is higher than in the NSSS. A further requirement in the approach of Eurocode 3 is that this out-of-verticality is considered in combination with wind loading.

These positional tolerances may not reflect the practicalities involved in modular construction because of the difficulties in precisely positioning one module on another and in making suitable connections. For a single module located on another module, it is proposed that the maximum out of alignment is 12 mm on plan relative to the top of the module below, which requires careful control on site, especially in windy conditions.

For a vertical stack of modules, the cumulative positional error, e, due to installation can be partially corrected over the building height, and may be taken statistically as e $=12\sqrt{n}$, where *n* is the number of modules in a vertical group. Typically, for *n* = 10, the total cumulative out of alignment that is permitted becomes approximately 40 mm. An alternative simplified procedure that is easier to control on site is to limit the cumulative out of alignment to 5 mm per module in orthogonal directions.

Added to this positional error is the possibility of a systematic manufacturing error in the geometry of the module. For a single module, the maximum permitted tolerance in geometry may be taken as illustrated in Figure 5.

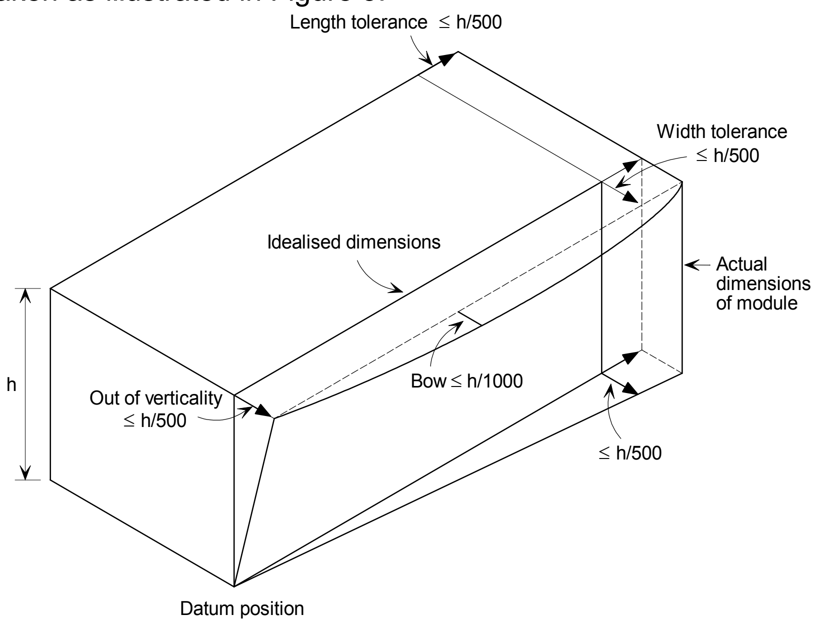


Figure 5 Permitted maximum geometric errors in manufacture of modules

However, over a large number of modules, the average out of verticality of the corner posts may be taken as half of the permitted maximum tolerance per module, or *h/1000*, where *h* is the module height (typically 3m). Therefore the total permitted out-of-verticality δ_H over the building height, consisting of *n* modules vertically, is a combination of out of alignment and geometric tolerances, as follows:

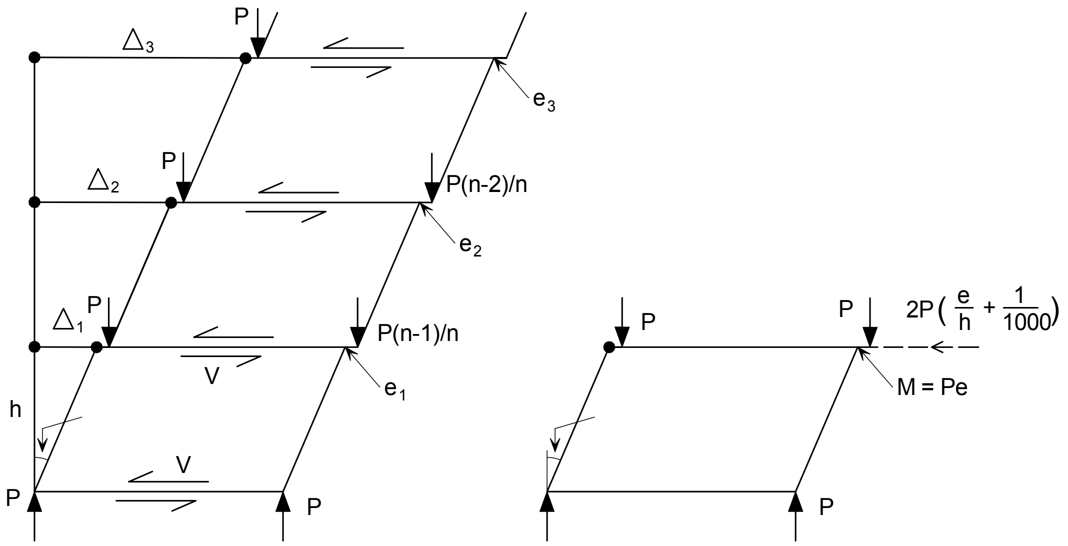
$\delta_H \leq e + nh/1000 = 5n + 3n = 8n < 50$ mm (1)

Using this formula , it follows that $\delta_H =$ 50 mm for n=6 storeys, which is equivalent to approximately h/350 per floor.

Application of Notional Horizontal Forces in Modular Construction

A way of assessing the sway stability of a group of modules is using the notional horizontal force approach for steel framed structures given in Clause 2.4.2.3 of BS 5950-1. For steel frames, this horizontal force corresponds to 0.5% of the factored

vertical load acting per floor, and is used in the absence of wind loading. It represents the minimum horizontal force that is used to assess the sway stability of a frame.
The combined eccentricity on a vertical assembly of modules takes into account the effects of eccentricities of one module placed on another, and the reducing compression forces on the walls acting at the increased eccentricity with height. This effect is illustrated in Figure 6. The equivalent horizontal forces required for equilibrium are transferred as shear forces in the ceiling, floors and end walls of the modules.



(a) Shear in end walls due to eccentric loading for a four-sided module

(b) Transfer of eccentric loading to stabilising system for corner supported modules

Figure 6: *Combined eccentricities acting on the ground floor modules*

The total additional moment acting on the base module due to an effective eccentricity Δ_{eff} is given by:

$$M_{add} = P_{wall}\Delta_{eff} = P_{wall}\left[\frac{(n-1)}{n} + 2\frac{(n-2)}{n} + 3\frac{(n-3)}{n}.......+\frac{1}{n}\right](e + h/1000) \qquad (2)$$

P_{wall} = compression force at the base of the ground floor module
n = number of modules in a vertical assembly
e = average positional eccentricity per module

As a good approximation, it is found that the following formula holds for the effective eccentricity of the vertical stack of modules, Δ_{eff} , as a function of *n*:

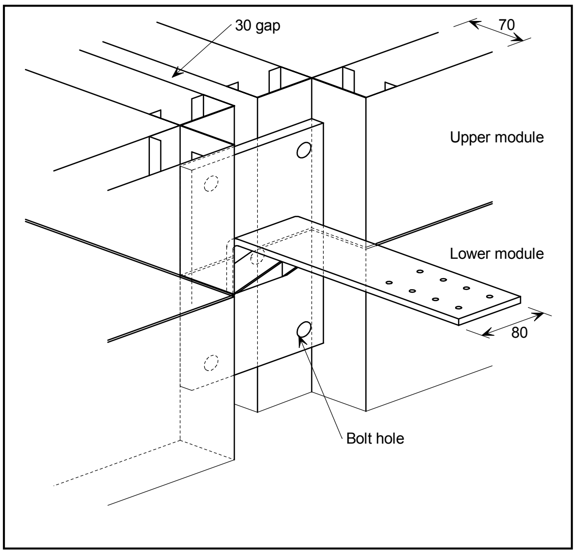
$$\Delta_{eff} = \left[\frac{n-1}{6}\right](8\ n) \qquad (3)$$

For modular construction, it is recommended that the notional horizontal force is taken as a minimum of 1% of the factored vertical load acting on each module, which reflects the higher tolerances in modular construction. It is used as the minimum horizontal load in assessing overall sway stability of the structure. If the modules are unable to resist this horizontal force, the notional horizontal forces are combined at each level and transferred to the stabilising system.

Forces at module inter-connections

The structural inter-actions within a group of modules are complex. The horizontal forces may be transferred by tension and compression forces in the ties at the corners of the modules by utilising the diaphragm action of the base and ceiling of the modules.

Shear forces may be transferred through the continuous corridor members and the connection of the modules to the corridor may be made by a detail of the form of Figure 7. The extended plate is screw fixed on site to the corridor members and is bolted to the re-entrant corners between the modules so that it also acts as a tie plate. This detail is not used to provide vertical support to the corridor, which is supported on continuous angles as part of the manufacture of the modules.



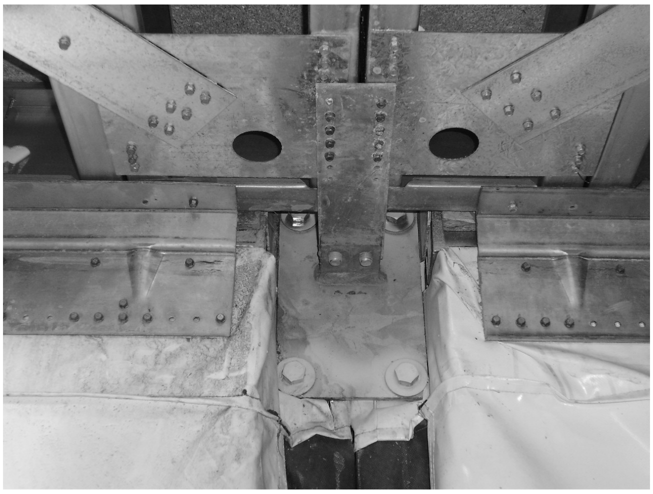


Figure 7 *Connection between the corridor cassette and modules- sketch detail (left) and actual detail (right)*

Robustness to accidental damage

The ability of a group of modules to resist loads in the event of serious damage to a module at a lower level is dependent on the development of tie forces at the corners of the modules (Lawson, Byfield et al). The loading at this accidental limit state is taken as the self weight plus a proportion of the imposed load. Figure 8 shows the results of a finite element analysis of a module when one corner support is removed.

The applied load is taken as 10kN/m per wall for a heavy weight module using the partial factors noted above. The torsional stiffness of the module is developed by diaphragm action of the walls. From this analysis, the maximum horizontal tying force is equal to 26% of the total load applied to the module (rather than 48% in a simple cantilever formula) and the maximum vertical load is approximately 40% of the total load.
For simple design, it is proposed that the tie force should be taken as not less than 30% of the total vertical load applied to the module and not less than 30 kN in both directions. The same connections may be used to transfer wind loads to braced walls or cores for overall stability.

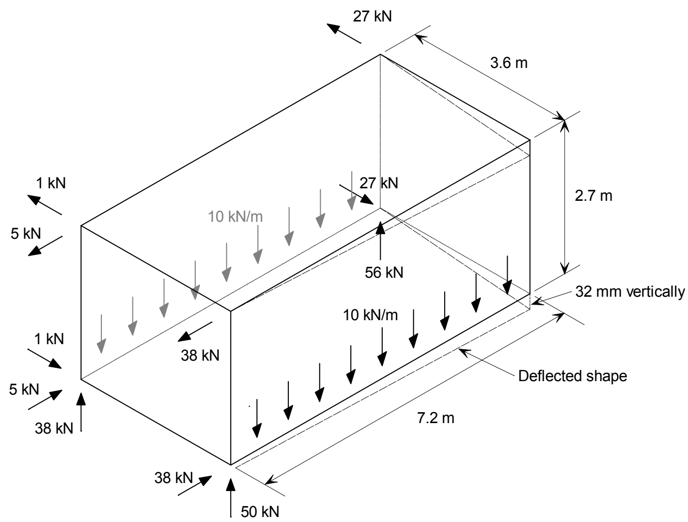


Figure 8 *Tie forces when support to one corner of a module is removed*

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OCCUPANT SATISFACTION IN RESPECT TO INDOOR ENVIRONMENTAL QUALITY IN ENERGY EFFICIENT CERTIFIED BUILDINGS IN MALAYSIA

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ABSTRACT

Malaysia’s Green Building Index (GBI) encourages non-residential building to save energy and provide a high quality environment to the occupants. The highest point which is 35, will be awarded for energy efficiency and the second one 21 point, for indoor environmental quality (GBI, 2009). This challenging task to the building designers is in shaping the realization of the occupants’ indoor environmental comfort while controlling energy use for office working space.

This study has been conducted to investigate the occupants’ satisfaction in the working-space of energy-efficient office building in a tropical country, Malaysia. Two office buildings, which have been classified as energy efficient buildings in the Klang Valley, Malaysia were selected for case study. One of them is a Low Energy Office (LEO) Building, designed for low energy consumption and the other is a Green Energy Office (GEO) Building which was designed with renewable energy. The results showed that the occupants were satisfied with their work-space, with “slightly greater satisfaction” in the LEO building than in the GEO building.

Keywords: Comfort; Satisfaction, Indoor environment; Building Energy Efficiency
.

INTRODUCTION

In 2009 The Government of Malaysia launched the formal framework of Green Building Index (GBI), to provide measurement rating system for the accreditation of green buildings in Malaysian. Six criteria have been considered for the measurement (Fig.1).

Part	Item	Maximum Points	Score
1	Energy Efficiency	35	22
2	Indoor Environmental Quality	21	21
3	Sustainable Site Planning & Management	16	14
4	Material & Resources	11	10
5	Water Efficiency	10	6
6	Innovation	7	7
TOTAL		100	80

***Fig. 1**: summary of final score (GBI, 2010) (Shafii, 2009)*

United States Green Building Council (USGBC) classifies green buildings as buildings which have been designed with consideration of reducing or eliminating negative impacts on the occupants and environment (USGBC, 2009). Malaysia's Green Building Index for non-residential buildings includes indoor environmental quality as the second important aspect to be measured.

A study conducted by Abbaszadeh (2006), found that the occupants of a building which has been classified as one of the green buildings in the United States, were dissatisfied with its lighting and acoustic quality. The occupants have suggested the need of improvements in controlling the lighting system, and recommended innovative strategies, to accommodate sound privacy needs in open plan or cubicle office layouts. Another study conducted by Galasiu (2006) showed that the application of day lighting for office buildings required the inclusion of energy-efficiency lights, which are suitable to occupants, into the lighting system. Another study conducted by Hummelgaard (2007) showed results with high degree of satisfaction among the occupants. The building indoor environment was with natural ventilated workspace. Similarly, a study showed that a naturally ventilated and passively cooled buildings can be highly appreciated by occupants if they are designed with proper indoor climate (Wagner, 2006).

EE Buildings should be energy efficient compared to conventional buildings. In order to ensure good performance, the architects should take occupants' interactions with the building control systems into account at the design stage. This study was conducted to measure and evaluate the indoor environment quality of the two EE Buildings which looked into the occupants' response; such as how energy efficiency buildings are performing from the occupants' perspective. If they are performing well, this indicates that the goal is being achieved. A questionnaire survey requires the occupants to rate their workspace environment in terms of the most important indoor parameters in the tropics which influence the occupant satisfaction on the workspace; dry bulb temperature, humidity and air movement (Ariffin, 2002), in addition to lighting. The survey assesses indoor environmental quality (IEQ) in energy efficient office buildings requiring the occupants to directly respond on their satisfaction with IEQ in the workspace.

The comfort of building occupants is dependent on many environmental parameters including air speed, temperature, relative humidity and quality in addition to lighting and noise. The main physical parameters affecting IEQ are air speed, temperature, relative humidity and quality (Omer, 2008). The indoor comfort is dependent on several factors that include air temperature, air humidity and air movement (Zain-ahmed, 2002).

OBJECTIVE

The study aims to investigate how the two energy efficient buildings, LEO and GEO, have succeeded with their goal as EEB from the occupants' perspective, bringing User-Centered Design approach to the energy efficient issue, and the users satisfaction with their workspace; in terms of thermal comfort, air movement and visual comfort.

The significance of the paper comes from the fact that the imitation of the showcase building without evaluating, involves the repetition of mistakes. Similarly surveying the occupant satisfaction in the two buildings would be as occupancy evaluation to upcoming buildings. Thus the main purpose of this post occupancy evaluation study is to provide recommendation to improve the indoor environment of upcoming energy efficient building in tropics, Malaysia.

RESEARCH METHODOLOGY

A three phases of methodology are adopted in this study. The first phase was to define the area of the study; local climate and building description. The second phase of the study is based on physical measurement of the buildings environment. Finally, the third phase of the study relied of questionnaire survey to collect responses from building occupants and this constitute a source of data to declare the occupants' perspective on their satisfaction at their workplace.

The study was carried out in the months of September and October 2009. A direct survey was conducted in the two chosen buildings. This is to evaluate the important parameters of indoor environment quality, that might be influenced the satisfaction of occupants on the workspace. Whilst the physical measurement is to compare the responses of the occupants to the same environment judged against the Malaysian Standard (MS 1525).

100 responders were selected from the two EE buildings were collected. The sample size is 50 responders per building. In addition to more general questions, the questionnaire address directly related to the workspace indoor environmental quality parameter such as; temperature, humidity (dampness), air movement and lighting,. The questionnaire survey collected have been evaluated together with measured data; outdoor/indoor temperatures, day lighting, air-velocity and humidity from SKYE and BABUC/A data loggers. The survey took one week to make reliable evaluation for indoor environment quality in the two buildings.

Local Climate

As Malaysia is an equatorial country (Kula Lumpur 3.13°, 348 km north), therefore its climate characteristics are relatively uniform throughout the year (Fig. 2). There are no large variations in temperature, relative humidity, and solar radiation during the daytime of the year, the variation significantly accurse throughout the day. The mean monthly temperature vary not more than 1.4^0C. From the mean average of 27^0 C was found in November to 28.4^0 C in May. The average mean temperature in a day ranges from 31.58^0 degree Celsius during the daytime to 24.56 ^{0} C during the night.

The monthly average of solar radiation in Kula Lumpur; Subang station is 1.39-1.83 kWh/m², with monthly sunshine duration ranging from 9 to 13 hours. The high solar radiation arises during August to November, (the survey and field measurement of this study contacted within this period), and January to February, while the low solar radiation occurs in April and May with 13.72 and 13.04 respectively.

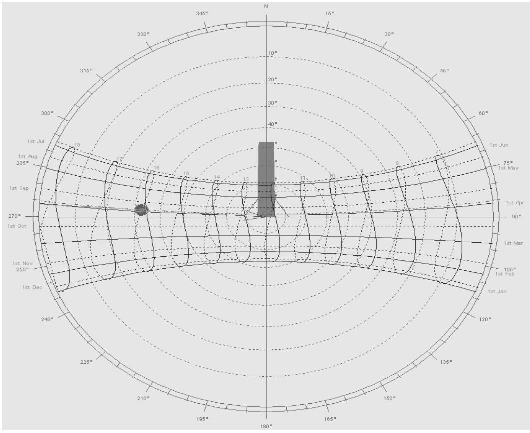


Fig.2: Stereographic diagram to Kuala Lumpur, Malaysia Latitude: 3.10 (12 Sep., 14:00hr)

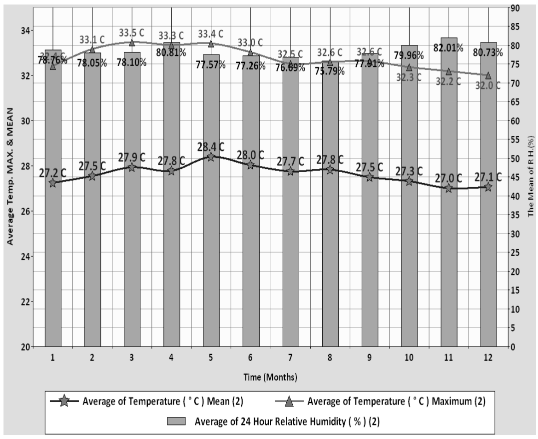


***Fig.3**: Monthly average of Relative Humidity and its relation to average max. and mean Temperature. (source: author besed on 10 years Subang J. station)*

Also the humidity is uniformly high all through the year due to the large body of water surrounding the peninsular Malaysia. The mean monthly relative humidity over the period was 82 % found in August and never falls below 75.79 % in November.(data based on 10 years 1999 to 2008, Subang Station) (Fig. 3).

Buildings and Experimental Settings

In Malaysia about 70% of energy consumption is used for cooling the environment (Abdul Rahman, 2006), this is why passive strategies is so important to efficiency reducing energy consumption in office buildings. The two office buildings LEO building and GEO building were selected to represent an energy efficient office building in the region and are built to be a showcase to the public. The LEO building (Fig 4) was awarded the ASEAN Energy Award in 2006 (Hong, 2007). It was built with ambitious goal of energy saving more than 50% compared to conventional new office building in Malaysia, with energy index of 114 kWh/m2 year compared to typical conventional of 275 kWh/m2 year (Lau, 2009). Whereas, the GEO building, (Fig. 5), has been stated in Malaysian's GBI as a showcase to Green Energy Office and the details of the building is cited on GBI website (GBI, 2009). The GEO building energy index of 65 kWh/m2 year compared to typical conventional of 250 to 300kWh/m2year (Lau, 2009).

__Fig.4:__ Low Energy Office (Wagner) Building, Putrajaya. (Source PTM)

__Fig. 5:__ Green Energy Office Building (PTM), Bandar Baru Bangi. (Source PTM)

***Fig. 6**: (a) Setting up the indoor data logger, (LEO building; **(b)** setting up the indoor data logger, GEO*

Instrumentation

“Babuc /A” data logger for indoor and “Skye” data logger for outdoor logging with a number of sensors (outdoor/indoor temperature, air movement, lighting, and RH sensors) were connected to the data logger, (Fig. 6-a&b). The outdoor temperature sensor was placed in a balcony in, LEO, at about 2m away from the building façade whereas placed on the roof in GEO case. The indoor temperature, air movement and RH sensors were stationed on a tripod located at about 1.0 m above the floor level. The readings of each sensor were recorded by the logger at 5 minutes interval for twenty-four hours duration in two weeks.

The satisfactory level of occupants was tested and obtained with a questionnaire and rate their satisfaction perceptions on their workplace environment covering most factors influencing the IEQ (Ho et al., 2009), they are lighting:(glare, brightness), thermal comfort (temperature, dampness, and air movement). The satisfaction level evaluated at two different locations of working space which is near window within less than 3 meter distance and away from window which is more than 3 meter distance. The questionnaires were given to 50 staff of each building. The number of responses was 40 (80%) in the GEO office, and 30(60%) in the LEO office. A likerts 5-point scale was used to range the level of satisfaction with endpoints from -2“very dissatisfied” to 2“very satisfied” level 0 of satisfaction is considered as positive or satisfied as the occupants who claim that were not complaining on any advantage or disadvantage.

RESULTS

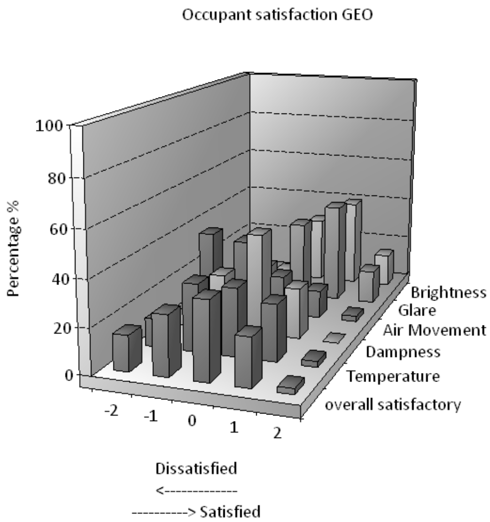
Measurements

The finding shows (Fig. A-1, Appendix), the workspace air temperature and the relative humidity in LEO building and GEO building measured during the sunny 7 days, the same days as the questionnaires were administered. LEO building showed the peak temperatures average of the 5 working days at 15:00h with 21.97 °C. While in the GEO it was 23.75 °C at 16:00h. The difference of indoor air temperatures between the two buildings were approximately 1.78 °C higher in GEO than in LEO. Differently on the off days the peak temperatures at 16:00h were approximately 0.75 °C higher in LEO than in GEO. The Figure A-1 shows also that the indoor temperature in the two buildings were lower than outdoor temperature before the office core hours. At 08:00h. the difference in LEO between indoor and outdoor was 23.40 °C and 25 °C respectively with 1.60 °C lower on indoor. In GEO indoor was lower with 1°C, as 24/25 °C indoor/outdoor. The measured relative humidity varies 60.03 % at 08:00h to 58.94 % at midday in LEO. Likewise in GEO relative humidity varies with 59.83 at 08:00h to 55.33 at midday. The indoor air movement in both buildings is approximately zero; with maximum average recorded were 0.01m/s.

The illuminance level of both buildings shows (Fig. A-2, Appendix) at distance less than 3m from the window and height of 0.75 m from the floor reaches to 300 lux, in LEO open plan workspace, before 09:00 a.m. and after 05:00 p.m. and never reaches to 400lux. For GEO the illuminance was 300lux after 10:00 a.m. and before 05:00 p.m., and exceeds 400 lux at 01:00p.m.

Questionnaire

Comparing the results of surveys in the two EE buildings, showed the occupants in LEO building are more satisfied in the following areas (Fig. 7): Air movement; humidity, temperature and; overall satisfaction with workspace, whereas the occupants in GEO building are quite more satisfied in lighting than in LEO building. In both building away to window the study (Fig. 8) found that the occupants are more satisfied with two indoor parameters: temperature and; lighting than those near the window. Similarly the figure 9 shows the occupants in GEO express dissatisfaction with day lighting and they prefer to work with artificial light. Whilst in LEO the occupants state their satisfaction to the mixed-mode with slightly more preference to day ligting.



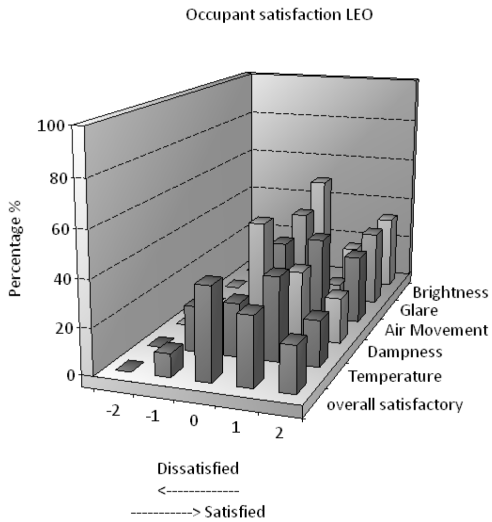


Fig.7: Illustrate the responses of occupants in the two buildings to all indoor environment parameters.

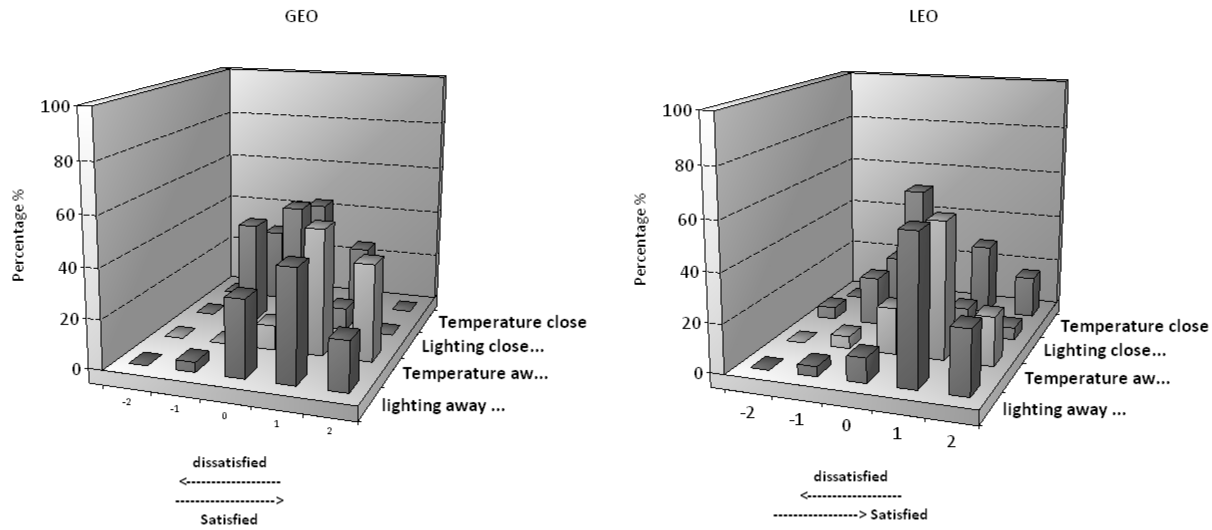


Fig.8. Illustrates the occupants' preference to workspace location with respect to the distance from the window

Figure 10 shows the votes in both of EE buildings, within the category "_2 to 2". the survey found that the occupants in LEO are largely satisfied with their workspace, only less than 5% rating it as unsatisfied and 95% of them felt satisfied in their workspace with the thermal aspects, and 93% satisfied with visual aspects. Whereas in GEO about 58% of occupants stated a satisfaction to the thermal comfort parameters, and there are about 41% of the occupants are unsatisfied. On the contrary, the occupants in GEO show positive response to the visual comfort with 93% are satisfied.

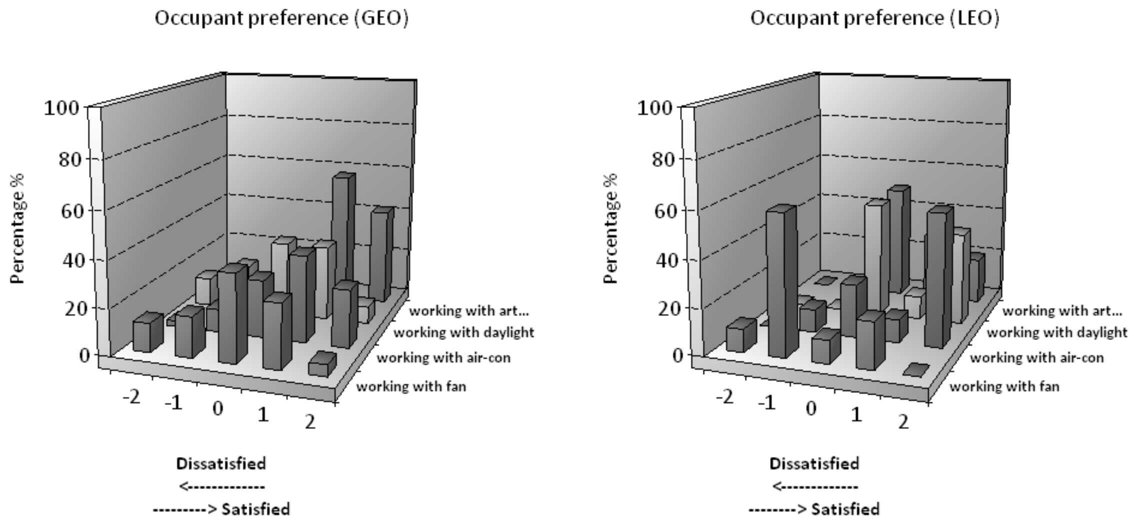


Fig. 9. Perceives the votes of occupants in both buildings to their preference with respect to lighting and temperature control

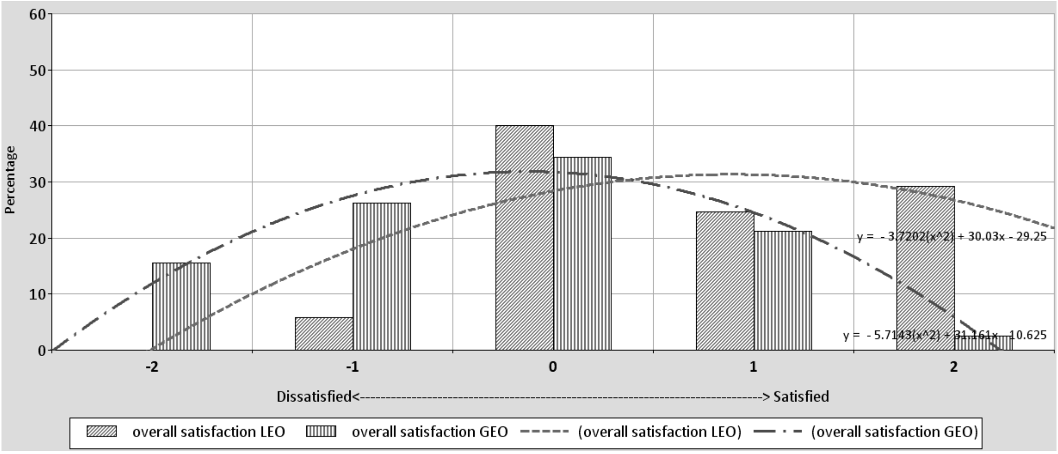


***Fig. 10**. Relationship between overall satisfaction in LEO and GEO. As the "0" is considered positive the chart shows that the occupants are satisfied with their workspace in both buildings with "slightly more" satisfaction in LEO than in GEO*

DISCUSSION

Based on field measurements, energy efficient buildings are perceived to be satisfied for their occupants. For thermal comfort the ideal conditions for Malaysian has been found to be between 22°C to 26°C (Zain-Ahmed, 1998) (Ministry of Science, 2007). Another studies presented the variation of thermal comfort in Malaysia of about 24°C to 28°C (Abdul Rahman, 2006) (Lee Chung Lau, 2009). The analysis of the two buildings (Fig. A1&7), shows that introducing air-con to sustain the indoor environment will increase the occupant satisfaction as occupants in LEO building show more satisfaction to temperature 22°C, than those in GEO with 23.75 °C, after employs air conviction system to indoor environment. However, physical measurement found that the indoor temperature lies on comfort range of Malaysian standard, which is below 24 °C; the mean recommendation of MS1525. However, the indoor temperature in the two buildings was found lower than outdoor temperature before the office core hours, 08:00h. Nevertheless, the occupants show desire to implement additional mechanical controlling to maintain their indoor environmental quality. Linked to this and more highlighting on occupant judgment the study found that the occupants in both buildings away to window are more satisfied than those near the window. This proposes that the amount of heat gain and glare are still a problem near the window in these two energy efficient buildings.

The results also showed that the workspace lighting of the two buildings lies in an acceptable range for most of the time, complying the Malaysian Standard (2007) which recommends that the interior lighting for offices should be between 300 and 400 lux. The difference in the two buildings is that the occupants in LEO building show the occupants' preference are in mixed-mode, where it should be consistent with what was proposed at its design stage, to attain reduction in energy consumption of 18% for lighting when this data compared to other government buildings (Lee Chung Lau, 2009). In GEO the day lighting was implemented with almost 100% (PTM, 2009), however the impact showed the occupants in GEO are less satisfied with its lighting system due to the brightness and glare, the LEO occupants shows their preference to use blinds with artificial light to get a satisfied luminance level and avoid the glare.

The ideal comfortable thermal environment for Malaysia is to have a sufficient air movement and a cool surrounding (Abdul Rahman, 2006). The recommended air movement to obtain satisfaction in workspace is varied from 0.15 to 0.7 m/s (Ministry of Science, 2007). This study showed occupant's judgment was negative to the air movement in the workspace. This confirms the result from measurement that found the air movement in two buildings is (0.01m/s maximum), which is lower than the air movement recommended to air-conditioning office in tropics (Ministry of Science, 2007).

According to ASHRAE when 80% of occupants are satisfied, this indicates to be an acceptable environment for building (ASHRAE, 1992). With respect to this concept, the survey found that the occupants in LEO are largely satisfied with their workspace, this due to implementing additional affective mechanical cooling and controllable interior blinds. In GEO building about 58% of occupants stated a satisfaction to the thermal comfort parameters. This is probably due to the orientation and their workspace position against the windows. A study suggested providing each occupant a flexible adjustment to their personal working space indoor comfort with for example, ceiling fans and open-able window (Nicol, 2007). For tropical climate as in Malaysia the reduction of thermal condition by passive design in where the average air temperature is about 33°C with relative humidity of about 80% is not enough to reach to the occupants comfort without the additional of active systems (Abdul Rahman, 2006), particularly for introducing the ample air movement to control the high humidity of tropical climate.

CONCLUSION

The study examines satisfaction at the two EE buildings, in Klang-Valley, Malaysia, in the context of occupants. The study found, in general, that the occupants are in satisfaction with indoor environment quality of their workspace in the two buildings with preference to LEO building where implementing air-con. The study concluded that the strategies employed in energy efficient buildings have been, on average, effective in improving occupant satisfaction by eliminating air movement that was seen by not to their satisfaction. This position was confirmed from measurement was registered on workspace.

Comparing the measurement and occupants' responses of environmental quality in the workspace of the energy efficient buildings in Klang-Valley, Malaysia, revealed that responses were based on the occupant's experience with the questionnaire surveys. Therefore, it is important to take occupant's interactions with the control systems into account when designing EE buildings, especially within tropical climate.

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APPENDIX

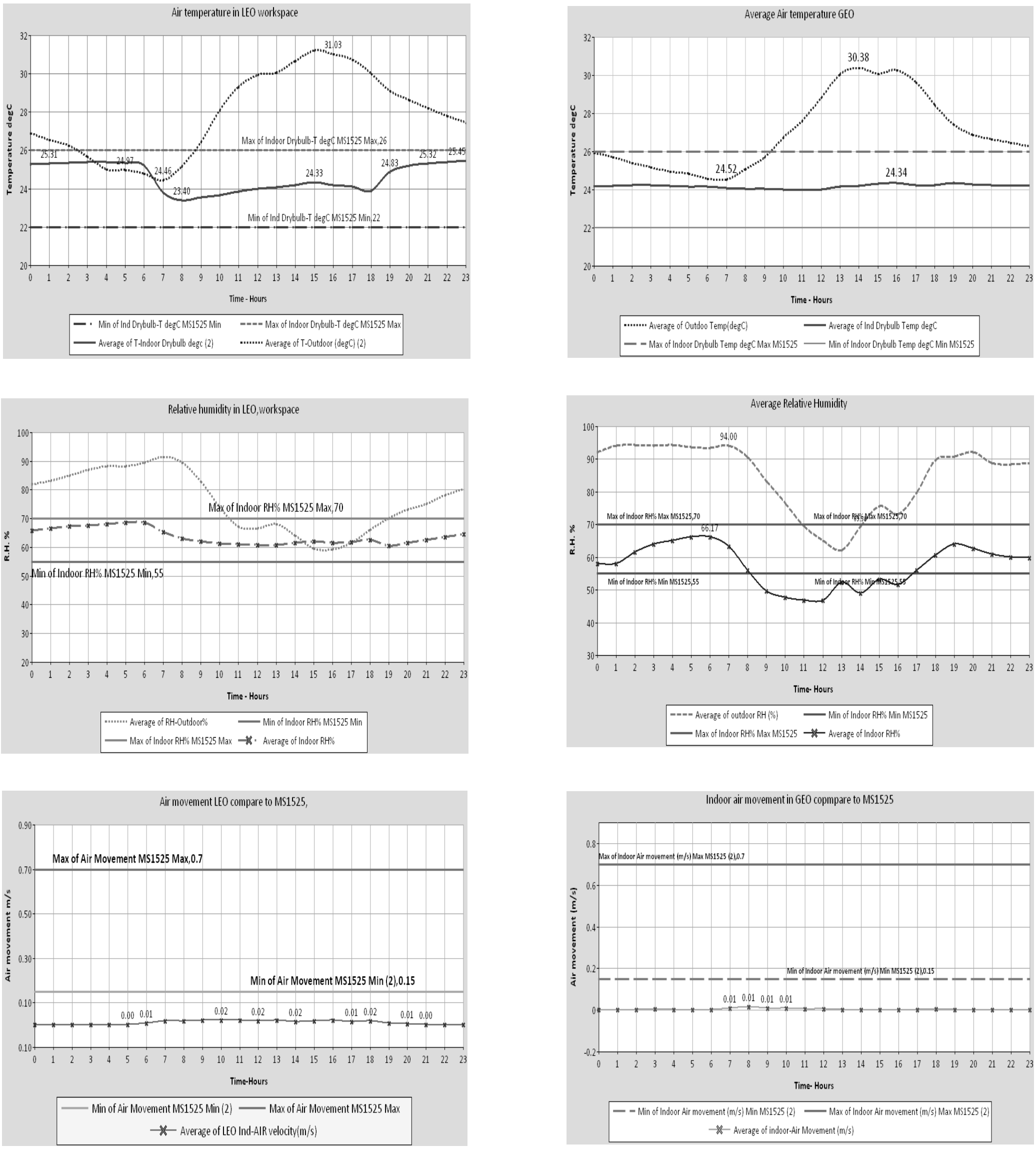

Fig. A-1. *Illustrate the main indoor thermal comfort parameters: Air Temperatur; Relative Humidity; and Air Movement to workspace of Energy Efficient, LEO building & GEO building.*

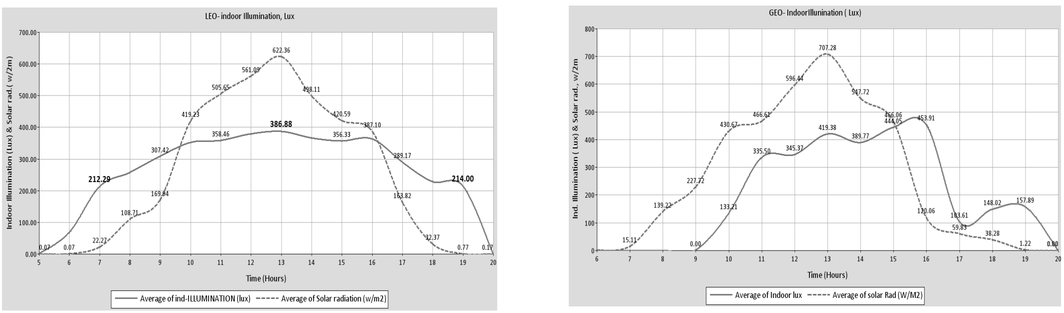

Fig. A-2. *Illustrate the indoor Lighting of workspace during working Hours to Energy Efficient Buildings; LEO & GEO.*

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RESEARCH FOR A CONSTRUCTION SYSTEM FABRICATED BY COMPUTER NUMERICAL CONTROL MACHINERY

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ABSTRACT

The main issue of this study is to create a Construction System, based on prefab pieces, made in a CNC machine. This system has to insist in the recyclability of all components. The system should allow for a bioclimatic performance of the whole building. The construction system will allow interior division flexibility. This means that the building user could easily move the partitions by himself or herself. In order to guaranty precision and security on the construction site and simplicity on the transportation system, there must be a complete coordination between the project and the building site. Adaptable to any geometry and measurement. Most of the prefabricated buildings, are not suitable for a non orthogonal site. Working with a CNC machine can avoid this.

Keywords: CNC, Recyclable, Bioclimatic, Adaptable, Flexible

APPROXIMATION TO A CONSTRUCTION SYSTEM

The following paragraphs and pictures show how the approximation of this Construction System has been.

The main goals of the construction system are the recyclability of all elements, energy saving, bioclimatic performance, economy, accuracy and safety in the building site and simple procedures to write the project documentation.

Far from creating new architectural forms and styles, we can say that creating new spaces for architecture is not the purpose of this research. The work is based in standard and normal spaces: it is not the main issue of this research, to create new scenarios.

Neither is the purpose of this research to create new installation facilities.

The first steps made, have tried to define an optimal building form. So the optimal building form means that the building, has to be as bioclimatic, as adaptable, as recyclable, as flexible and as precise as possible.

Nowadays, in order to make a building more flexible, it is necessary that all the installation could go by independently from the partition or structure. Guarantying an independence will make it easier to transform a kitchen space into a bedroom.

When designing a pipe pathway, it is appropriate that all tubes can be placed between the ceiling and the floor, for horizontal pieces. When it is a vertical section, it's better to place them without disturbing every-day spaces of the building. It's also appropriate that the tube could be registrable in all its length.

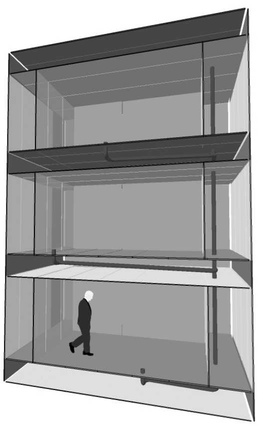

***FIGURE1**: finding the optimal form*

It is proved that a double facade system is the best choice to accomplish bioclimatic functioning of the building. In a nut shell, it's easier to get a comfortable acclimatization inside when we have double protection skin that includes a big air space in between.

We can say that we have a primary space, which people normally use, and a secondary space, that can be used for quotidian human use, but also a space which allows for pipes and installation flexibilities. And then a third horizontal space, exclusively for pipes and structure.

So if we see this form, then, we can easily embody the structure in this way, by using a Vierendeel or a Truss joist and a double support structure.

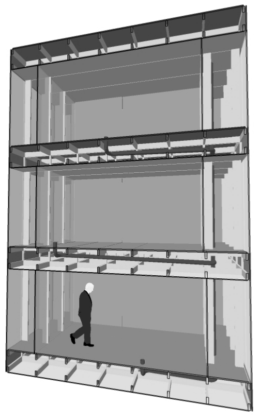

***FIGURE2:** embodiment of the structure*

APPROXIMATION TO AN OPTIMAL STRUCTURE

It will not be pre-established, but in the previous works, the structure pieces have been approximately 5x18cm. The process to get a optimal structure scheme, has been contrasted by three different types, and finally we have chosen one. In the end, the structure scheme could be simplified in a diagram like the one shown below. The first calculation showed that a building of 4 floors could be built with this system. The structure, in case of need, could be reinforced with steel.

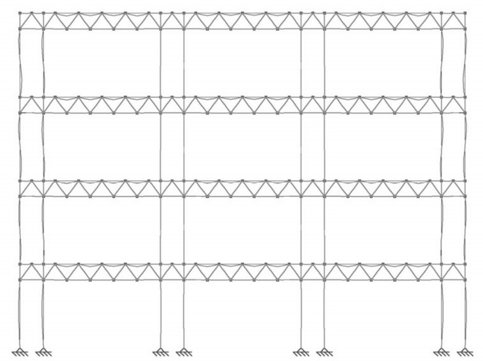

***FIGURE 3:** diagram made from the structure calculation and the movements on it.*

The reinforcements will be considered as a part of the system, so in case it will be needed, each piece will be coordinated with the rest of the pieces, in the way that all reinforcement elements will have a hollowness already made for the pieces. All the solutions for the reinforcements will be predesigned, and it will be proper in the future, to have a catalogue of solutions for this purpose.

APPROXIMATION TO BUILDING PROCEDURE

How can all these pieces be produced in a proper or a synchronized manner? CNC technologies offer a solution. Nowadays, after making a precise 3D model, it's easy to produce each element of the building in a proper CNC machine. The furniture industry is already using this technology. This way, working on the building ground will be just assembling the pieces fabricated in the factory. For the development of the Construction System, it will be necessary to create a specific plug-in between the CAD that will be used for elaborating the building project and the CAM that the CNC machines use. This plug-in or program, will offer a library of solutions, also the possibility to adapt to the geometry of the place and calculate different aspects of the building such as the structure and the thermal insulation.

And of course, if this construction system wants to work well in the market, its price has to be competitive. The uncommon parts compared with a ``normal´´ building are the structure and the partition. The first studies made in this field, show that the quantities of the budget referred to these uncommon elements are similar to those in a normal construction system. But this construction system works better for achieving energy savings. An edification built with this system saves at least 30 percent of the consumed energy compared to a similar construction made with common systems. It has to be said, that once the pieces have been fabricated, a none specialized person could easily assembly the building with a proper and computerized guide, using bar-codes for recognizing pieces and for placing them in the designed place.

To accurate the process of the construction system, it´s necessary to define some details. This definition will be proved by making prototypes and testing them in specialized laboratories. It is shown in the next pictures, how the construction system is during the building site. Anyway, it has to be said that, for now, the foundation system hasn't been redeveloped. This means that the foundation that are used in this system are normal or common.

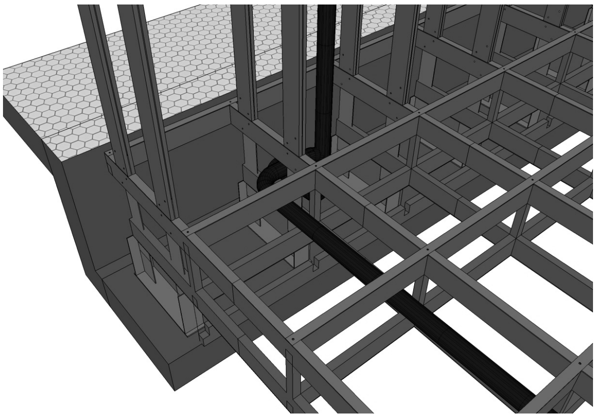

***FIGURE4**: the foundation system will require special attention as not to damage the soil ground of each place. The structure is based in the foundation. The reinforcement is already precut and available to put it in the hollowness of the structure the pipes have enough place to move along their spaces. These pipes can ``appear´´ whenever they are required, by cutting the floor, partition or ceiling panel when it is needed.*

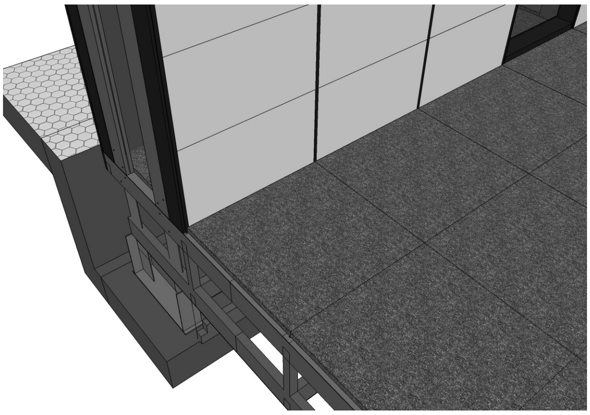

FIGURE 5: *the floor's and the ceiling´s panels, already precut in the CNC machine, are put on their place. the facade´s double skin is assembled. It's a design choice to make this secondary space habitable or just consider this place for a wardrobe, installation box or whatever else. Of course, it will depend on what length we leave for this secondary space, and then see if it's possible to make it usable.*

ADAPTABLE TO DIFFERENT USES

The system is both flexible in structure, in partition and in installations. The joists of the structure and partition could be opened or closed with a simple wrench. So the user, with the help or guidance of a architect (or similar), could move the partition, the installation or even the structure.

All this is supported by a flexible installation, partition and structure scheme. Almost everything is moveable, The only element that should be kept in place or fixed on every floor, it´s an installation shunt (even this could me movable but not recommended).

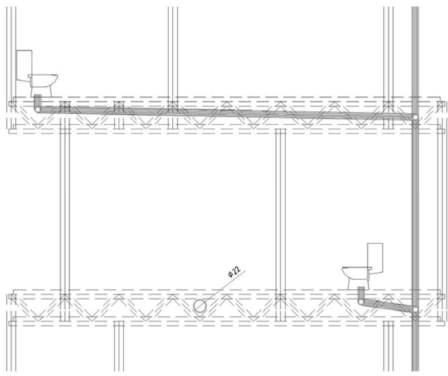

FIGURE 6: *as it is shown in the figure, the system's elements are moveable from one floor to the other .*

I will show an example of a hypothetical case. Let´s say we can make a 4 story building in a 900x600 cm plot and that we have 4 different types of use, which are:

a.-artist's atelier: a diaphanous space with a big terrace plus a toilet.

b.-couple apartment: living-room, kitchen, bedroom and a bathroom.

c.-bachelor apartment: a diaphanous space and a bathroom.

d.-office: a diaphanous space plus a toilet.

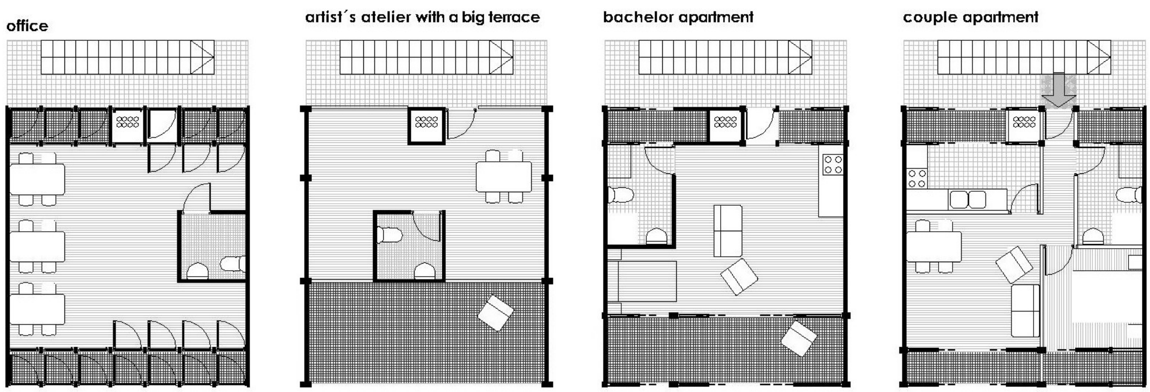

__FIGURE 8:__ All these types can be used and be combined in different stories. Just the installation shunt and the staircase is maintained in every floor.

Buildings and places change from hand to hand . If we want to have this adaptability, there must be a maintenance, a parallel service has to be provided. This way, there will be a permanent link between the contractor and the user. This is not new, not even in construction world. The ideal situation would be that the building user could install or uninstall the partition walls or structure elements wherever he or she is interested. The client or the space user could request this parallel service to provide change of structure from place to place. If he would need a piece, he could buy or rent from the maintenance service. Of course, a technician should allow all these changes.

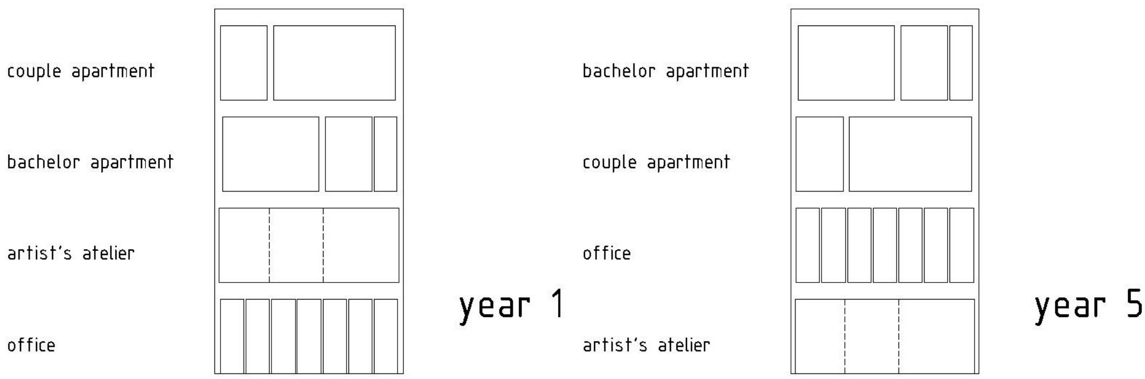

__FIGURE 7:__ as it is showed in the figure, the system elements are moveable from one floor to the other .

ADAPTABLE TO DIFFERENT PLOT'S GEOMETRY.

If we don´t want to artificialize virgin land, we have to re-build in the actual non used plots of our cities. The main problem with Prefab systems is that these are quite difficult to adequate to existing plots and geometries in the city centers. They normally need a flat orthogonal ground and a certain modulation or measurement. In the actual urban context, a plot may be 13 meters 39 centimeters long. Could a normal prefab building adequate to these sizes and local laws? I guess it´s quite complicated. A CAD-CAM coordinated system can avoid this. Why? Because the material is cut in the exact measure we want and in infinite number of angles. So, the geometry of the joists are flexible enough to be adopted into a city center plot and facade laws.

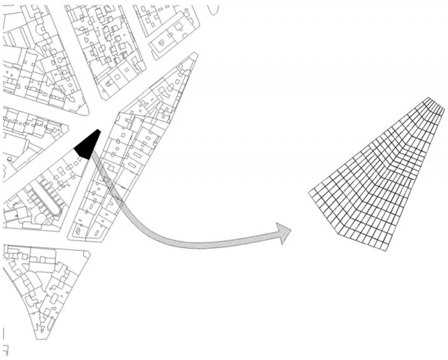

FIGURE 8

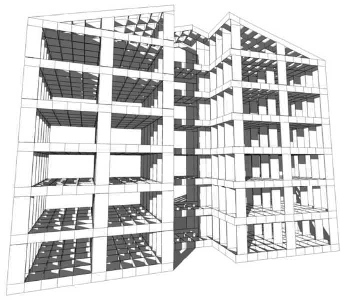

FIGURE 9: *3D cross-section*

FIGURES 8-9: *the construction system is adaptable to any geometry. If we take one of the most ``complicated´´ plots in the Bilbao city center, we can easily adequate the system to the geometry.*

This structure is easily adaptable to non-orthogonal geometries and measures. In the CNC machine, the joists can be made in infinite angles and the cutting of a piece can be produced in any length we want, so we can say that the system is free from modulation. So, even if creating new forms was not the main purpose, this construction system is adaptable to a variety of forms and spaces. This can be really useful when adapting a project to specific ground geometries and urban rules.

REFURBISHMENT: THE SYSTEM APPLIED TO OLD BUILDINGS

Another strategy to avoid consuming new land is to refurbish actual buildings. I will explain the experiences of refurbishment in the old city quarter of Bilbao, and how could this system be a choice for these cases. Nowadays, there are more than fifteen thousand apartments with no use or not occupied in the municipality of Bilbao (a municipality of 350.000 inhabitants).

It has to be said that historic center´s buildings have crooked geometries. The typology of the buildings are the same as in the Middle Age Bilbao, meaning that typology between two parallel walls and two facades is kept. The main rooms are in the front facade facing the street. During the first industrial era, in the historic city center buildings, the insertion of plumbing system in a wooden structure building has not been always successful. Even more, because of the humidity created by those pipes, the wooden structure near these plumbing infrastructure, is almost always rotten or damaged. The structures are so damaged, that the municipal urban office asks for an architect to certify the structure whenever a refurbishment is made.

The structure is considered a common part of the building, but at least in Spain, each apartment normally has its owner. And normally he the owner lives in that apartment. It is rare when there is just one owner of the whole building. Plus, in old city centers, they don´t have too much money. In this situation, total refurbishments are quite difficult. So only partial refurbishment are made when a particular apartment owner decides to renew his apartment. The most problematic sides of this partial refurbishments are the wet rooms, that is the kitchens and the toilets.

So let's say, as a general view, that we have a problem of damaged structure in wet rooms, an old plumbing system and an insufficient insulation of the back facades. And the owners of the apartments have economic limits to make a complete refurbishment.

FIGURE 9: *comparative of the two kind of refurbishment.*

How are these reparations done? Normally the wooden structure is replaced or reinforced by steel beams. This situation is quite difficult for the user who lives in the floor below, because normally, part of their ceiling gets tore down. So during the reparation the two apartments are unfortunately communicated. To bother the neighbor below is unavoidable in the actual property system, and the neighbor can´t be placed in another apartment.

Normally, the wet rooms are close to the plumbing main pipe, to avoid pipe long distances. But when the renewal of the house is done, the client may not want the same distribution as it was before. So the fecal pipe needs more length. And that's why the whole wet rooms usually have their floor 20 cm higher than the rest of the apartment. So what would happen if the user of the apartment required a change, again, on his wet rooms? He would have to tear down the 20 cm step and then change the pipes.

The construction system described in this paper may offer a solution to this problem. As we can see figure 9, a normal wooden structure's framework is almost 60 cm high. So this new system can be placed and it's compatible with the old structure. With this system, as it is said before, the user could change the installation from one place to the other whenever it is required. An there would be enough space to put more installation, such as And of course, no other neighbor would be disturbed using this system.

Finally, there is another choice to implement the system in concrete structure buildings. Unfortunately it is quite difficult to replace the structure. But we can improve the facade conditions. This is was the aim when doing the renewal of the entrance hall of the Architects Chamber in Bilbao. Here, a refurbishment of the facade was needed in order to let natural light in, fit a new air conditioning systems, place a book-shelf and design a shop window.



FIGURES 10,11,12: *previous situation, process and final result in the Basque and Navarre Architect's Chamber, Bilbao. Project by Metak Arkitektura Tailerra .*

CONCLUSION

For now, the design of the construction system is in the middle of its process. The precise 3D models are already made and have been proved with calculation programs. The next step to be made is the production of prototypes and to prove them. Once the prototypes are tested, a tool to make this construction system more efficient will be needed. That is the plug-in program. And after this, all the procedures to put this system in the market will be needed, such as patents, special codes and classes for getting specialized in designing, creating and fabricating with the system.

This Construction system offers the possibility of the maintenance of the building. In a way, if the tenant of the building requires a change in it, he or she should ask for a supplier to get the necessary pieces to make the change possible. This maintenance concept is developed in further fields, such us transport (renting services). So it can be interesting to have an offer of this kind, specially for social dwelling, hotels, office building and etc.

This construction system has to be compatible with other systems. Of course, like any other construction system, it probably cannot solve all the details or problems that occur in the construction. It´s almost impossible. That´s why it has to be amicable with the other systems.

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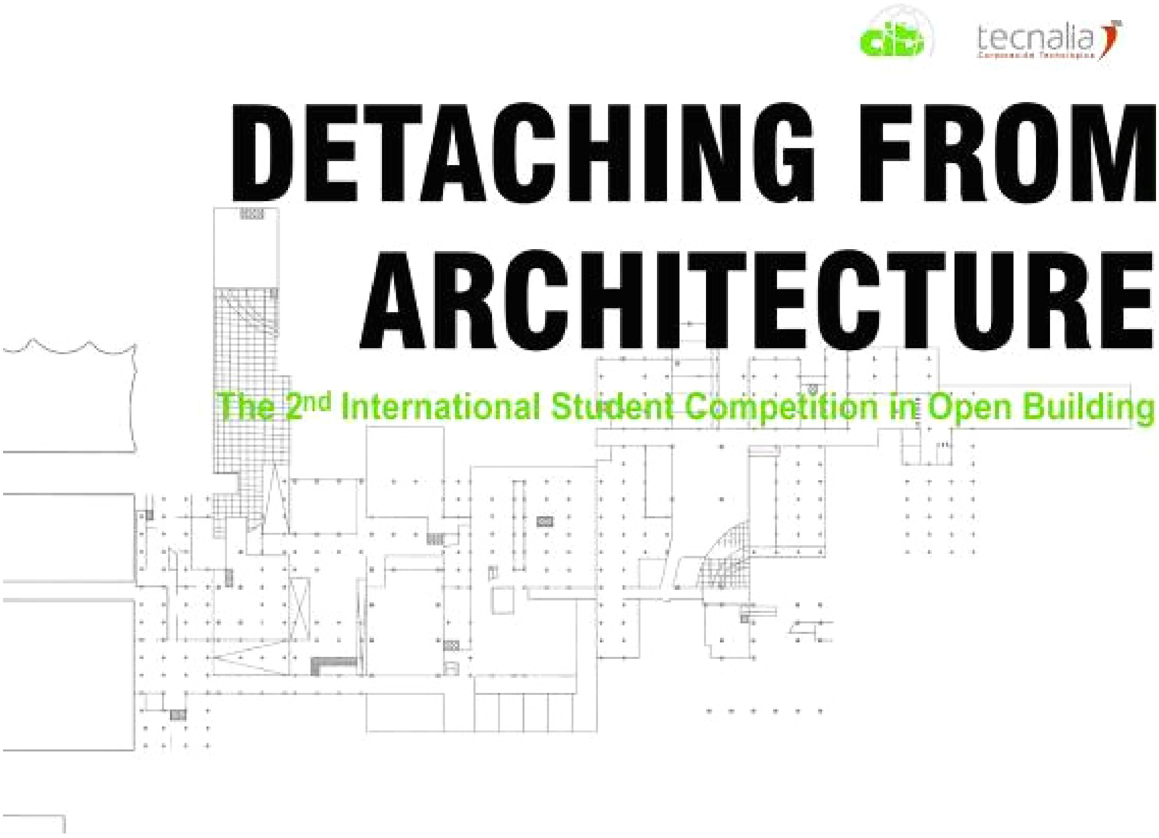

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Introduction

After the successful completion of the First International Student Competition in Open Building in 2008 (Ball State University, USA), the ***CIB W104*** was organizing the 2nd student competition in association with the ***LABEIN-Tecnalia*** in Bilbao, Spain in May 2010. The competition had two aims:

1. To invite critical observation of the traditions of architecture as a profession, and
2. To invite creative and focused thinking on the needed advancements in design methodology to meet the challenges of a dynamic new urban morphology mutating with the changes of contemporary urban life.

Architectural design has been traditionally regarded as a decision making process used by architects for clients on the form, space, programs of use, and associated technical and social issues related to buildings. When the first sketch of a building appears, it is meant to be static, and permanent, even if it is not necessarily intended to be like monumental. The programs of use are determined by the designers and clients, who often do not represent the actual users and people. In the extreme cases, buildings become the very individual self-expression of the designers, who are more interested to create signature buildings than anything else.

Architecture as a profession has never been in such a critical, problematic and isolated situation as it is now because of the ever increasing social diversities and rapid changes in the social, economic, and technical circumstances in the contemporary cities around the world.

Detaching from Architecture aims to contribute to reversing of the traditional concept of architecture, in order to allow two important components of reality to play equally important roles in architectural design. The first component is time. To ensure that a building can last as long as the physical structures allows, it has to be flexible and adaptable enough to accommodate changes of uses, circumstances, and as many as unforeseeable matters as possible, arising from the building's service period. The second component is people--the real people beyond any statistics, function or program of use made by programming. If pluralism is the word characterizing the conceptions and behaviors of the people of today, no building can ever be satisfactory without interaction by everyday use. People collectively and individually look for opportunities to change and adapt to their environment.

Taking the two components into account, the competition of ***Detaching from Architecture*** was not interested in a comprehensive or complete design, or a "design for everything." It called for proposals with an understanding of an

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environment as distinct but related layers in intervention. The designers might focus on some layers of the built environment while intentionally, strategically, and technically offering form and space to be undetermined, undersigned, open for mutation in time, and open for interpretation, again with physical interaction with people. To be more provocative, the competition called for project designs which address:

- **Time-space** rather then *form-space*
- **Strategic** rather than *tactic*
- **Interactive** rather than *passive*
- **Operative and instrumental** rather than *objective and complete*
- **Conditional** rather than *situational*
- **Structural** rather than *compositional*

This was an open competition with limited restrictions. Submissions could be part of the academic work or independent works. Students could work individually or in groups. For the academic work, this competition also aimed at assisting instructors in developing a range of teaching approaches for use in their courses. Studio teachers and students were encouraged to explore the many varied functional, social, political, aesthetic, and environmental issues in different scales and types of projects for their own places or cities. However, the projects should have had sites and context.

Nearly 400 students from all over world registered to join the competition. The committee received 78 qualified entries. These entries were critiqued and judged by an international jury of experts with backgrounds in Urban Design, Landscape Architecture, and Architecture. 27 projects were selected as finalists to enter the second round of evaluation by the international jury board. From these 27 projects, the international jury board finally awarded 6 projects as First Prize, Second Prize, and Third Prize respectively.

Jia Beisi
Associate Professor at University of Hong Kong
April 29th, 2010

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Awards

First Prize

Nº.638: "*New Compound Courtyard House*"

Zhuangzhuang Song and Ruiqing Li, Tsinghua University, China.

Second Prizes

Nº.605: *"Glenluce Musical Commune"*

Laura Harriott, Glasgow School of Art, The Mackintosh School of Architecture, Scotland; and

Nº.625: *"Floating Market"*

Ho Kiu Leung, Ka Yat Kei, Tak Yeung Chan, Hon Chu Hansen Chan, and Ching Kwong Wu, City University of Hong Kong, Hong Kong.

Third Prizes

Nº.517: *"Dynamic Open Structure"*

Tong Dou and Miao Sun, University of Stuttgart, Germany;

Nº.551: *"Community of longevity--Reconstruction of community in Hankow"*

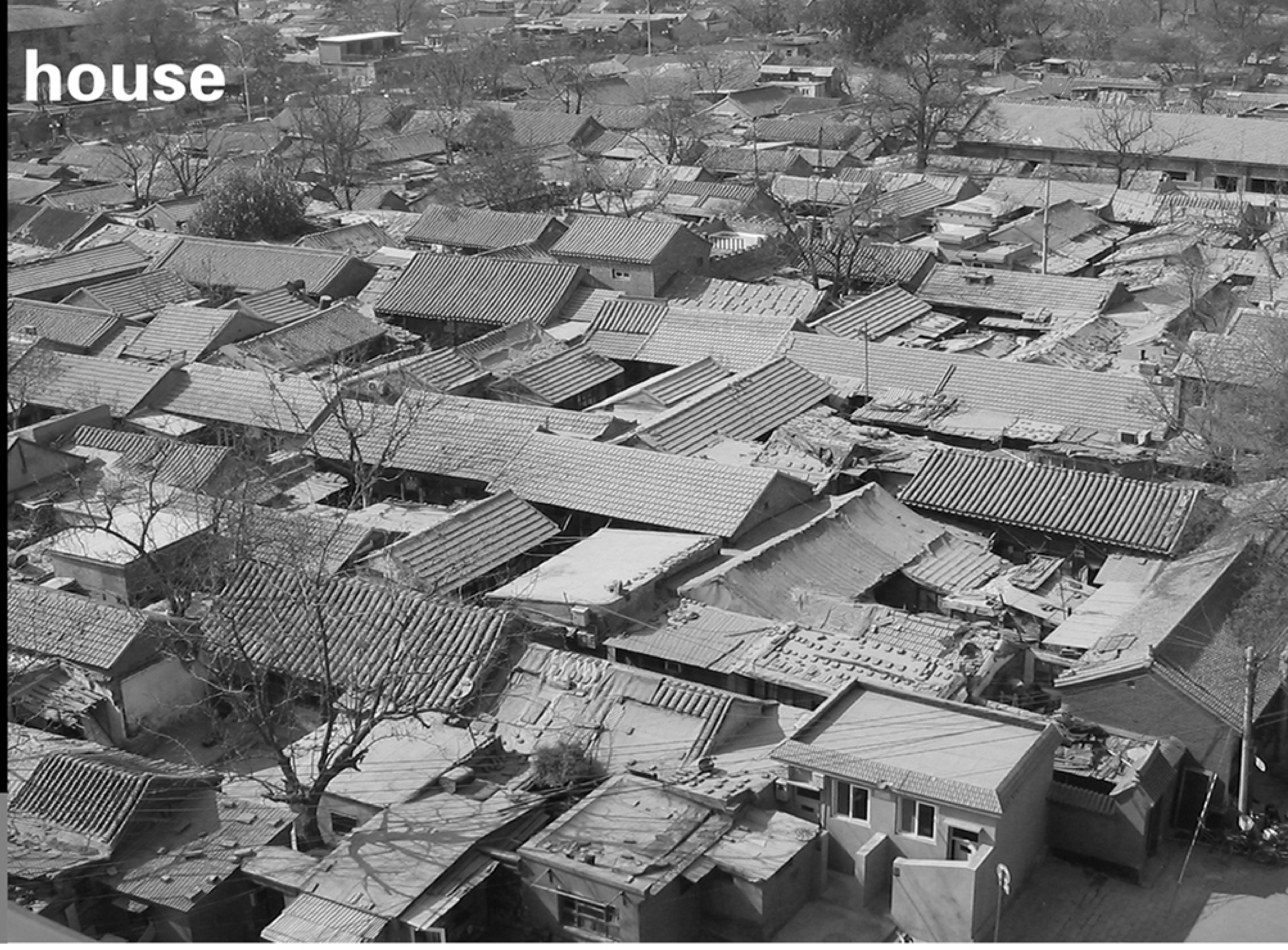
Zijian Jia and Shiyin Zhang, Huazhong University of Science & Technology, China; and

Nº.601: *"Infinite loop – A new concept for living and working"*

Jasmin Egerter and Vivien Stoffers, University Stuttgart, Germany.

new COMPOUND courtyard house

Beijing is a famous historical city. Hutong and courtyard house system constitutes the basic urban fabric of Beijing's Old City. In the past, the main form of traditional residential houses in Beijing is the Quadrangle Courtyard House. Nowadays, however, most of them have become "Compound" Courtyard Houses, due to changes in settlement patterns and population growth. "Compound" Courtyard Houses, built by the residents themselves, can adapt to the changes in modern life, but have brought many problems at the same time. In other cases, the courtyard houses transformed by designer alone, although exquisite and comfortable, cannot meet more residents in the requirements for diversification. In this project, we propose a new "Compound" Courtyard House model: professionals and local inhabitants cooperate in varying degrees during different stages of the design, so that the courtyard houses can continue to serve as the basic living unit, rather than become luxuries, or slums.



Open Building I Professionals & Inhabitants

Compound courtyard houses (by the inhabitants alone) and courtyard house transformation (by professionals alone) both have their own advantages and disadvantages. In the building process of New Compound Courtyard Houses, professionals and local inhabitants cooperate in varying degrees during different stages, so as to promote the advantages of both sides.

100% inhabitants --- Compound Courtyard Houses

- difficult in adapting to changes in the future
- diversification
- based on individual requirements & preferences
- small-size redevelopment (adaptable to changes)
- damage to the traditional courtyard houses
- low living standards (noise, little sunshine…)

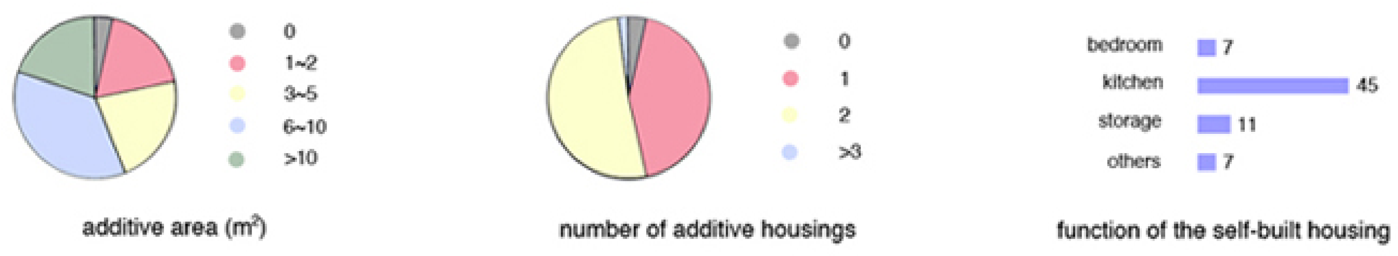
100% professionals --- Courtyard House Transformation

- conservation of the old houses
- high living standards
- multi-function (restaurant/ hotel/ store...)
- difficult in meeting diverse requirements & preferences

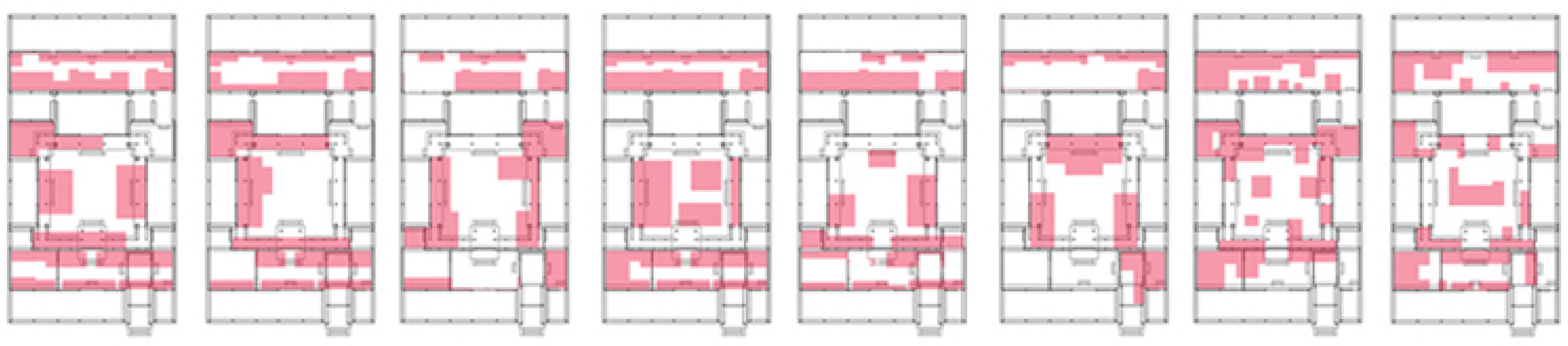
Additive Built-up Areas

At this stage, taking community needs, weather conditions, urban fabric and maintenance of old buildings into consideration, the planners put forward some areas in which new buildings can be added. The existing compound courtyard house model (by the inhabitants) is an important reference for the planners; at the same time, the inhabitants also participate in the discussion about the additive built-up areas.

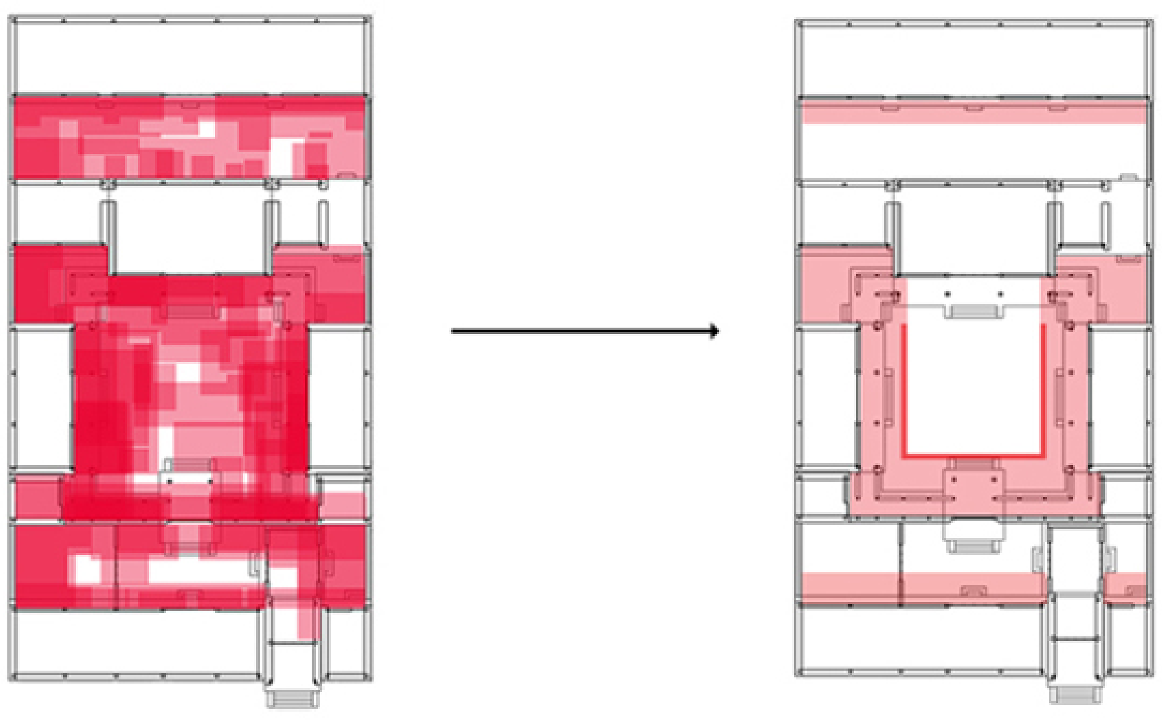
numbers of the compound courtyard house (according to a recent research)



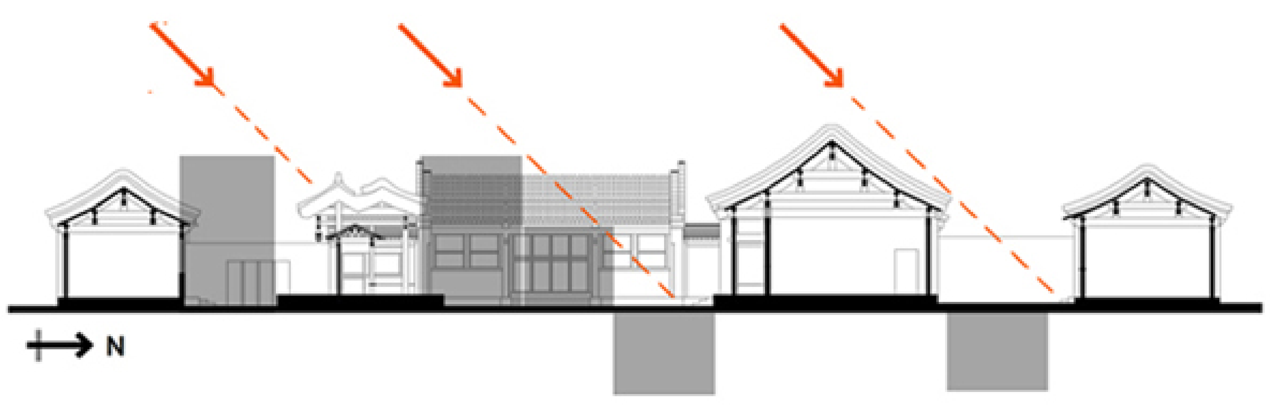
We believe that the idea of flexible additive built-up areas is conducive to maintain the openness of self-construction, while avoiding problems due to personal ignorance.

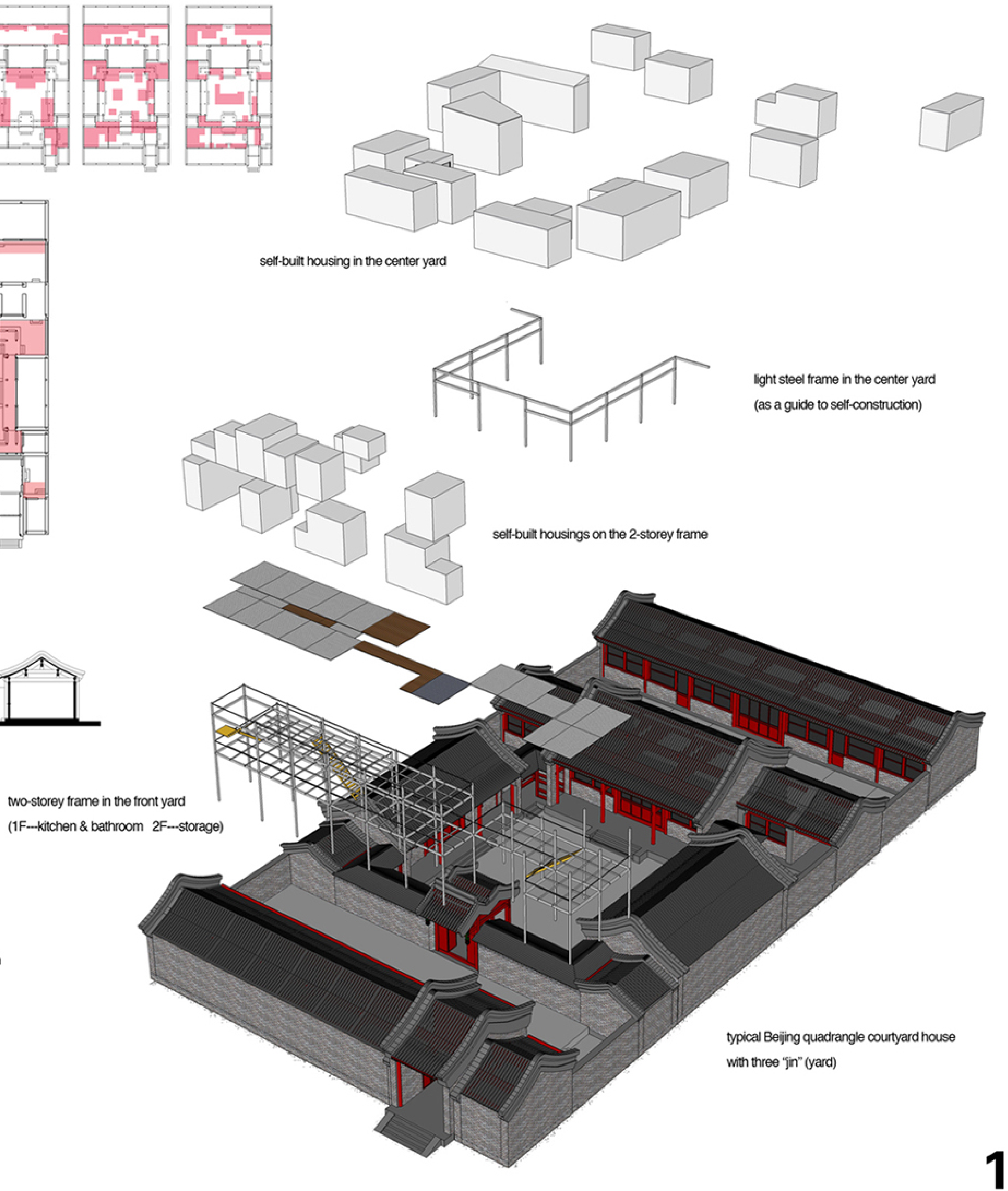


After analyzing numbers of existing compound courtyard, we found that in some regions there are more self-built housings than in other parts, and this indicates the basic needs of the residents. As for the situation of compound courtyard houses without a yard, we intend to preserve the yard as a communication center, activity space, and continuing the urban context. Taking into consideration the points above, we propose the additive areas.



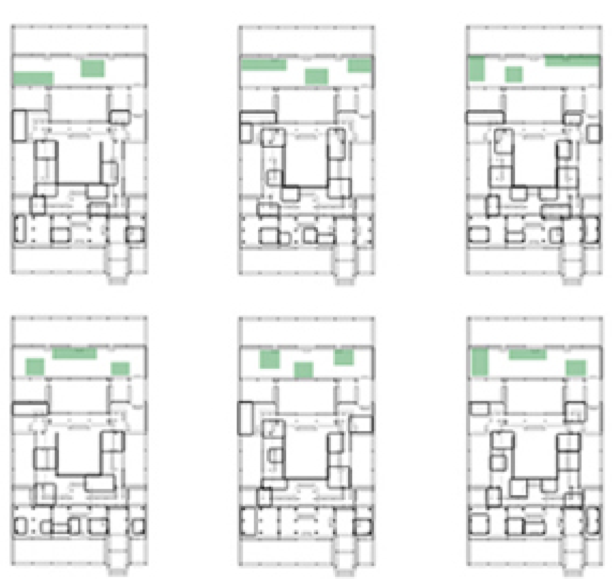
The design of traditional courtyard houses is suited to local climatic conditions, but in the compound courtyard this is scant sunlight. In the new compound courtyard, self-built housing will be located in three different heights, and this will also provide more active spaces.

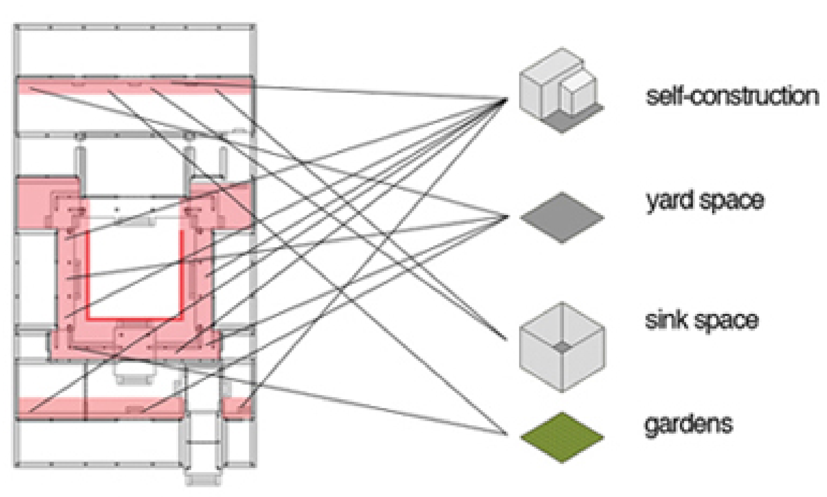




Additive Modules

Based on the additive built-up areas, the architect provides several kinds of additive modules, including self-construction, yard space, sink space and gardens. The inhabitants then select additive modules according to their requirements.

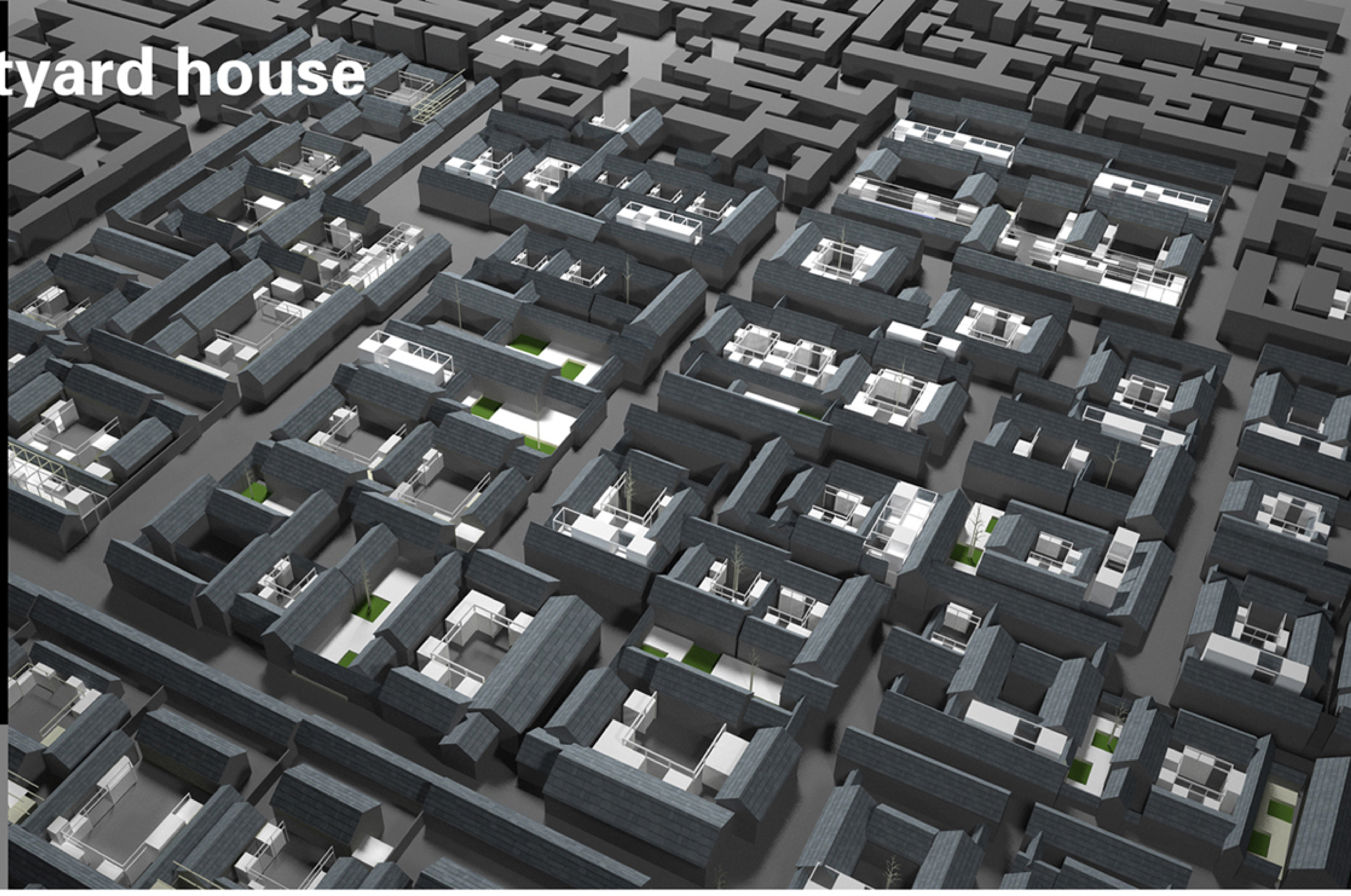




courtyard house with additive areas

new COMPOUND courtyard house

Due to the changes in modern life style, the traditional Hutong and courtyard system has transformed from street-Hutong-courtyard-indoor to street-Hutong-small Hutong-indoor with the typical form of compound courtyard houses. There is the third in New Compound Courtyard Houses: street-Hutong-small Hutong-small courtyard-indoor, which not only meet the diverse demands but also continues the historical context.
The New Compound Courtyard Houses, not just the temporary space used to meet some immediate needs, but an approach to organic renewal in the residential areas of old Beijing.

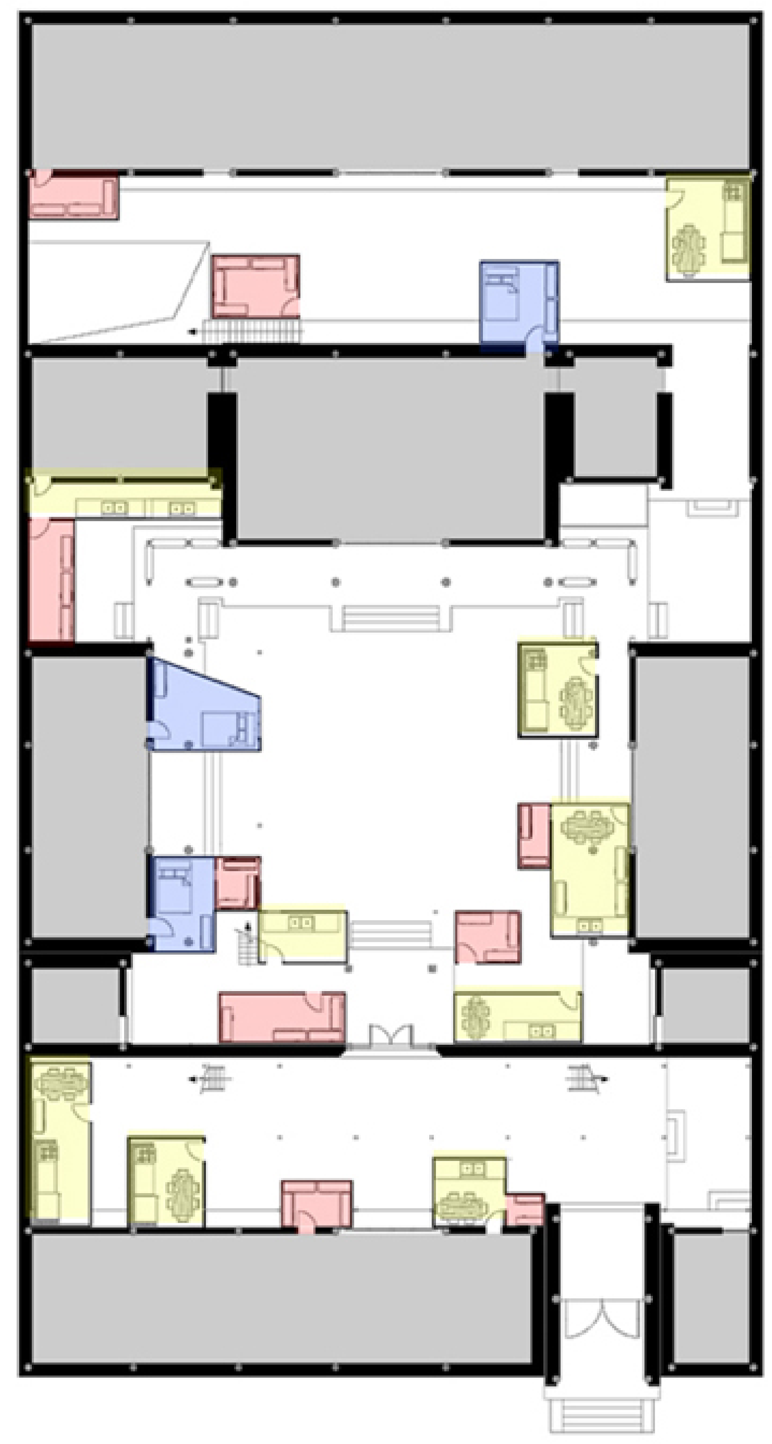


Self-construction with Flexible Materials

With the help of professionals, local inhabitants can build housing according to their own demands and preferences. What the professionals do at this stage is to provide building materials (light steel frame & wall plate replacing traditional but less flexible bricks) and skills to the residents.

section 1-1

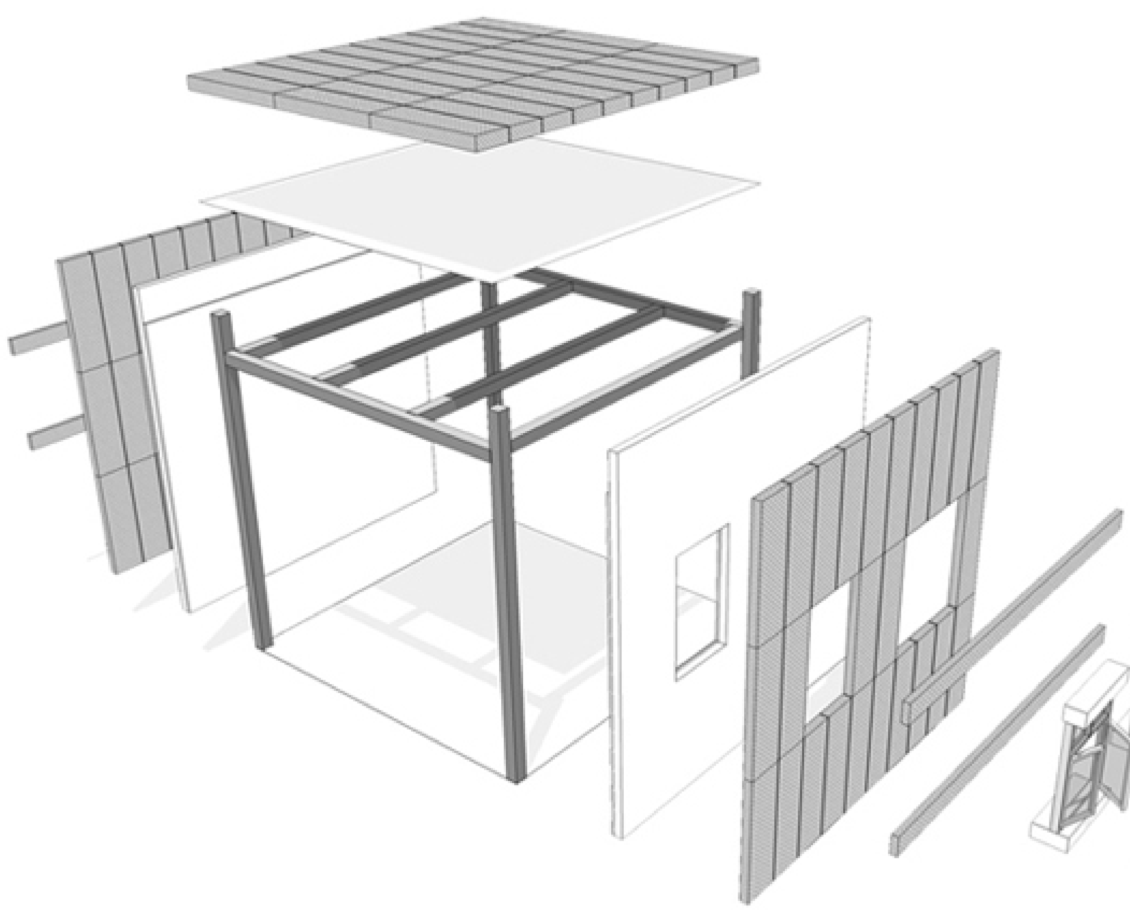
basement plan

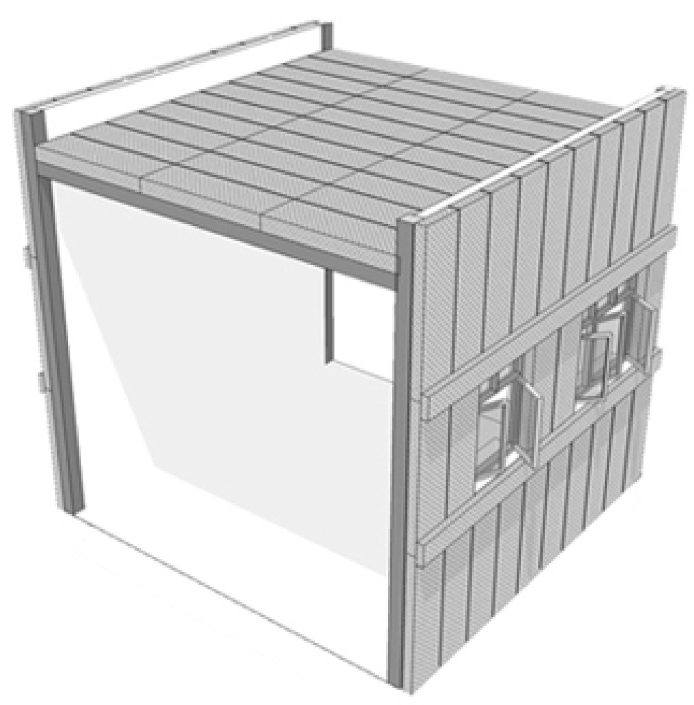


first floor plan

Our users are provided a metal frame, so that they can select building materials according to their own preferences.

This model has the following universal nature of the basic application requirements and it can meet them as much as possible under the premise of the construction of a simple and easy way, the maximum extent possible to ensure that enables users to quickly build, while allowing the demolition to accommodate future ongoing changes in actual demand.

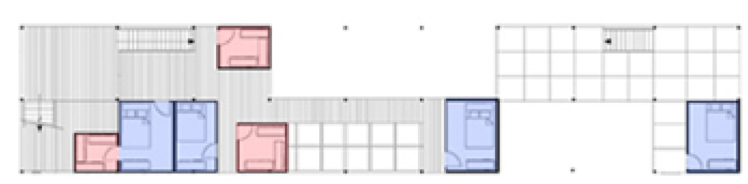




Individual Space

Despite the low living quality in the old compound courtyard houses, each inhabitant is unique and full of love for life. With materials at hand, they have created a lot of interesting individual spaces. As a result, it's better for the professionals not to intervene any more at this stage.

- bedroom
- kitchen
- garden
- storage



second floor plan

Street Space

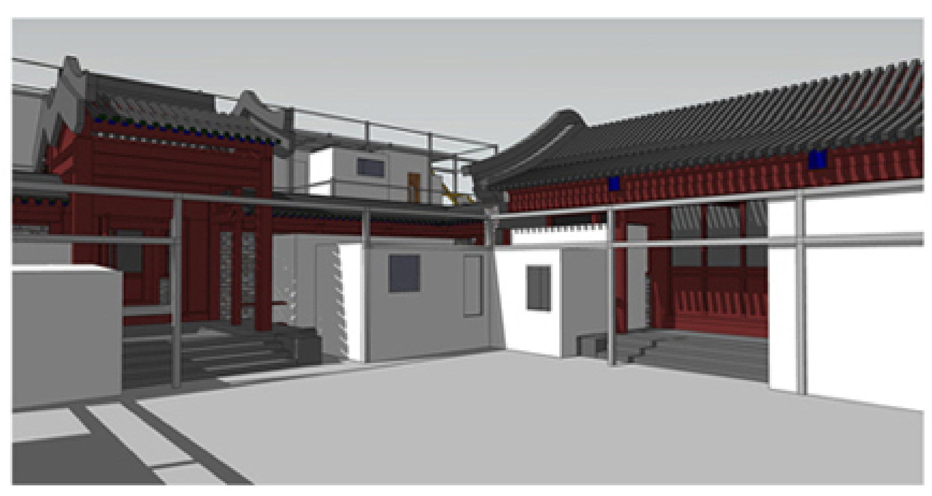
Hutong shows us an impressive drawing. As the two-story structure being purchased by the resident, every courtyard has its own style, which can be identified in the street.

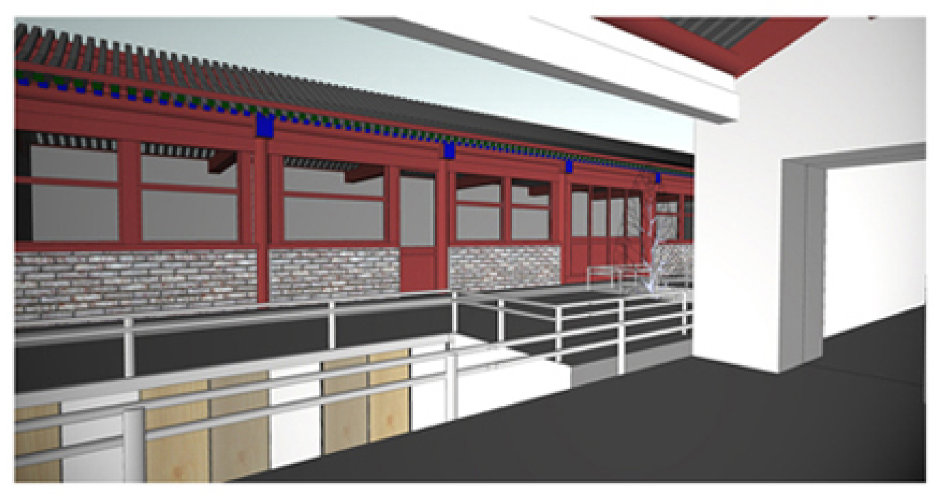
Yard Space

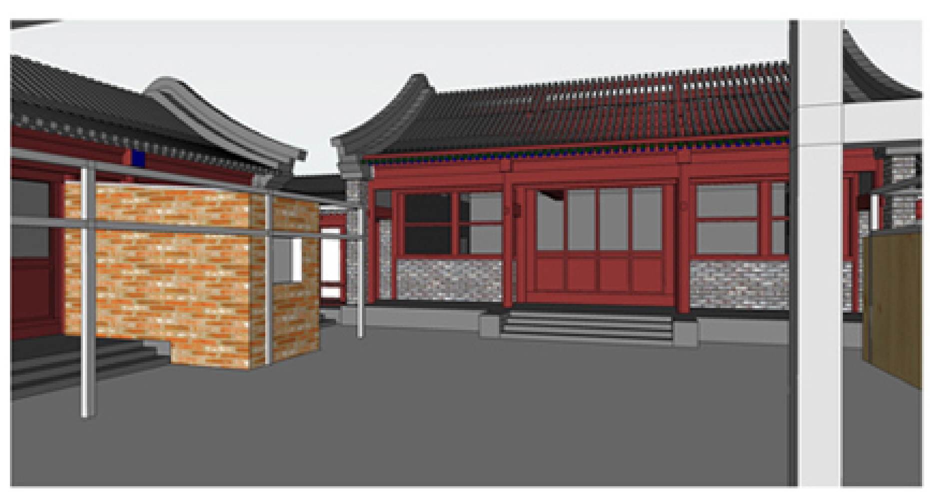
We design to ensure that every family has one individual yard besides the public courtyard, the face of the yard could be regarded as a material show. Different material reflect different lifestyle.

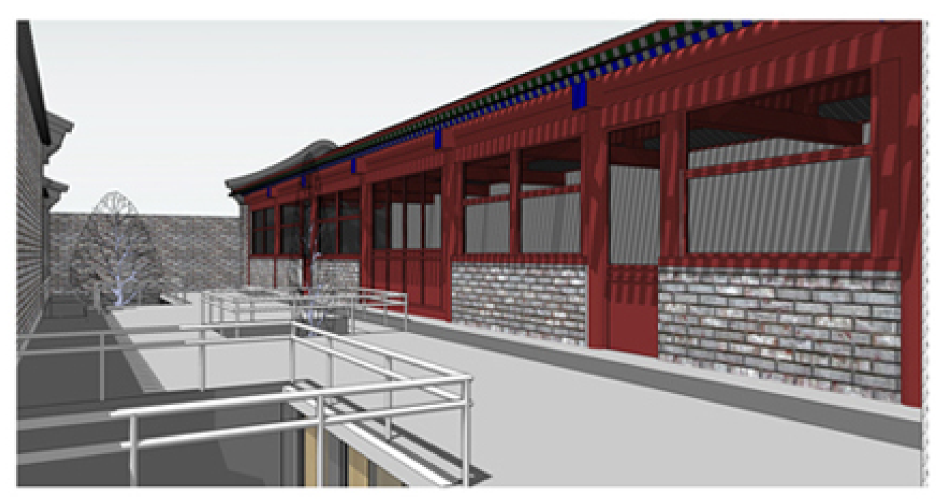
Sink space

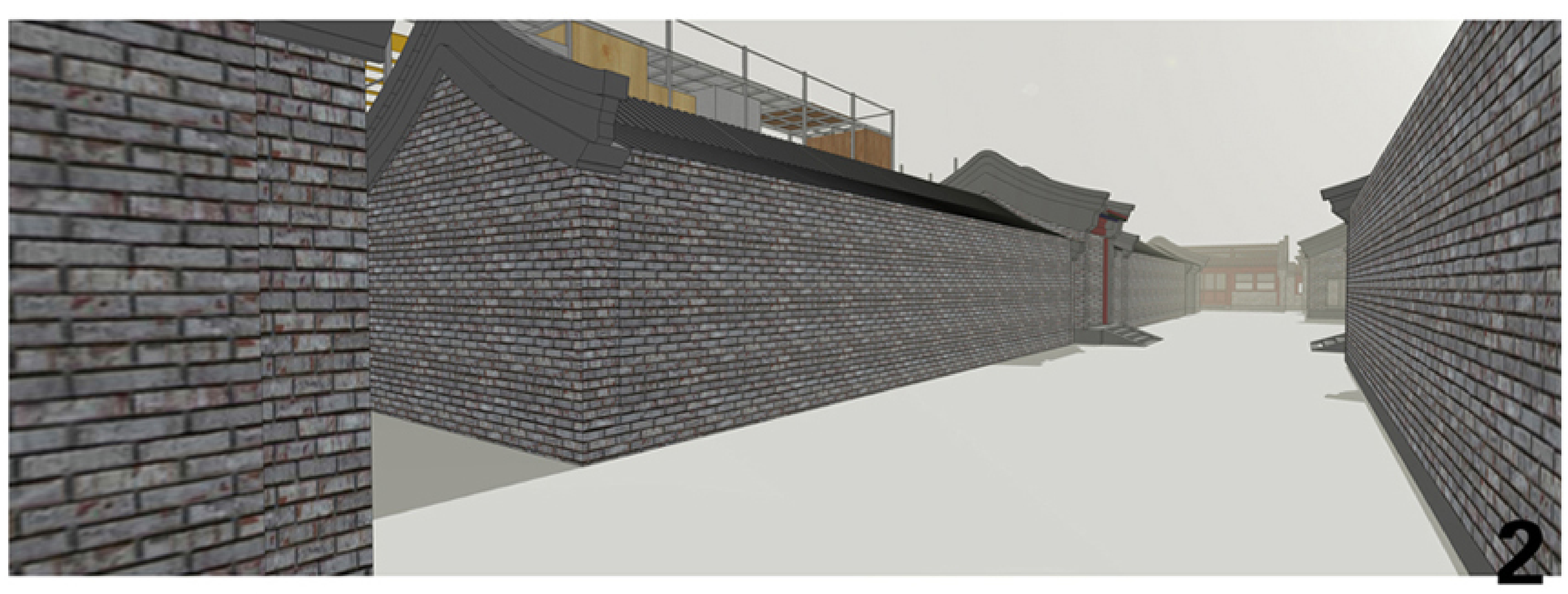
Trees are planted into the sink space, which is environmental-friendly. Users can dicide which plant to import as they like











Glenluce Musical Commune

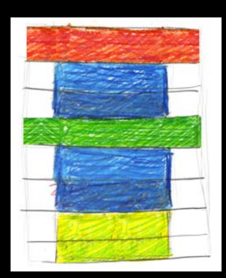
"Commune" - an intentional community of people living together, sharing common interests, property, possessions and resources. Communal economy, consensus decision-making and ecological living are important core principles for many communes.

Due to land shortages and the over development of the inner city built environment, people will adopt the ethos of communal living in off-grid locations. The "Glenluce Musical Commune" in rural Scotland will serve not only as a means of environmental protection but as a manifestation of community, expressing the presence of the individual and collective, facilitating the group interest of making music. The retreat will serve two contrasting activites of communal living and solitary space.

The off grid retreat will minimise its energy demands with emphasis on sustainable, holistic design to reduce the reliance on mechanical support. It is important that these technological demands compliment the human qualitative requirements.

Section B,B 1:400

Monumental remains of the Abbey create a verticality on the flat site of visual layering.



Concept of layering within the retreat - different levels for different functions.

Concept of containment. Escaping the everyday life vertically and reducing land consumption.

Castle of Park to the South. Fortified architecture - the retreat as a castle protecting and standing proud in the landscape.

Christian Dior store, Tokyo designed by Kazuyo Sejima uses milky glass as a wrapping skin to create depths of layers.

Kursaal Auditorium, Spain proves even a large building can appear soft and warm by being selective with materials.

TNA created an optical illusion of floating floors for the Ring House, Tokyo. Connecting the interior space with the surrounding landscape, creating a unity between nature and structure.

Baumschlager and Eberle focus on residential architecture, planning from the "outside to the inside" with importance placed on external appearance within the building's context. Often incorporating sunspaces into a design.

Site Plan 1:5000

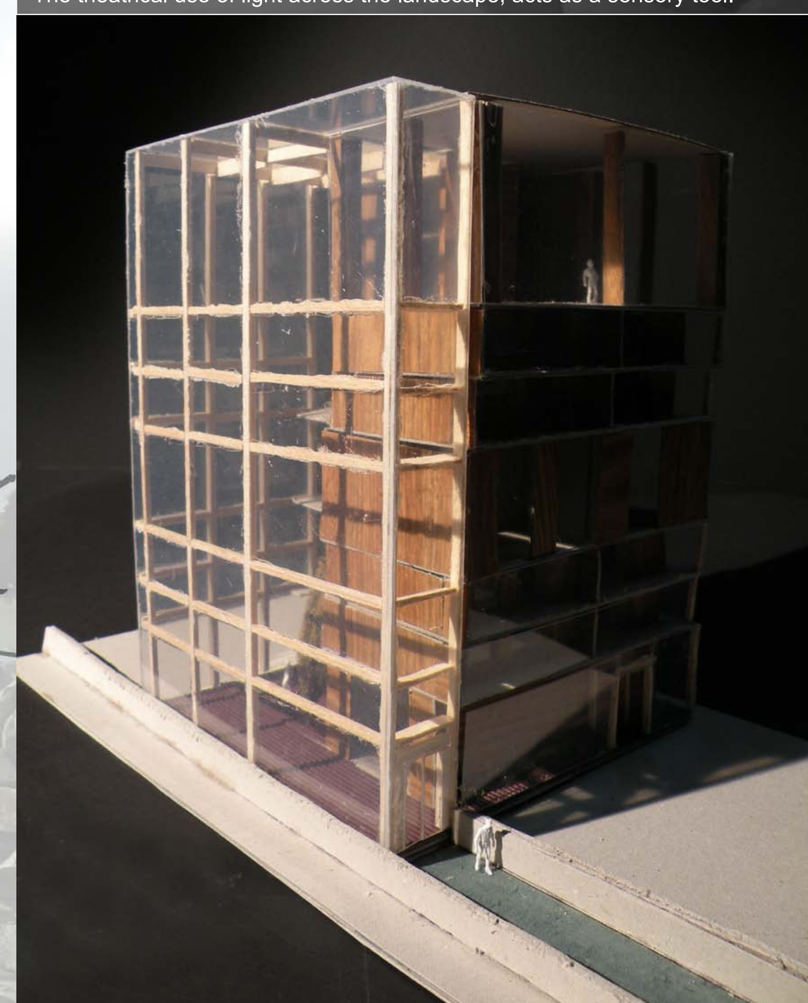
Glenluce, is a broad, fertile flat-bottomed valley, held by wooded high ground, surrounded by agricultural land with Glenluce Farm to the South. It is two miles inland from where the River Luce reaches the sea, which meanders to the West of the site. The remains of the 800 year old Abbey to the East is a historical reference to a place of retreat as it was once a monastery of 12 monks, views of which can be seen within the building.

Approach - The retreat in relation to the farm and Glenluce Abbey from the road.

The theatrical use of light across the landscape, acts as a sensory tool.

Entrance to the site - car park and bicycle facilities. The sense of retreat is not only highlighted by the close proximity of the Abbey but by a barrier wall preventing cars passing into the site. Creating a threshold and emphasising the retreat as a special place..

Journey to the site - A ceremonial approach, leaving vechicles behind the wall to journey towards a special place.



Model of building.showing the main entrance

Excavation of 6 meters to create a strong footing.

Driven piles to prevent a water logged area as the site is close to the River Luce.

Concrete pile caps connect the piles to distribute loads.

Concrete slab acts as a base and an insitu lift shaft acts as the core of the steel frame to add structural stability.

The L-shaped building and the glass atrium is constructed using a prefabricated steel frame.

Cross bracing gives lateral stability against high wind loads. Post tensioned cable tie rods create stability without obstructing views.

Composite floor slab and pre cast concrete stairs allow a fast construction process.

Masonry blocks create the walls of the L-shaped building.

Vapour barrier and wool insulation are pinned onto the masonry to prevent interstitial condensation.

A waterproof layer and Douglas Fir cladding are pinned to the insulation and masonry. The wood adds a soft texture to the sharp lines of the building.

Glass creates an ethereal boundary surrounding the L-shaped building with a strong connection to the surrounding environment.

West Elevation 1:200

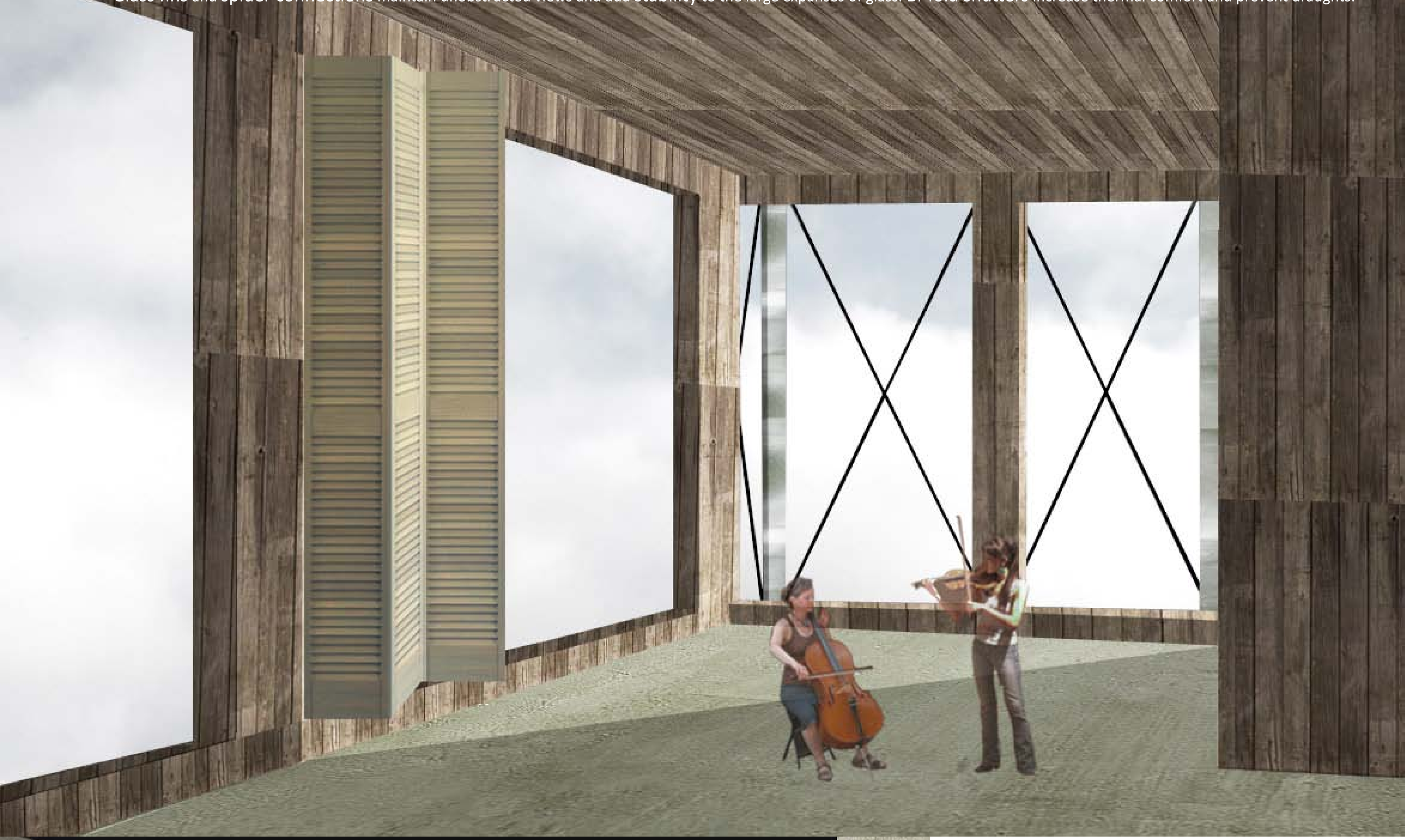
East Elevation 1:200

The Glenluce musical commune is a contained, multi-storey building which not only reduces land consumption but echoes the height of the surrounding trees and monuments, creating hierarchies of activites on each level. The L-shaped building is clad in Douglas Fir wood and wrapped by an ethereal layer of glass which softens the buildings aesthetics and also forms private sunspaces and an atrium; minimising heat loss. The atrium faces south for passive solar gain, the temperature fluxuates and acts mainly as a buffer zone, allowing heat to travel upwards throughout the floors. Using low energy aerated taps, dual flush fittings and locally sourced materials eg. sheeps wool for insulation, straw bales for fuel, Douglas fir; will reduce the energy consumption associated with the building and its effect on the environment.

Night Shot 1:1000

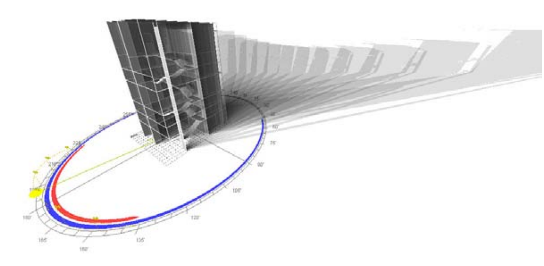
The use of light as a marker - At night the retreat transforms into a lantern, a beacon on the landscape. The changing sources of light emanating from the retreat creates a sense of movement, like a theatrical piece. The monumental quality of the retreat within the agricultural setting echoes the verticality of not only the Abbey but the Castle of Park to the South.

Main Rehearsal space - a place for creativity and escapism, to feel amongst the clouds through the buildings vertical progression.
Glass fins and spider connections maintain unobstructed views and add stability to the large expanses of glass. Bi-fold shutters increase thermal comfort and prevent draughts.



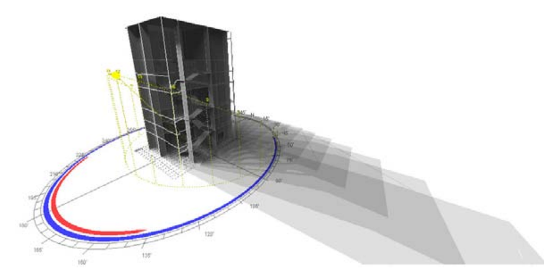
Solitary Space - A place to sleep, think and relax.

Winter shadow ranges - 24th December



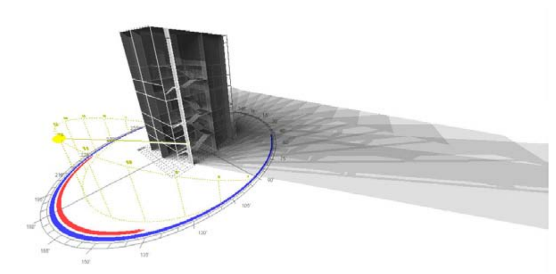
Winter shadow ranges are concentrated to the North.

Summer shadow ranges - 21st July

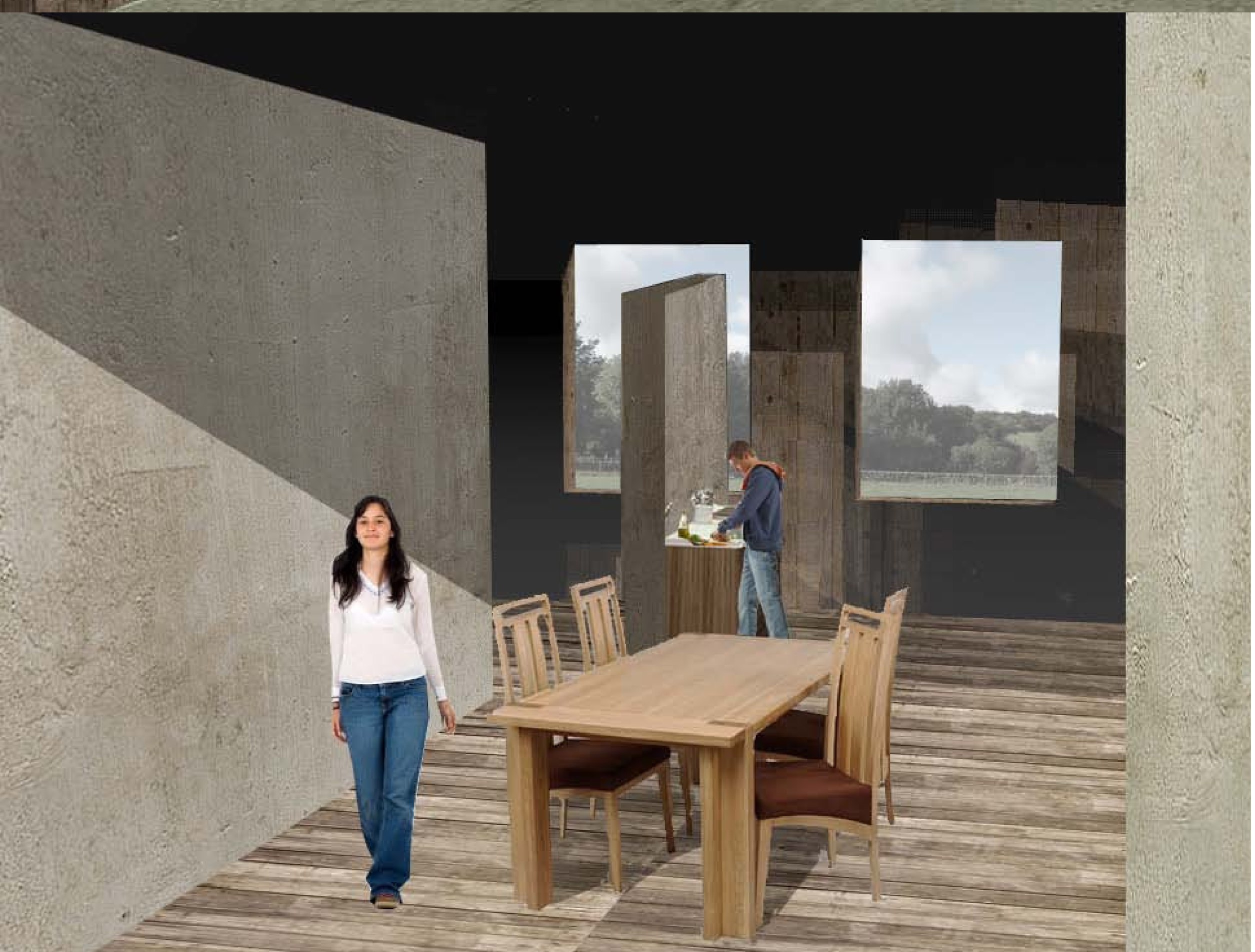


Summer shadow ranges are concentrated to the East.

Autumn/Spring shadow ranges - 21st March



Autumn shadow ranges are concentrated both to the North and East.



Communal Living - A place to eat, socialise and share.

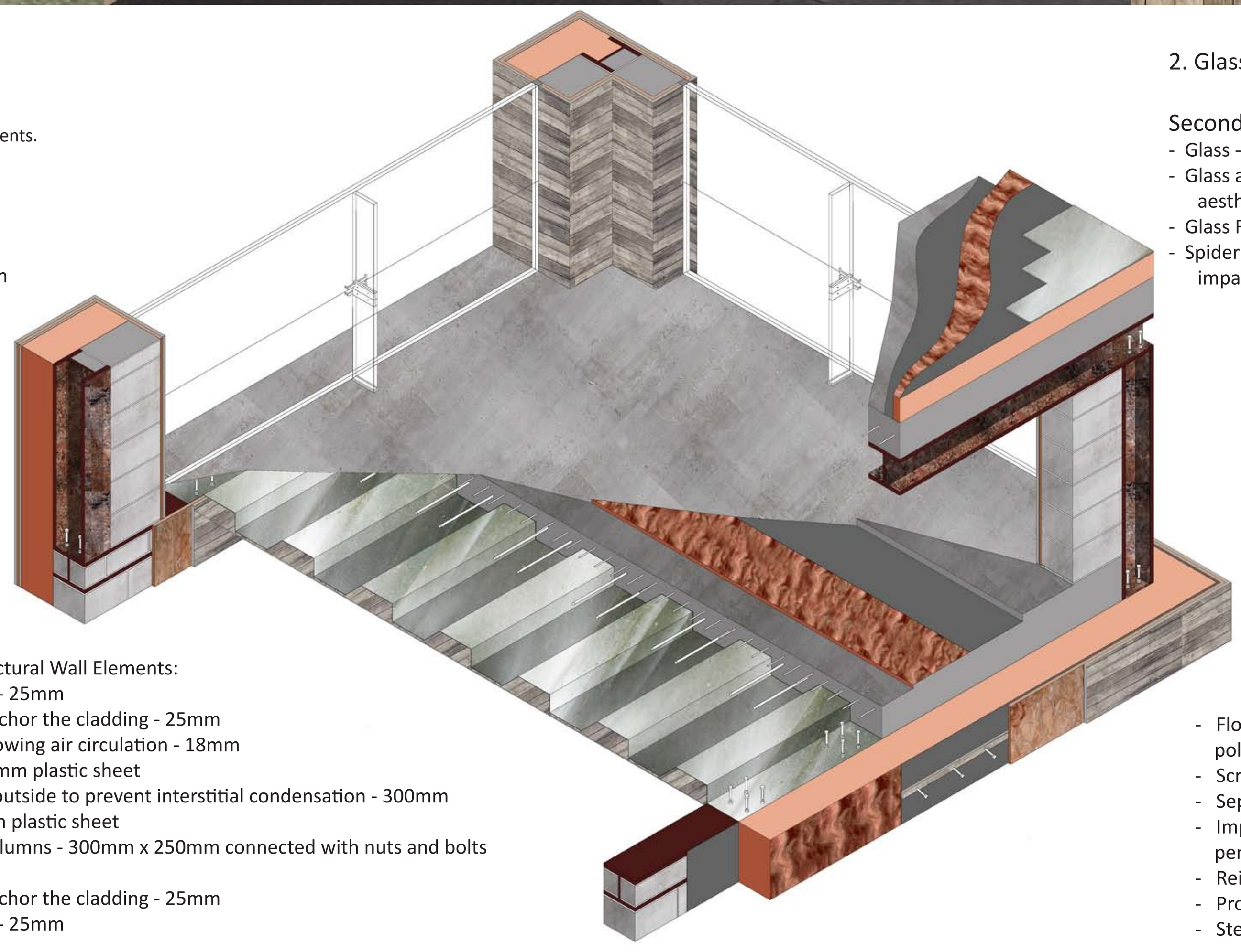
Structural Build-up
Main Rehearsal Space 1:50
Detail is cropped in order to show the floor and roof elements.

1. Roof elements
Primary and Tertiary Structural Roof Elements:

- Sloped aluminium guttering and flashing - 20mm
- Roof sealing layer - 1mm plastic sheet
- Wool insulation - 200mm
- Vapour Barrier - 1mm plastic sheet
- Reinforced concrete slab - 300mm
- Steel I beams - 300mm x 250mm

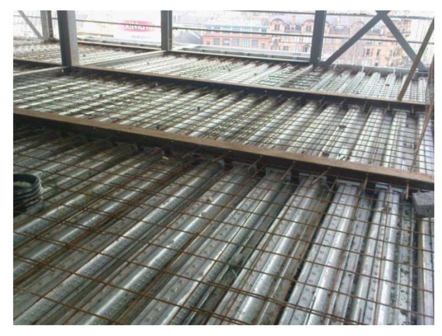
3. Wall components

Primary and Tertiary Structural Wall Elements:
- Douglas Fir cladding - 25mm
- Plywood board to anchor the cladding - 25mm
- Wooden battons, allowing air circulation - 18mm
- Waterproof layer - 1mm plastic sheet
- Wool Insulation, on outside to prevent interstitial condensation - 300mm
- Vapour barrier - 1mm plastic sheet
- Steel I beams and Columns - 300mm x 250mm connected with nuts and bolts
- Masonry blockwork
- Plywood board to anchor the cladding - 25mm
- Douglas Fir cladding - 25mm



2. Glass Fins and Spider Connections

Secondary Structural Glass Elements:
- Glass - 1.5 m x 3 m, 60 mm thick
- Glass anchored into the floor and walls to create a seamless aesthetic.
- Glass Fins - 200mm x 100 mm
- Spider connections - depending on manufactors sizes, not impacting on visual connections.



4. Composite Floor Slab

Primary Structural
Composite Floor Slab Elements:
- Floor covering, skimmed concrete which will be polished - 10mm
- Screed with underfloor heating - 60mm
- Separating layer - 1mm plastic sheeting
- Impact sound insulation, to prevent noise penetration into floors below - 20mm
- Reinforced concrete topping - 120 - 260 mm
- Profiled metal sheeting
- Steel primary I beams - 300mm x 250mm

Ground Floor Plan 1:200 - Communal eating and living space.

First Floor Plan 1:200 - Private bedrooms, communal bathroom and plant room.

Second Floor Plan 1:200 - Private bedrooms and communal bathroom.

Third Floor Plan 1:200 - Rehearsal spaces and library yet flexible for other uses

Power needed for the building is 47,539 kWh with 8,593 kWh for the Eco Space lift service. Hydro Electric power obtained from the River Luce will generate 31,068 kWh with a head of 1 meter. This will act as support energy for appliances and the Eco Space lift, manufactured by Kone which requires no oil and made from 95% recycled materials will half the energy consumption of a conventional traction machine.

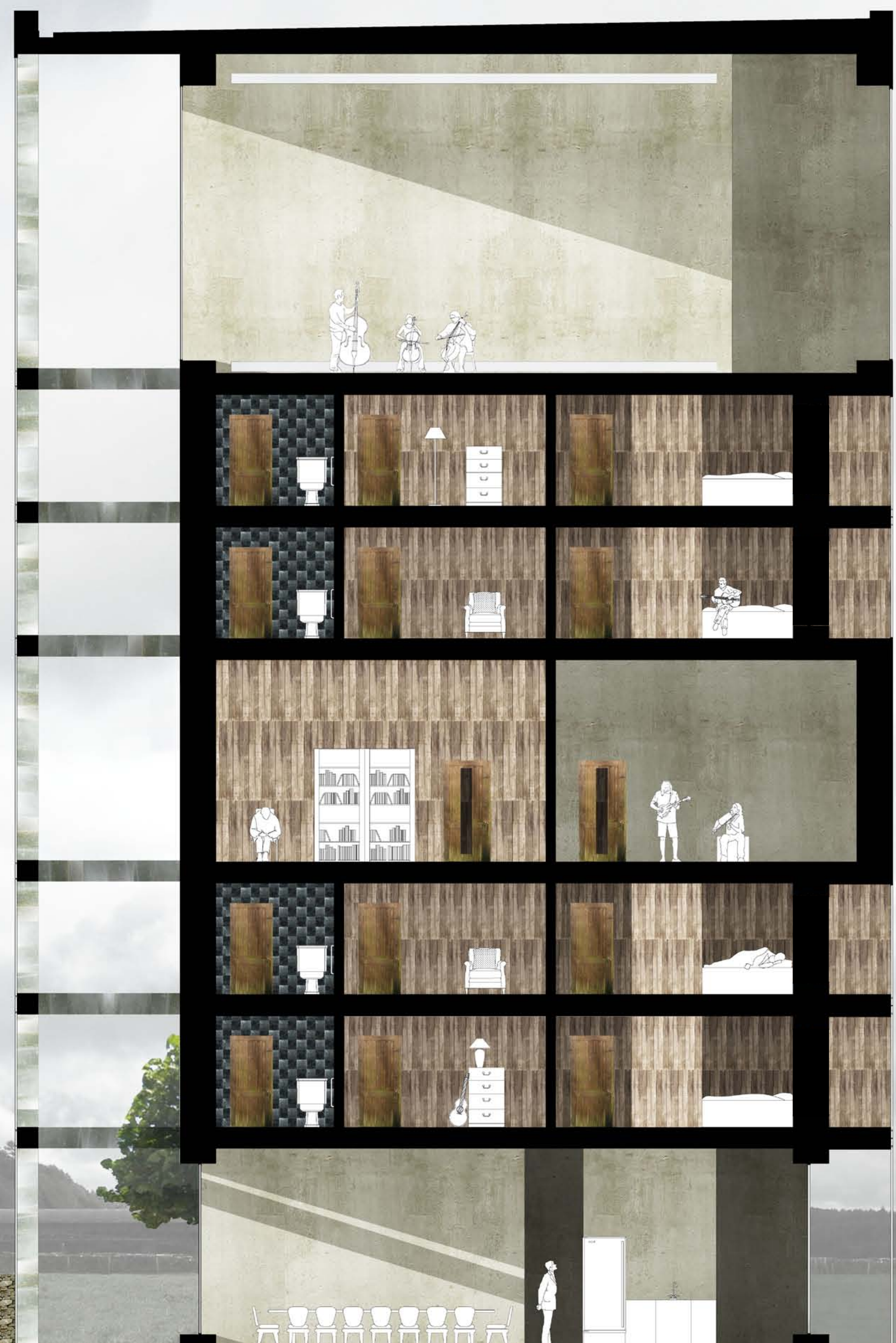
147,403 litres of rain water collected from the roof per year can be used for cooking, washing clothes, cleaning and gardening which will be heated by the CHP unit. Toilet and shower water will be pumped from the river and stored in a tank. The spring near the farm can be filtered, pumped and stored on site to be used for drinking.

Grey water from the bathrooms and kitchen will be pumped to a septic tank and vertical flow reed bed system for treatment of domestic sewerage. This can be recycled and used as compost in the vegetable gardens.

A Micro CHP, biomass fuelled system housed in the first floor plant room, will provide the main source of heat and electricity. Straw bales are a cheap and locally sourced fuel which can be easily stored in an outhouse.

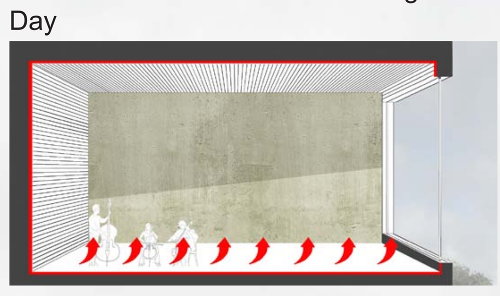
Underfloor heating is divided into zones for more control which is important especially in the main rehearsal room which requires a stable environment for the musicians to play. During the summer months the system can be reversed to create an underfloor cooling system.

If hydro power creates 31,068 kWh the CHP unit will need to create at least 16,471 kWh, possibly more with seasonal river height changes. A small straw bale will produce 40 kWh, for this system to work 412 bales will be used, costing at around £0.50 (possibly cheaper if the farmer agrees on a cheaper deal). Per annum the system would cost at least, £206.

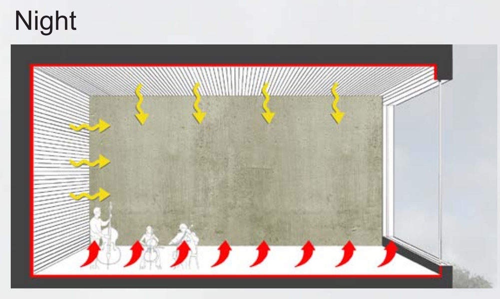


Main rehearsal room - Winter Diagram 14C

Day



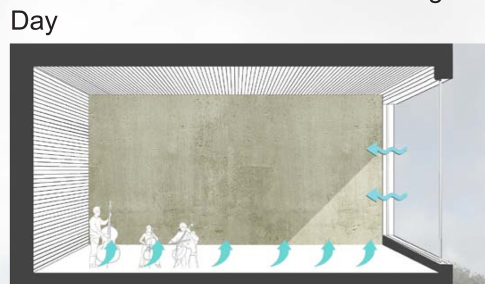
Night



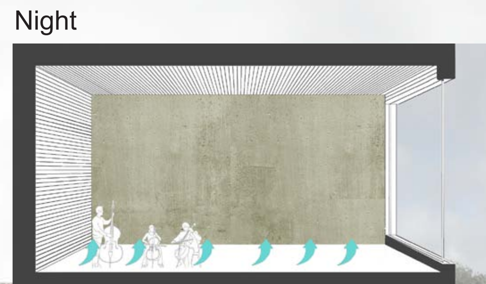
The winter sun heats the concrete floor (thermal mass) within the rehearsal room, gradually releasing heat to the building throughout the night. Underfloor heating may be used in very cold conditions. Windows and louvres provide ventilation whilst bi-fold shutters give extra thermal comfort.

Main rehearsal room - Summer Diagram 26C

Day



Night

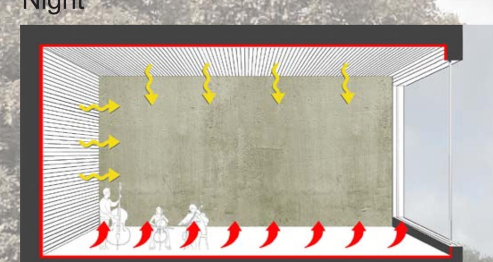


The sun is higher during the summer months creating shaded areas within the room. Underfloor heating may be reversed to create extra cooling, with windows and louvres used for ventilation. The building will not need much heat during the summer with night time getting hotter.

Main rehearsal room - Autumn Diagram 20C

Day

Night



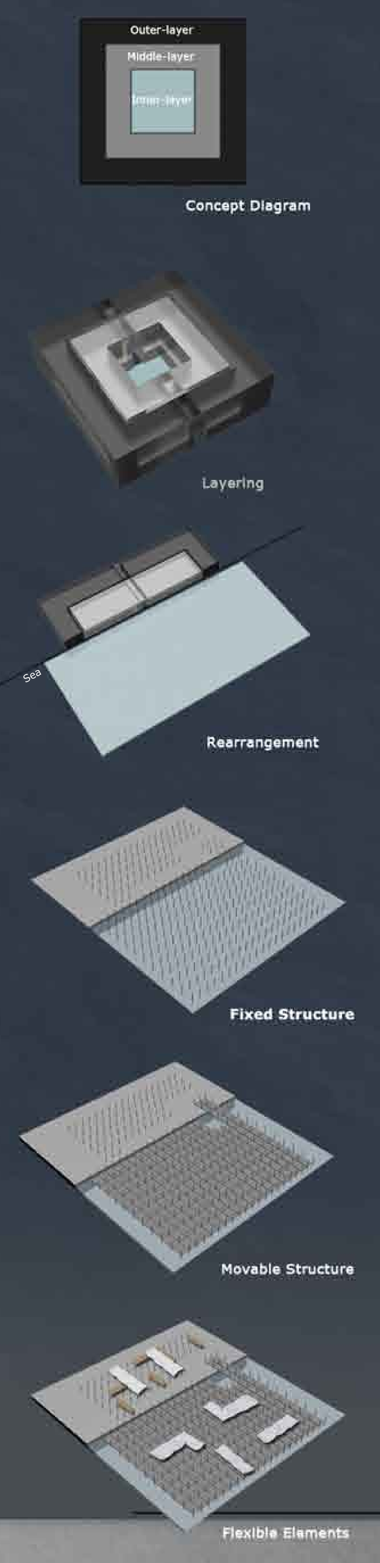
With a lower sun the solar rays hit the concrete floor (thermal mass) which releases this heat during the night when it is cooler. Underfloor heating may be used during colder nights and could be reversed during the day to cool the room during hotter days.

Section A,A 1:100

Fourth Floor Plan 1:200 - Private bedrooms and communal bathroom.

Fifth Floor Plan 1:200 - Private bedrooms and communal bathroom.

Sixth Floor Plan 1:200 - Main rehearsal space but flexible for multiple uses



Floating Market

Time Human Events

In the old days, Hong Kong People lived on sea and engaged in fishing to earn a living. In the 21st century, Hong Kong is a very cosmopolitan city and people nearly forget the history of their mother land. At the same time, people are facing economic downturn these years. Therefore, the revitalization of fishing industry that representing the struggle of primitive Hong Kong people could be used to cheer the discouraged people. With the collaboration of Hong Kong people, people would definitely make a success.

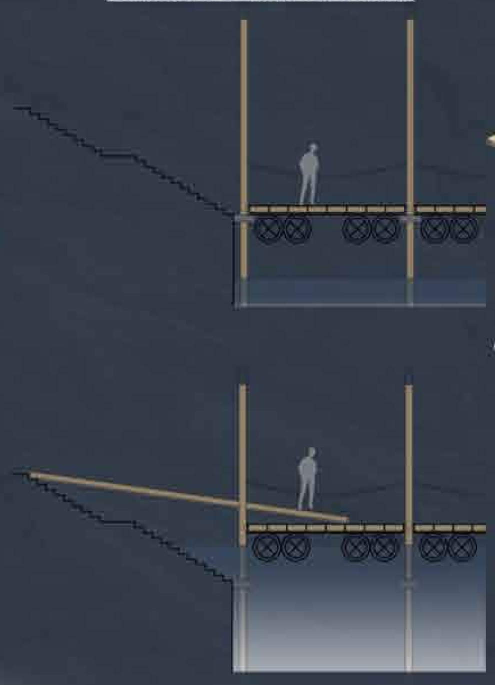
On the other hand, Aberdeen is an existing typhoon shelter next to the urban area. In the 2000 square meters of costal waters, there are only several fishing boats which supply fresh seafood to people everyday. However, Hong Kong is a tiny little place. From the perspectives of architecture, we can make use of the same piece of land to serve the four purposes: fish terminal market, wet market, restaurants and weekend market.

The proposed project is derived from the interaction of architecture: time, human and events. The definite time frame is divided by three layers. The outermost-layer is surrounded by urban area. It can be affected by external or environmental factors more easily. It is hardly for human to manage unanticipated events. Therefore, it takes the longest time to make a change. On the other hand, the innermost-layer is most isolated and thus has the greatest potential for the events to change more frequently, either daily or weekly.

According to this relationship, the layers are arranged towards to sea. Sea is considered as innermost-layer as it is least affected by urban fabrics and has flexibility because of its nature condition. Hence, the project can make use of this layer to create different arrangements with the frame structure, to adapt different events or conditions, while the outer-layers would be more rigid.

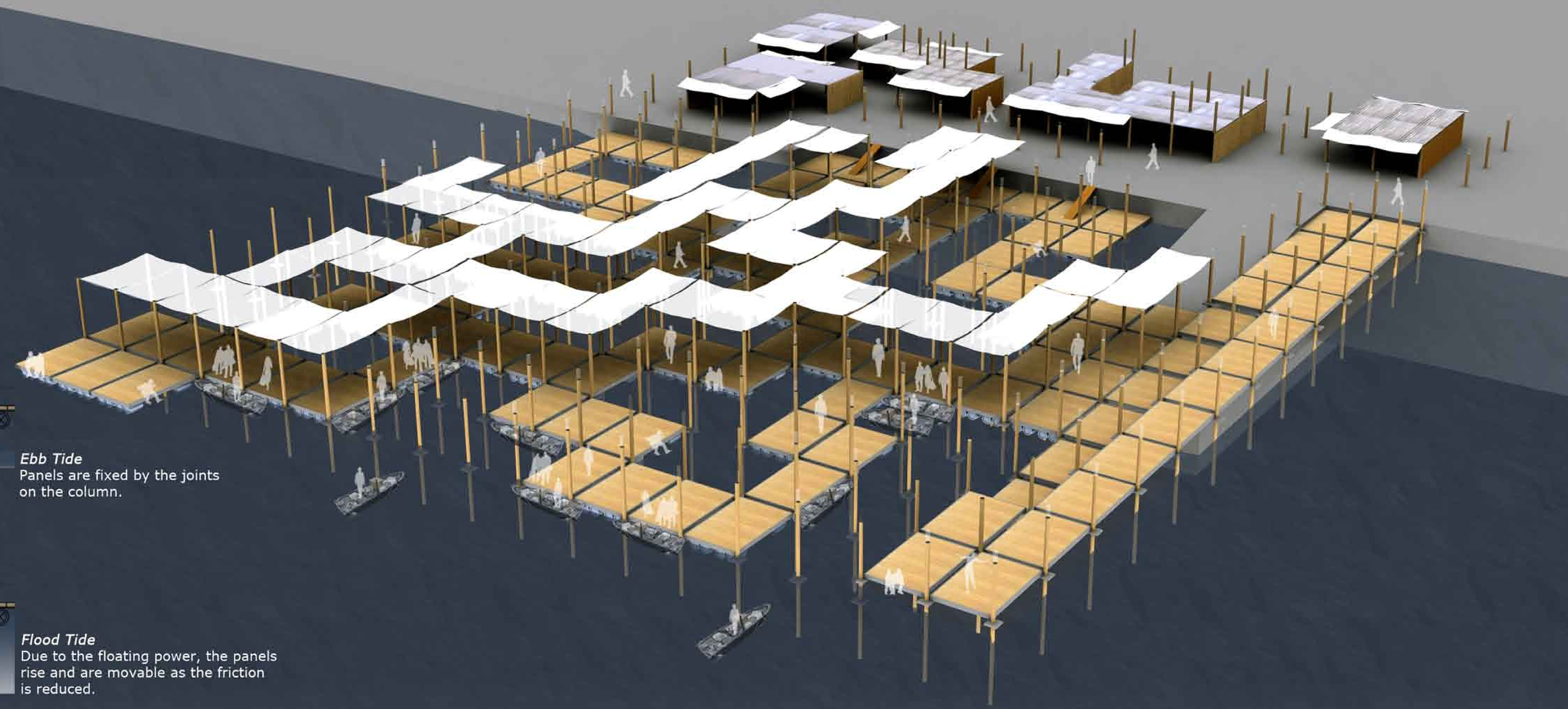
The project, Floating Market, is a touchstone on how architecture can transform the same space into different functions with the effective use of different time frame. It would be a prototype to interact with time, human and events in architecture.

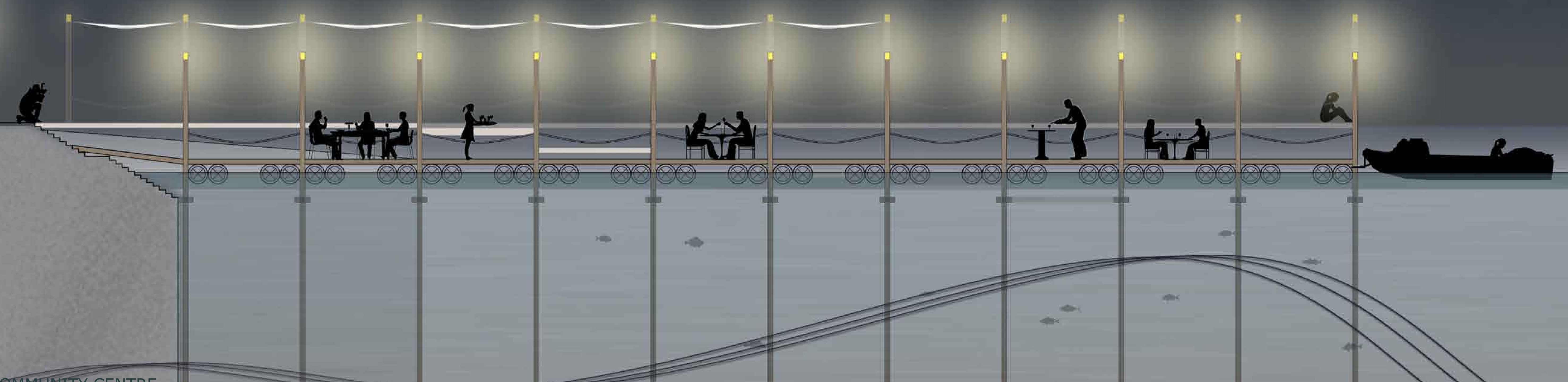
Technical Detailed Section



Ebb Tide
Panels are fixed by the joints on the column.

Flood Tide
Due to the floating power, the panels rise and are movable as the friction is reduced.





F L O A T I N G M A R K E T

T I M E , H U M A N & E V E N T

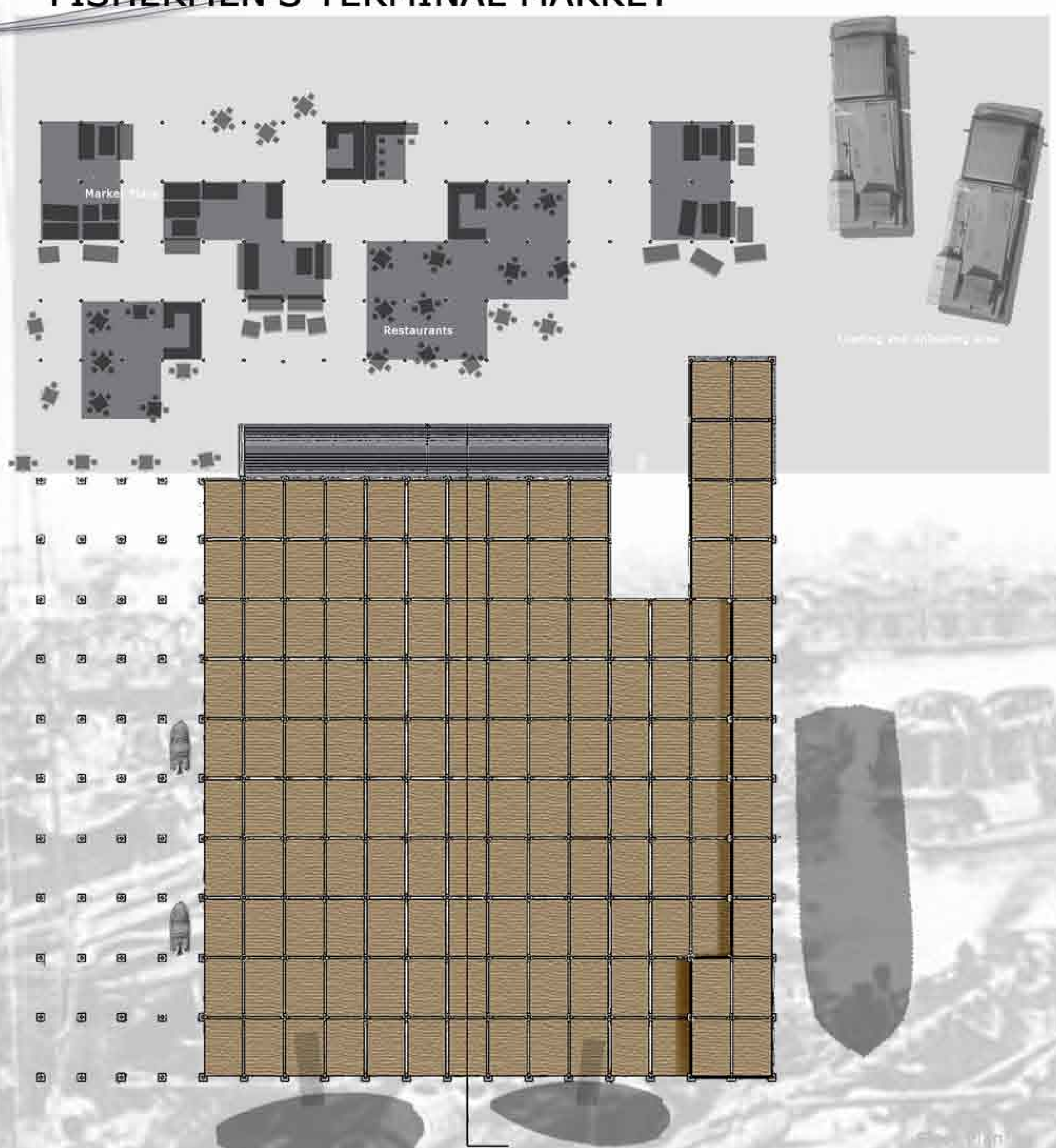
In this timeline, the wave shows the different water level of a day. Below the central line means ebb tide and the panels are fixed on the column; Above the central line means flood tide and the panels are floated on the water.

WEEKDAY FISHERMEN'S TERMINAL MARKET — WET MARKET — FISHERMEN'S COMMUNITY CENTRE

0000 / 0100 / 0200 / 0300 / 0400 / 0500 / 0600 / 0700 / 0800 / 0900 / 1000 / 1100 / 1200 / 1300 / 1400 / 1500 / 1600 / 1700 / 1800 / 1900 / 2000 / 2100 / 2200 / 2300 / 2400

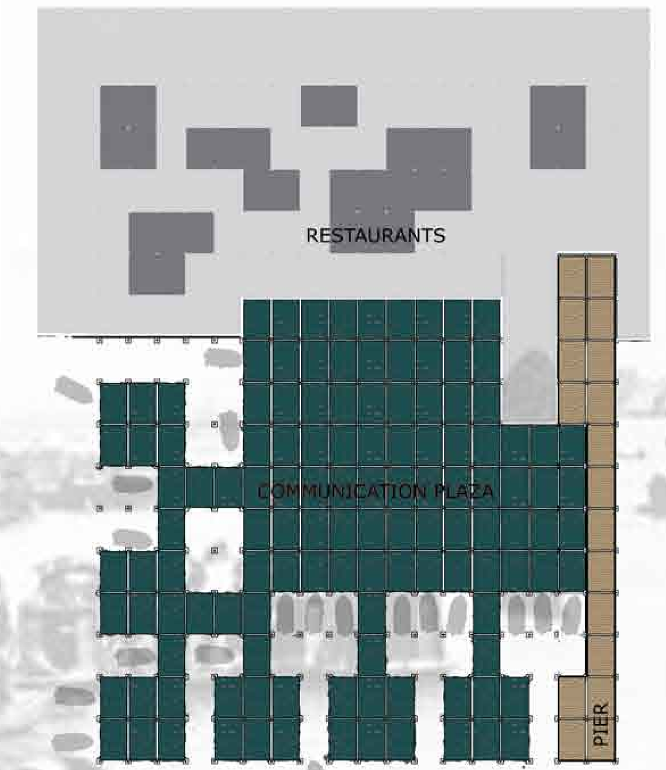
WEEKEND FISHERMEN'S TERMINAL MARKET — WEEKEND MARKET — RESTAURANT

FISHERMEN'S TERMINAL MARKET



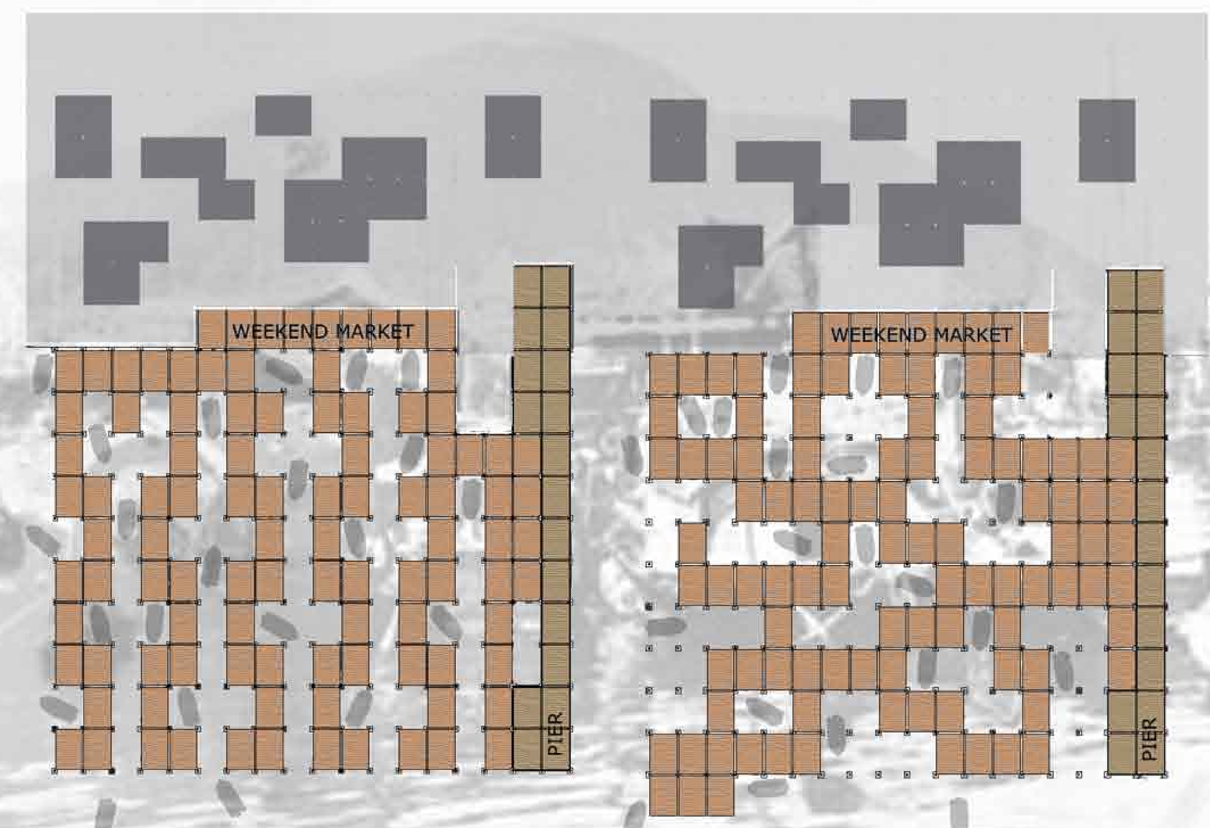
COMMUNITY CENTRE

Floating panels provide a gathering place for fishermen during the non fishing period which develop their social relationship between fishermen and also with the non-fishermen (people who live on land).



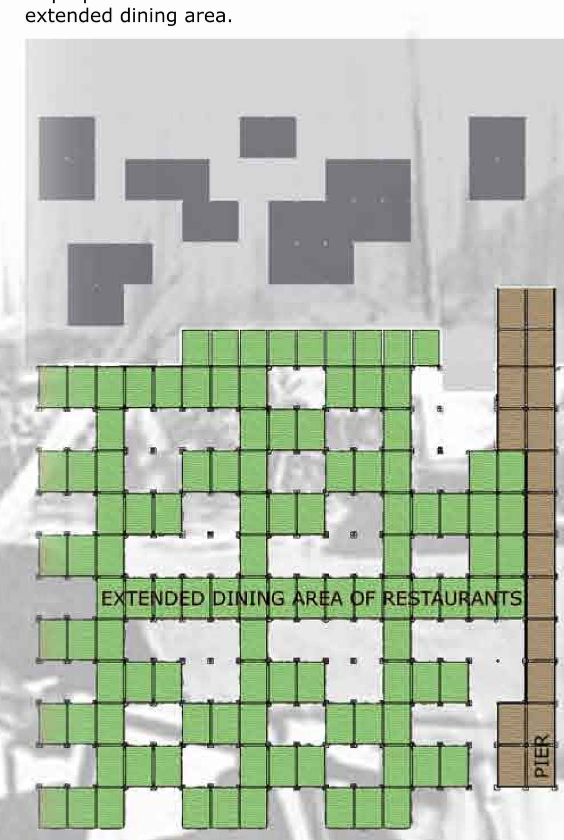
WEEKEND MARKET

Floating panels could be formed as a floating market on the weekend which serve the local people and the tourists and the working hours for the market could be justify by the tenants themselves. Sometimes, the boats may shuttle frequently between the market and others pier, then the open ended market provides the convenience for those boats to circulate in the market. While the closed ended market which would be more suitable for a whole day market where the boats can steady stayed in the market area. The closed ended market provides more platforms and increases the interaction between people and boats (fishermen), and a communication network is strengthened.



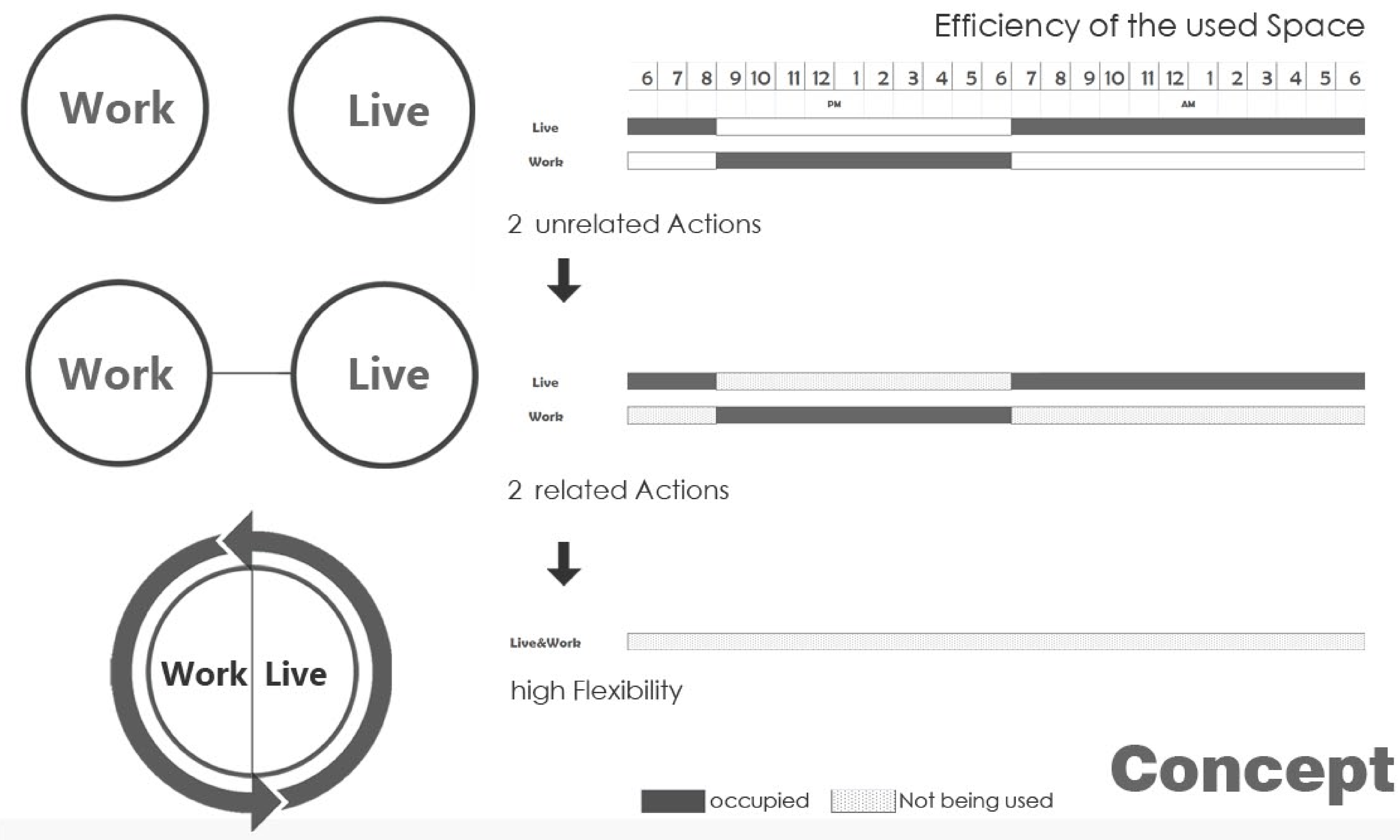
RESTAURANTS

Floating panels are divided into rooms and the corridors as part of the dining area. Customers bring the uncooked seafood, which usually buy from the nearby fish market by themselves, to the restaurant where they want to dine at and the restaurant will help to prepare the dishes and serve the customers at the extended dining area.



DYNAMIC OPEN STRUCTURE

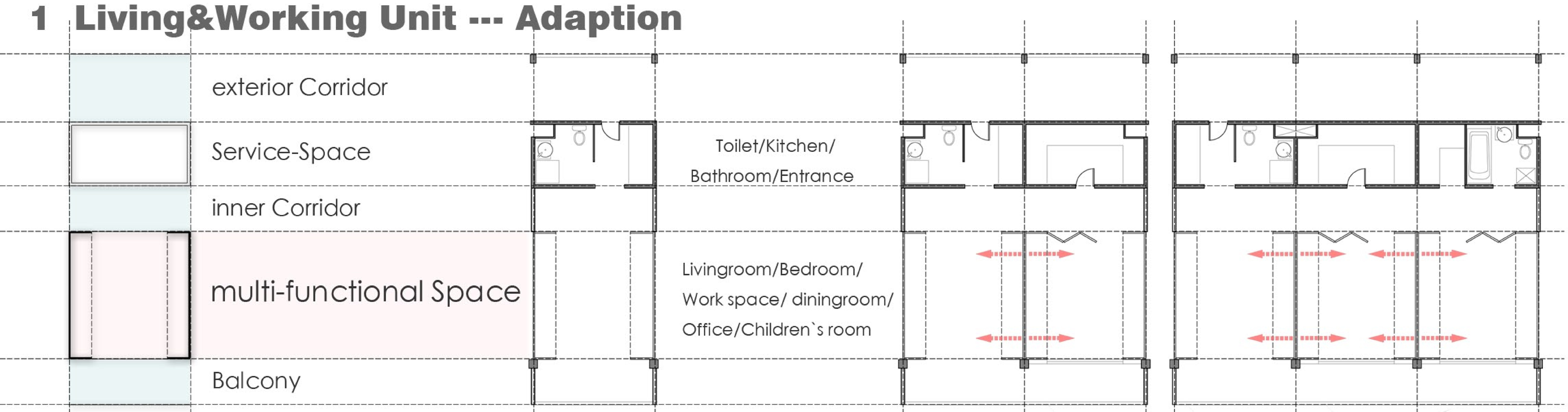
Living and Working in a highly adaptable building

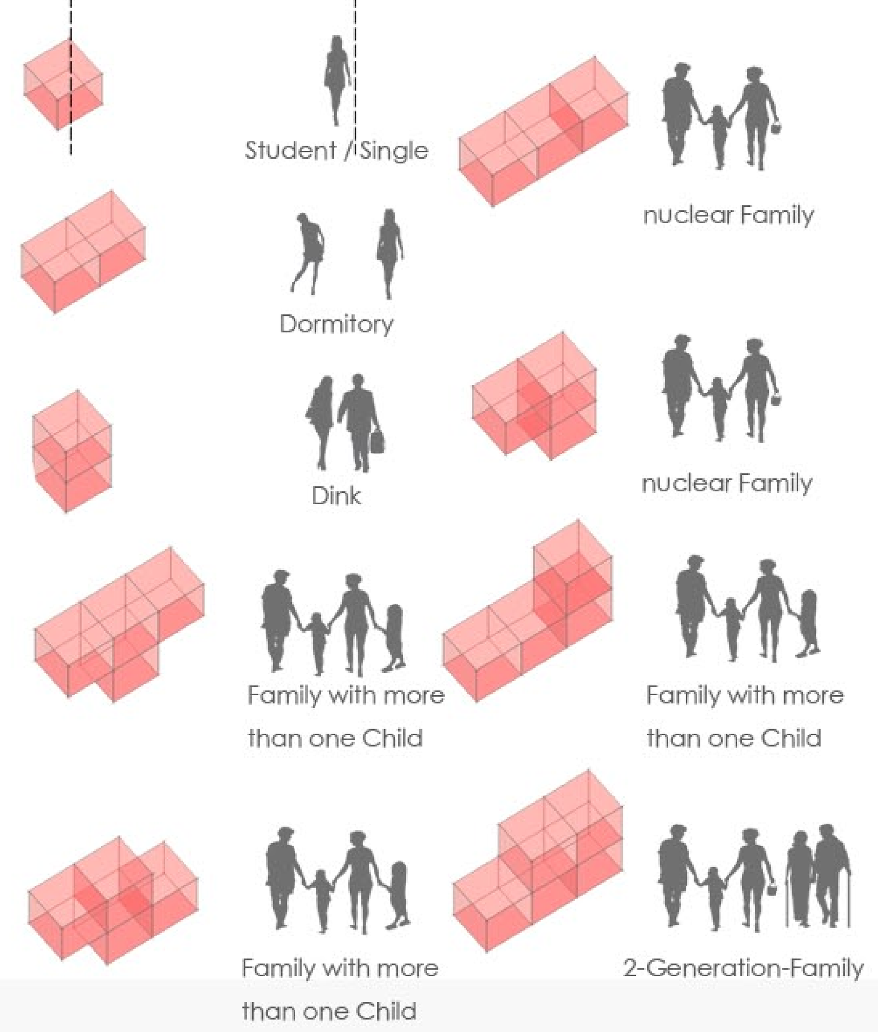


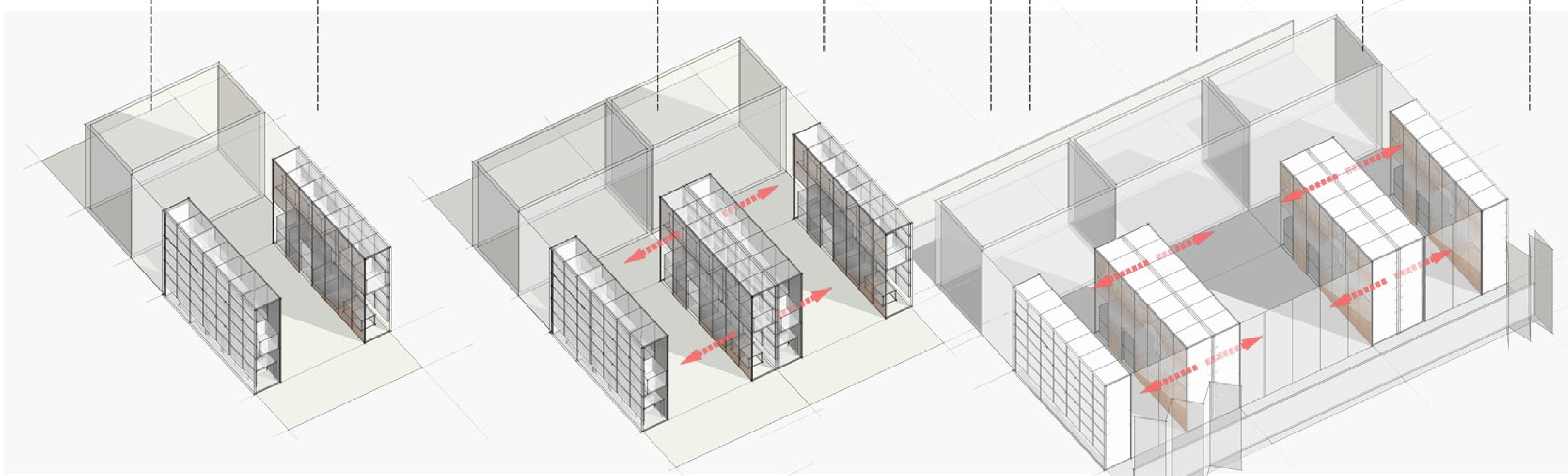
Concept

In the metropolis of East Asia, land resources are becoming more and more insufficient for the reason of the rapid process of urbanization. On one hand, high housing prices, expensive rents and narrow space of the life and office are degrading the quality of life for the people who live in the city. On the other hand, Low utilization rate of architectural space causes a crucial waste of resources. Therefore how to finding an efficient, multi-functional architectural pattern in high density city is a duty to architects. We know, the daily life and work have a direct and most important influence on the city status. In term of time, however,they are always in opposition to each other. so we try to seek an architectural mode between them in order to be suitable for the metropolis.

1 Living&Working Unit --- Adaption



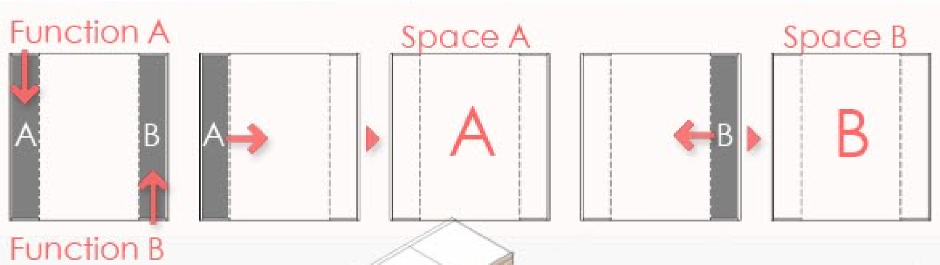


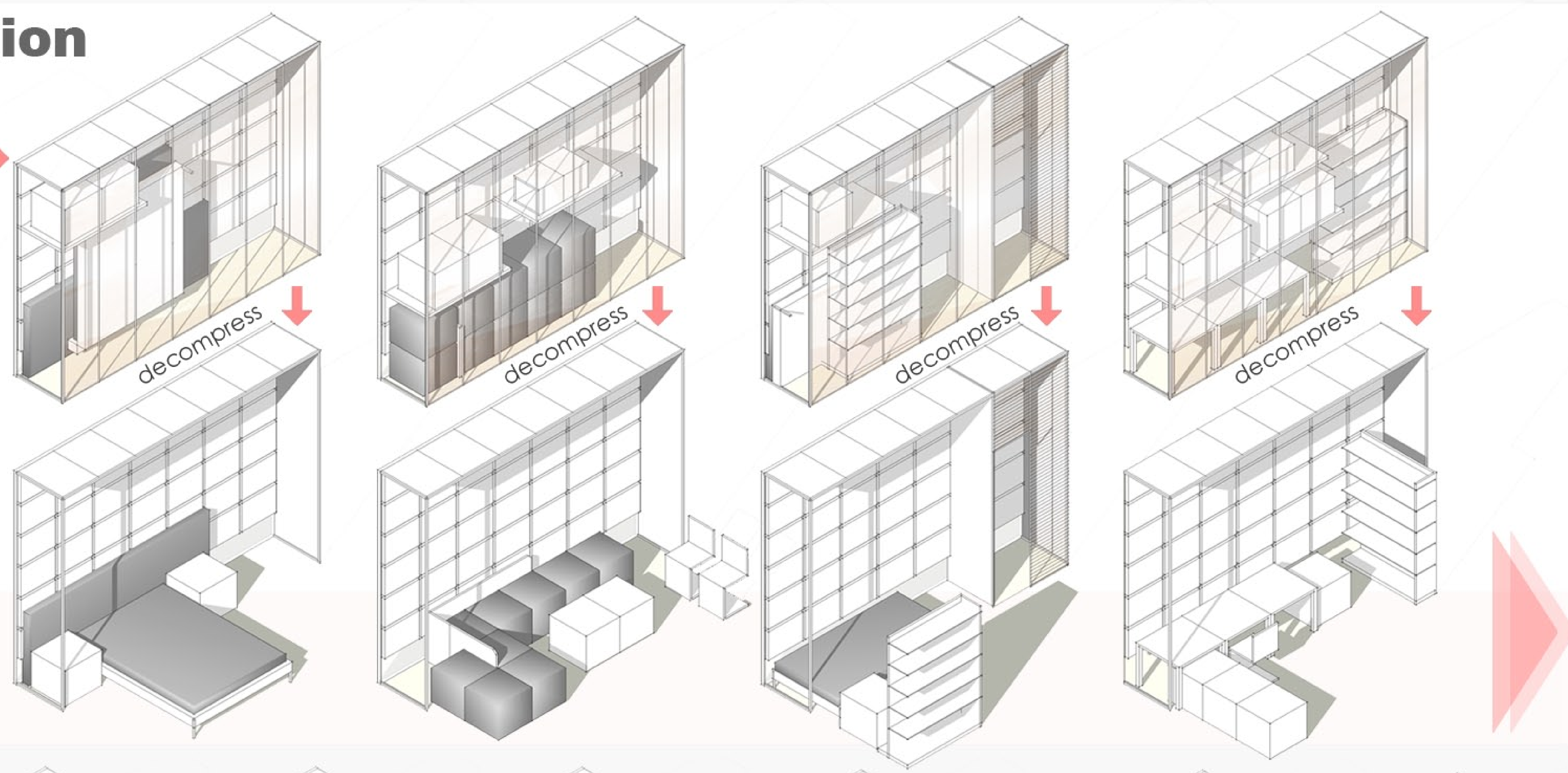


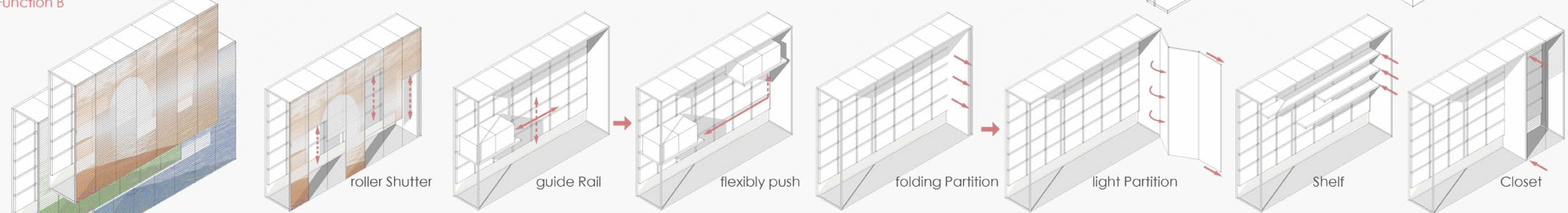
This project embodies the efficiency, flexibility and multifunction of the space. Firstly, users can select the number of cells to set up their own need of the space mode. By the movement of the thick wall, moreover, they also can decide their own floorplan.

2 Thick Wall --- Define Function

The thick wall is like a suitcase, a space for the Compression of the furniture.



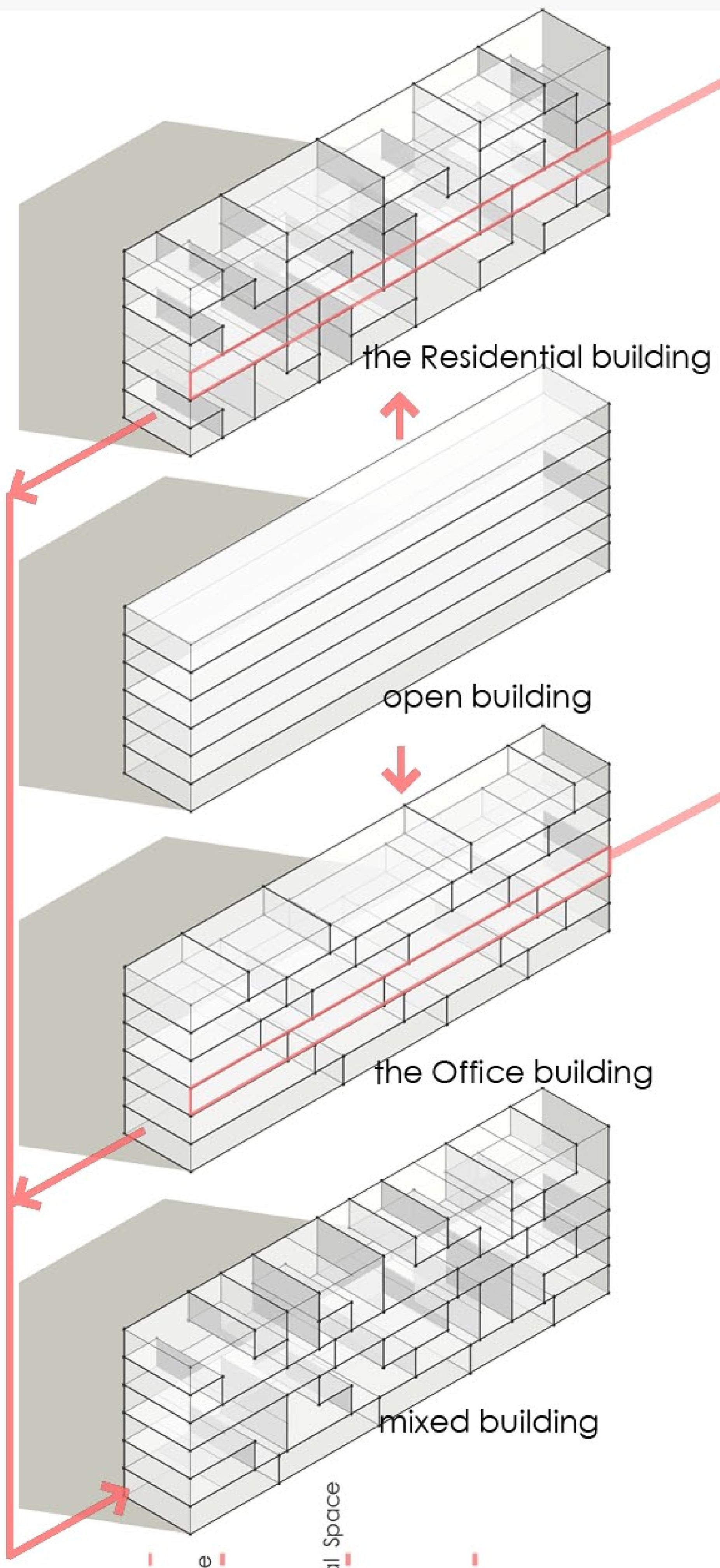


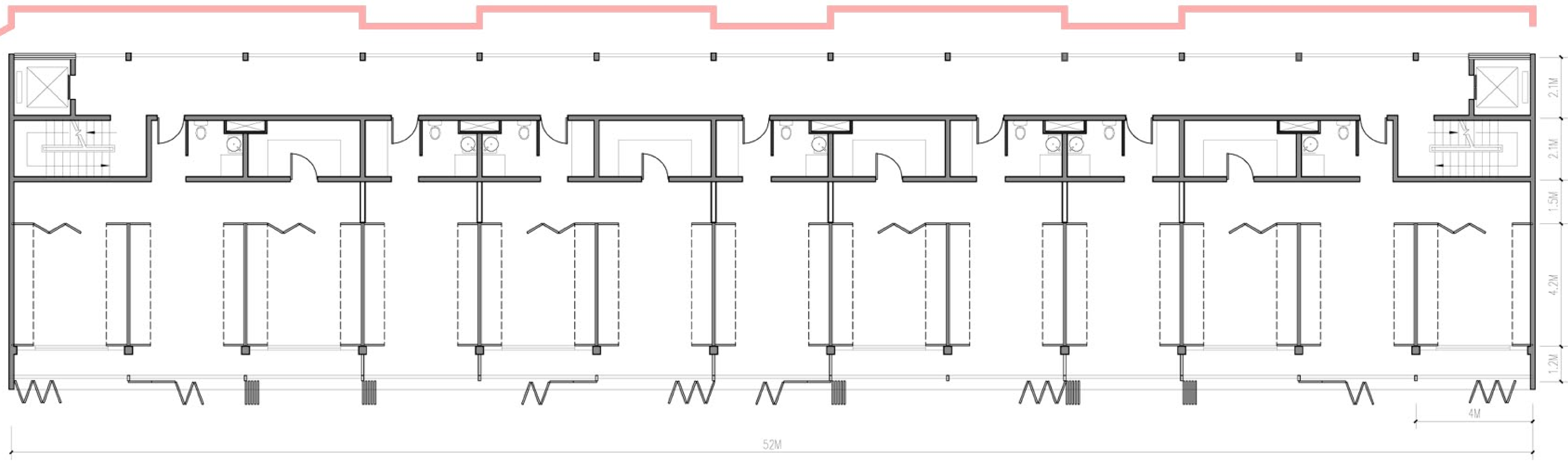


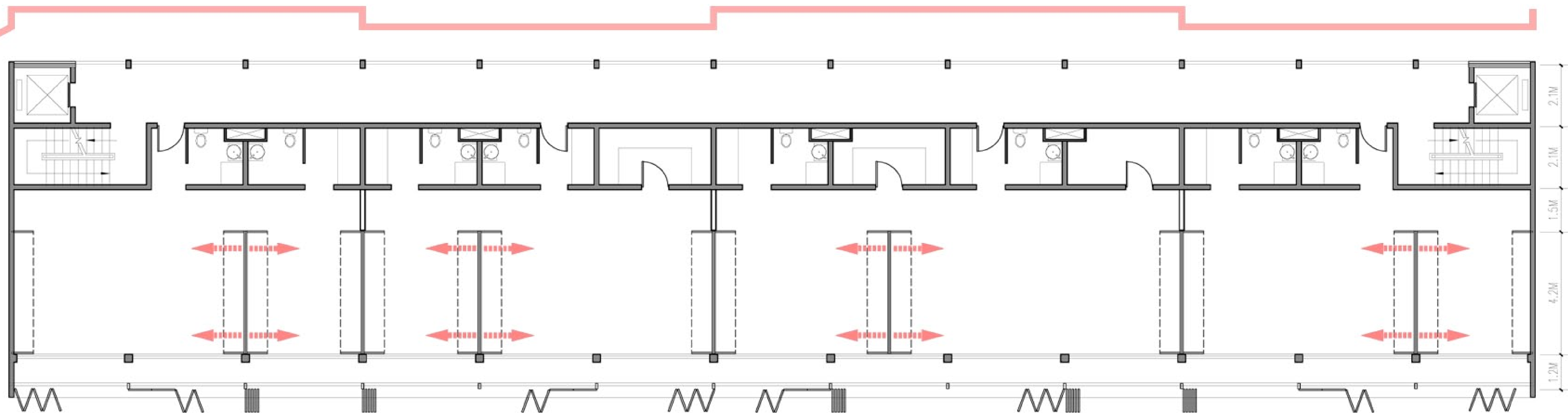
Every cell can be divided into different functional space by the compression and decompression of the thick wall. No matter work or private life could be accomplished in only one space by this way.

DYNAMIC OPEN STRUCTURE

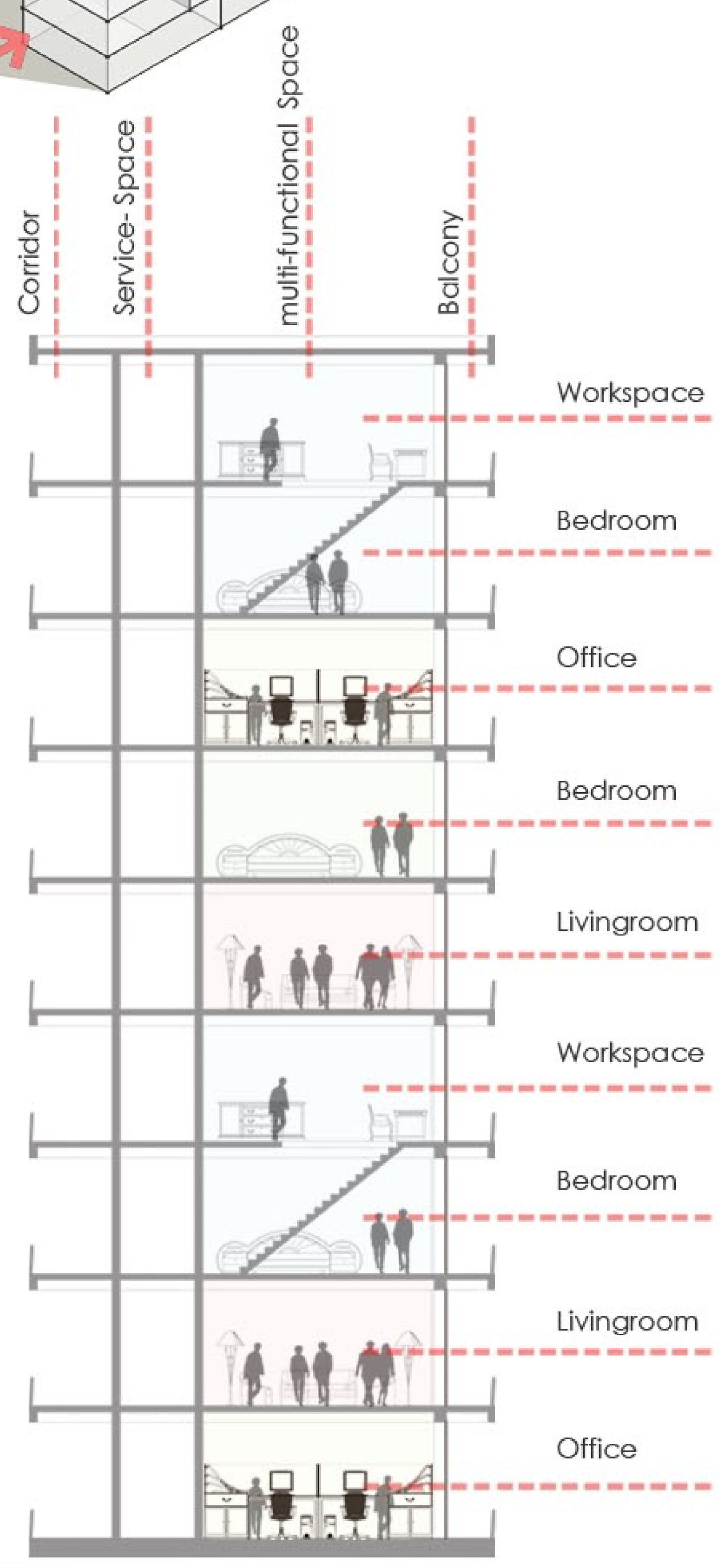
Living and Working in a highly adaptable building



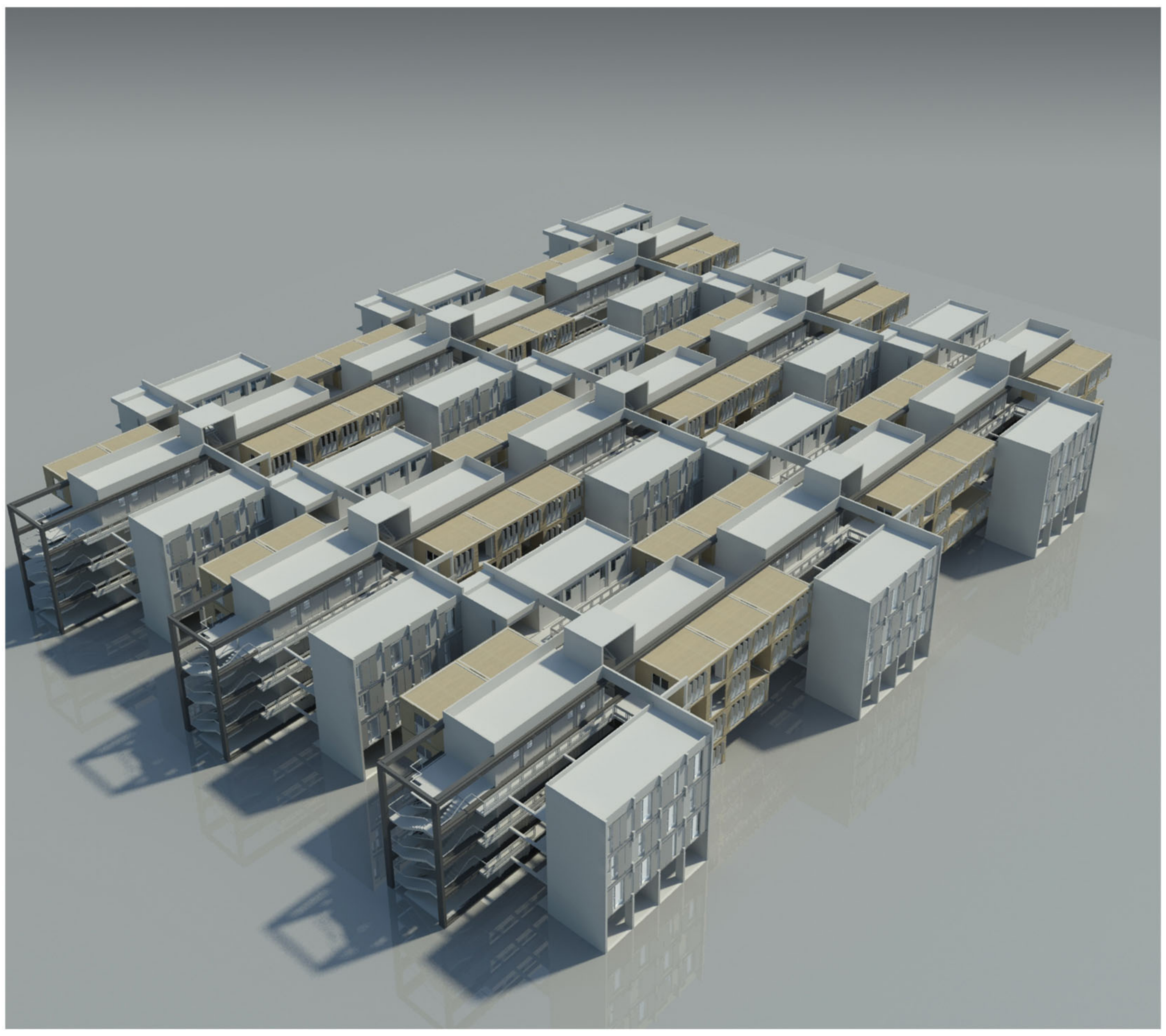




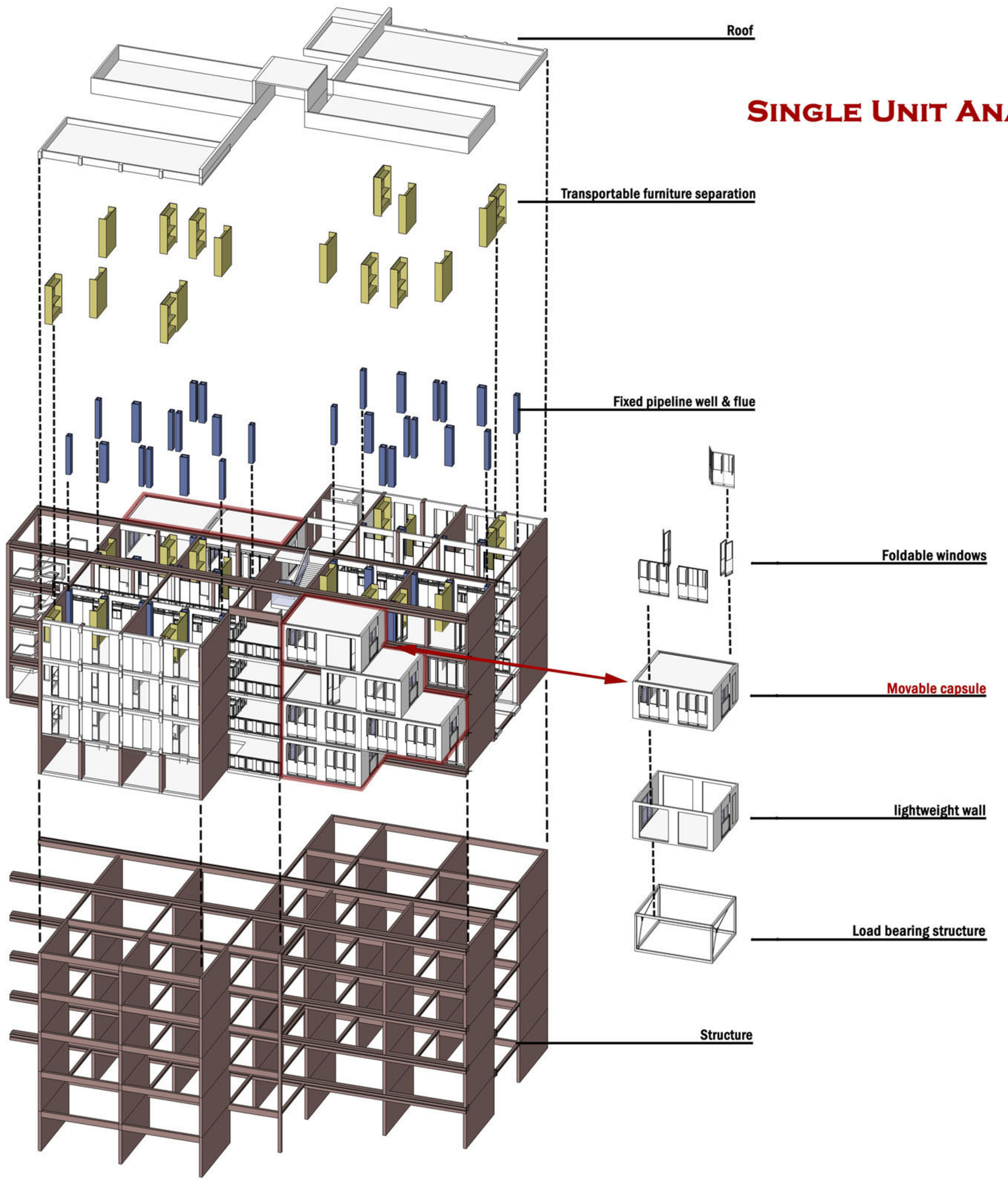
Define Function by changing dynamic thick wall & by choosing different wallelement

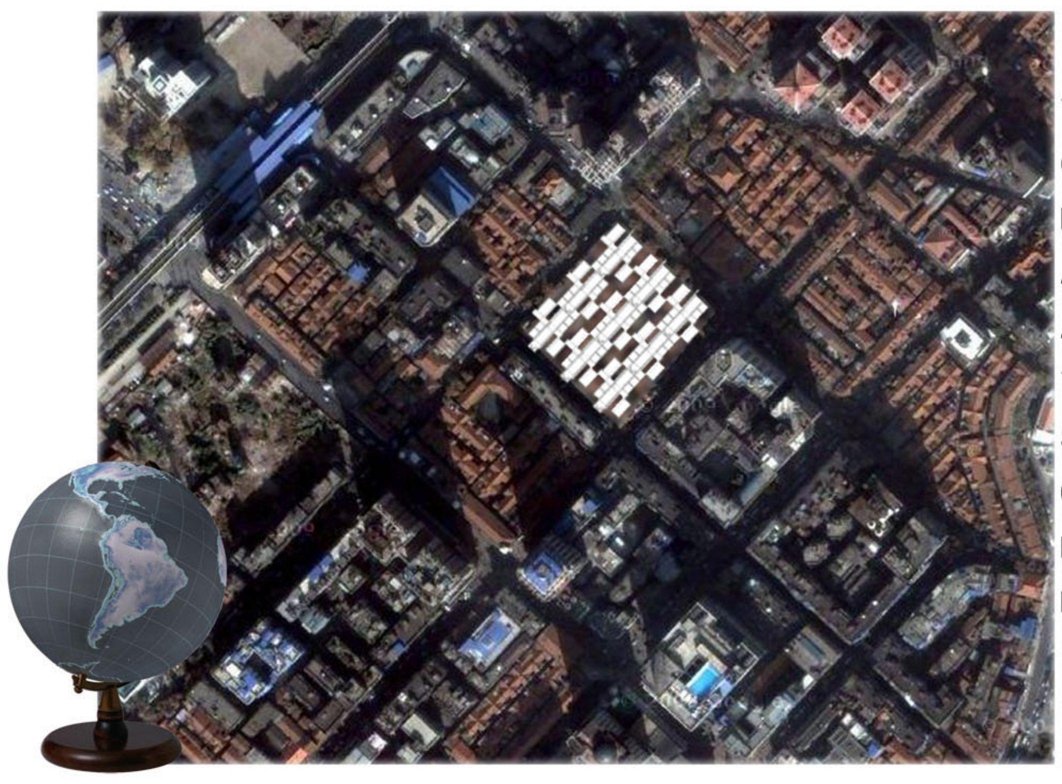


--Reconstruction of community in Hankow



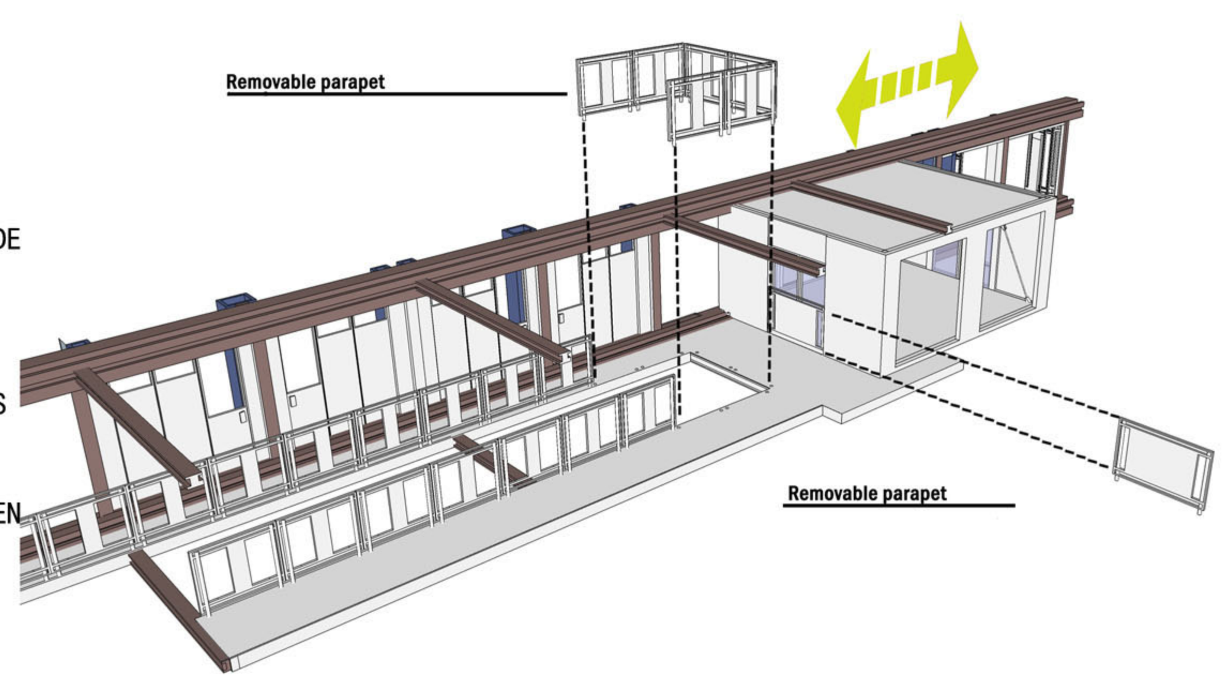
Single Unit Analysis



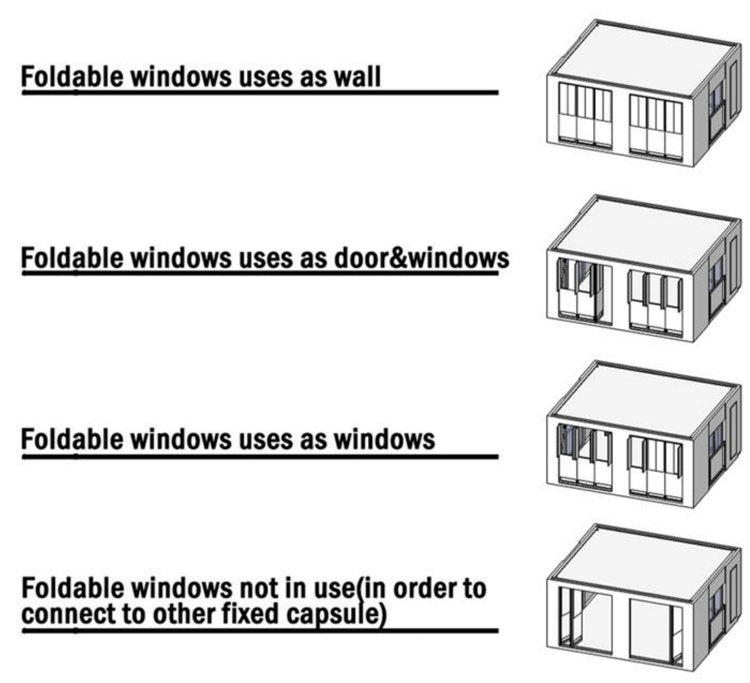


THIS PROJECT CONSISTS OF FIXED CAPSULES AND MOVABLE CAPSULES. MOVABLE CAPSULES ARE LIGHT AND ADJUSTABLE, FIXED CAPSULES INCLUDE ADJUSTABLE FURNITURE WHICH USED TO BREAK UP SPACE, LOAD BEARING STRUCTURE AND PIPE LINE, RAILINGS ON THE PLATFORMS ARE REMOVABLE, MAKE IT EASY TO TRANSFORM BETWEEN MODE 1 AND 2

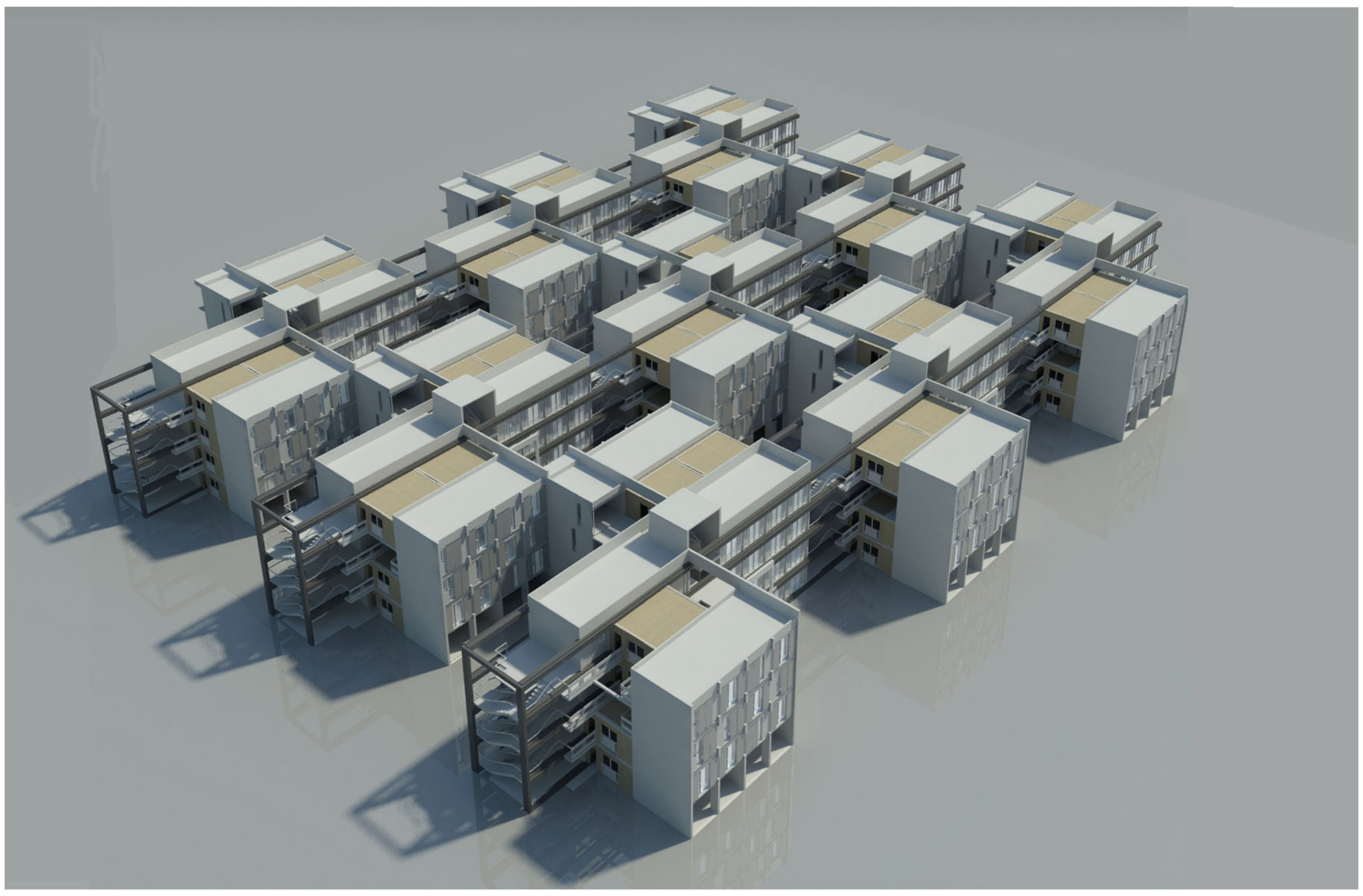
Moving track analysis



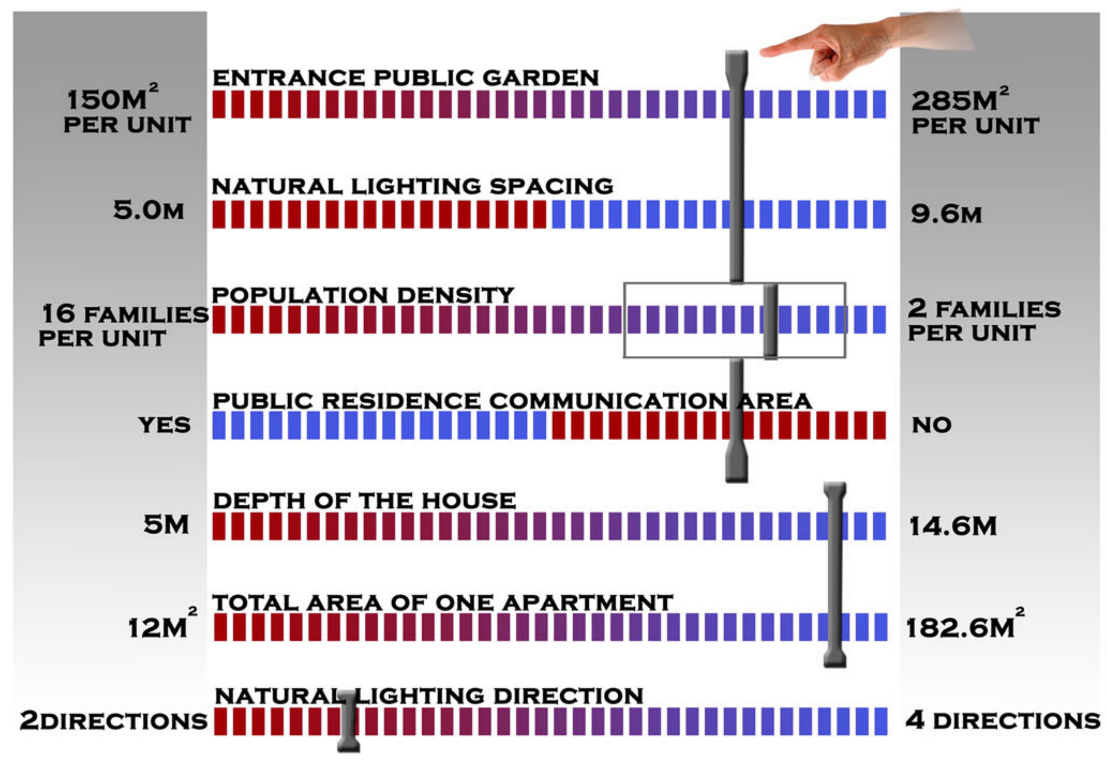
Moving capsule analysis



COMMUNITY OF LONGEVITY



CHOOSE PARAMETERS YOURSELF



PARAMETERS OF THE HOUSE ADAPT TO THE CHANGING LIVING ENVIRONMENT

Introduction

This project focus on the countinuous changes of life pattern that exists in Hankow,Wuhan,China.In these area,houses are being taken over by different groups of people and being transformed by themselves or being completely demolished and rebuilt are happenning all the time.We have done a careful investigation and write in paragraph below which indicates that two major groups are living in this area,they have completely different needs and living standards ,both of them like transforming the house themselves due to the fast development of commercial business in this area.What we aim to do is to form a strategy to combine these two typologies to co-exist in one or be taken over easily by another,and let each of them transform their houses easily to meet the needs of them mutating with the changes of urban living mode through time.

step 3
FOR PERSON

more......

ADJUSTABLE FURNITURE TRANSFORMATION----

result: Available living pattern:

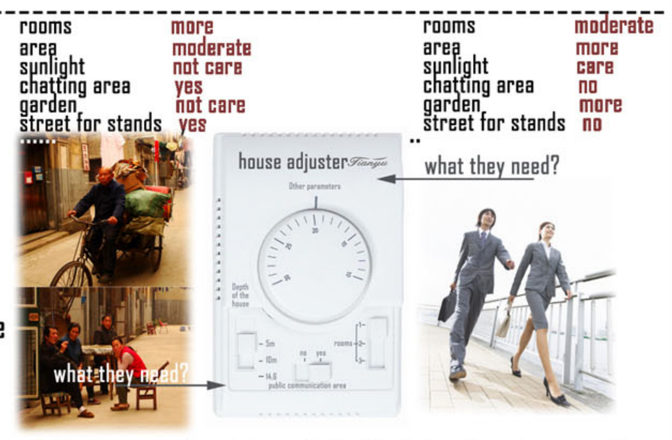
more......

Investigation

life in Hankow is changing everyday,a permanent building is never fit for this place.,part of the area was used as foreign settlement before,when the war was over and the foreigners left,their houses were taken over by local residences,they divided one house which belonged to one family into many parts and one house was occupied by at least four families .They live together,even share the kitchens and restrooms.As time flying members of one family have grown bigger,they transform house to be the one they like, use the original method to **gain more rooms and spaces,add additional function modules**, despite **sacrificing natural lighting.** After several years,some residences went to other cities to earn money,leaving old man and children at home.They make a living themselves **,transform the rooms in the first floor to shops,or selling the food they made themselves in the nearby streets.** now, the houses are no longer fit for the modern society and new residences such as white-colars,then **demolition and rebuild are happening.** But there are signs which indicate new houses are divided and transformed in its interior by owner and then rent to others.

Strategy

Our project aims at creating various types of houses and living style to meet different needs through 3 step transformations,living customs of two major groups of people can be preserved and interact with each other, This project consists of fixed capsules and light movable capsules,fixed capsules include pipe line well ,flue and adjustable furniture.



Additional structure

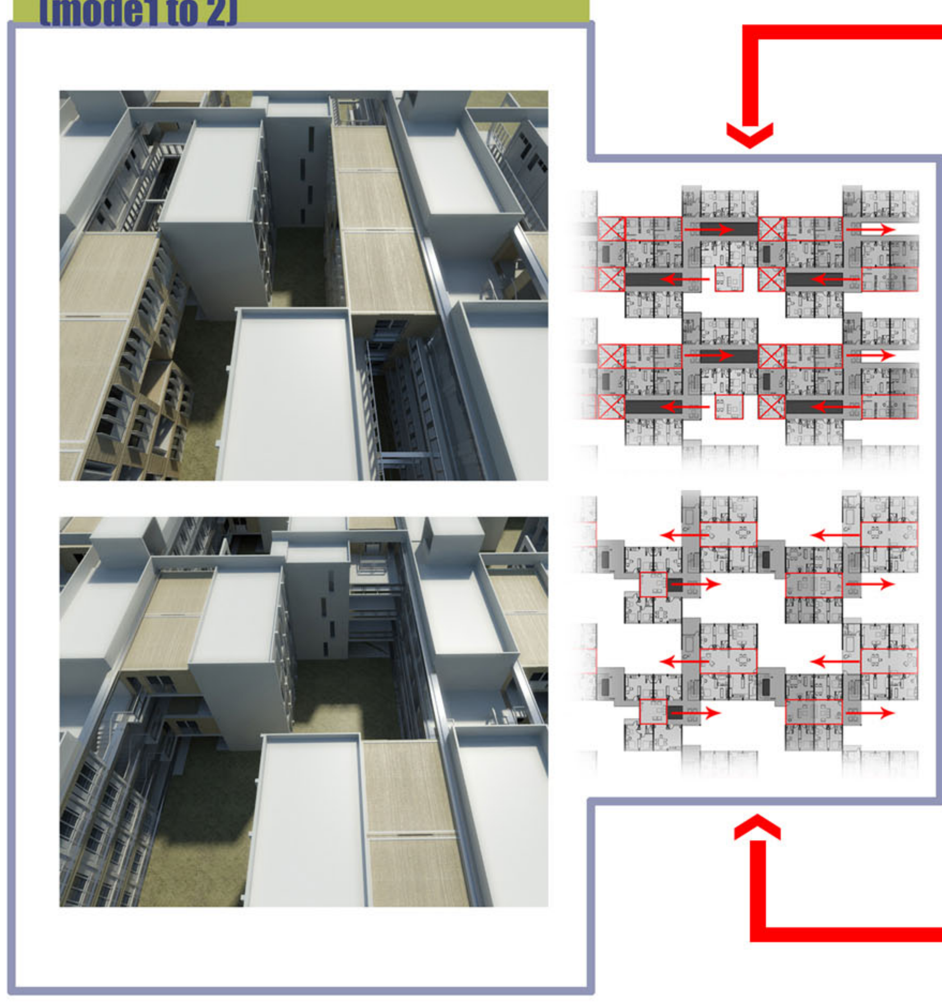
Communicating area

Some windows and stairs of the foreign settlement are preserved by now

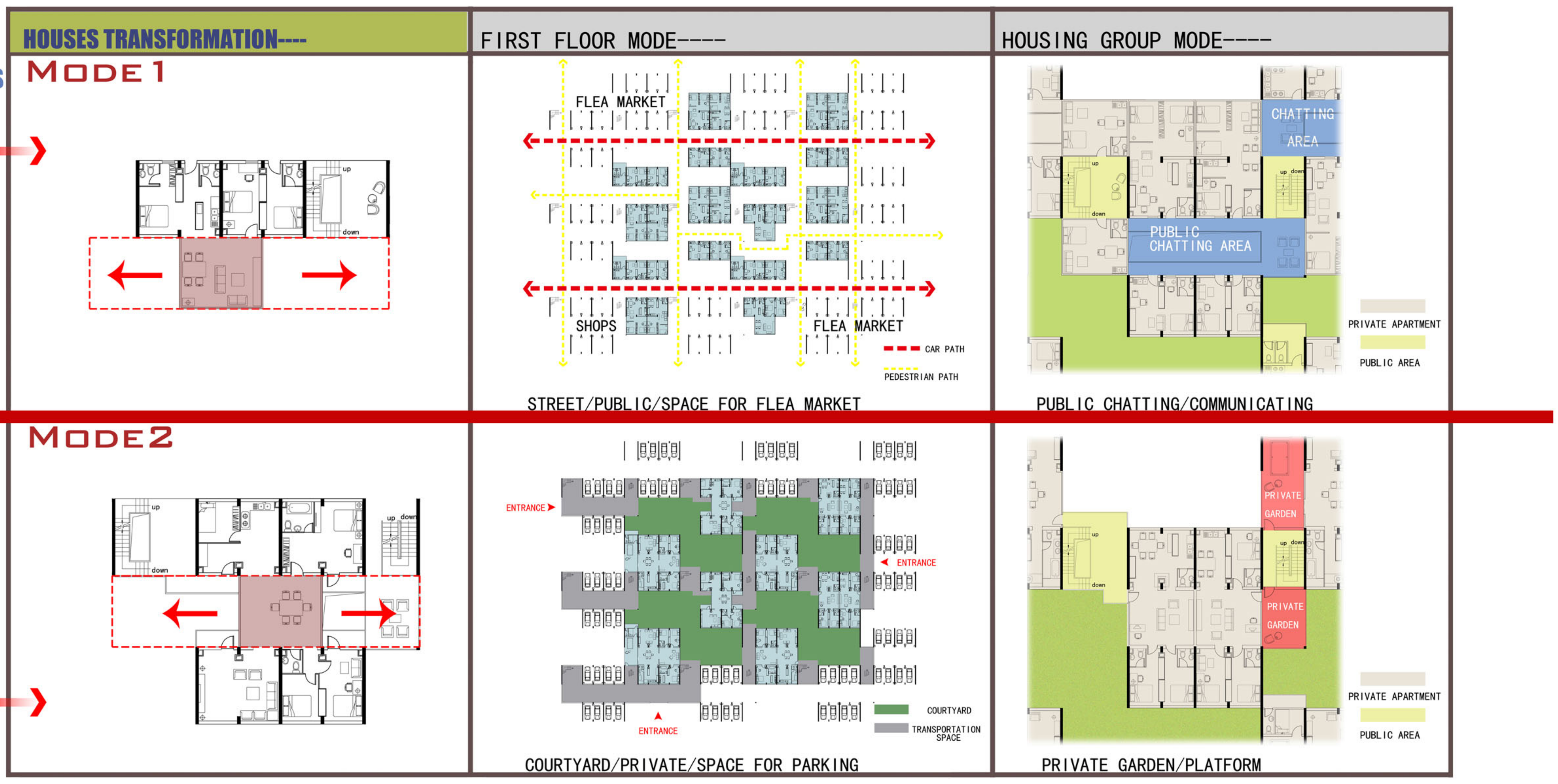
Some windows of the foreign settlement are preserved by now

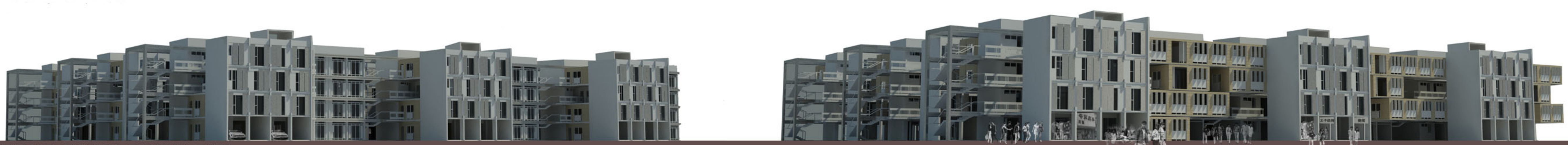
step 1
FOR GROUPS

HOUSE GROUPS TRANSFORMATION (mode1 to 2)



step 2
FOR FAMILIES





FACADE CHANGES THROUGH TIME

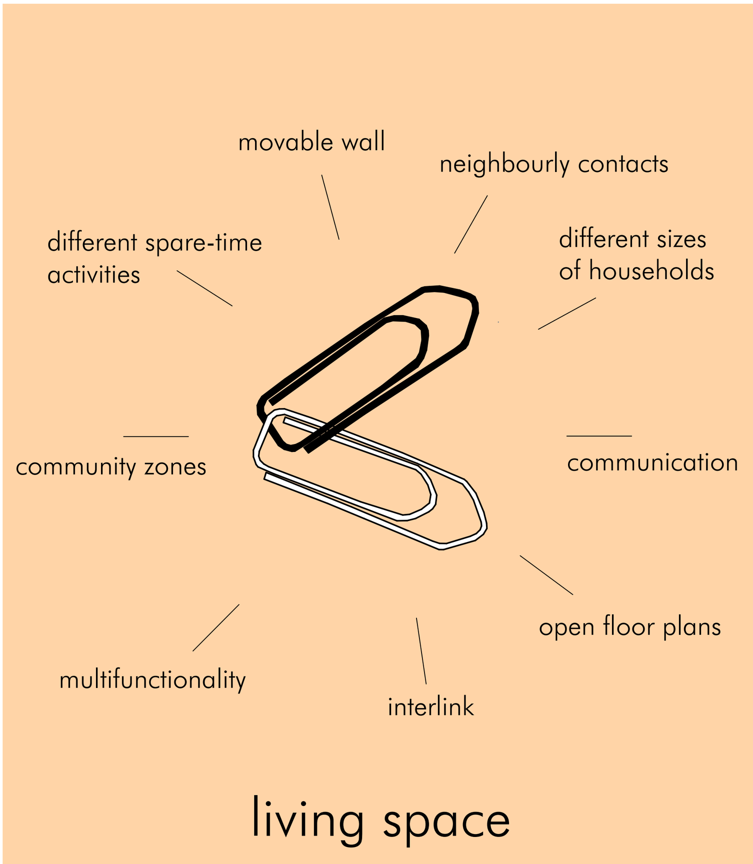
infinite loop

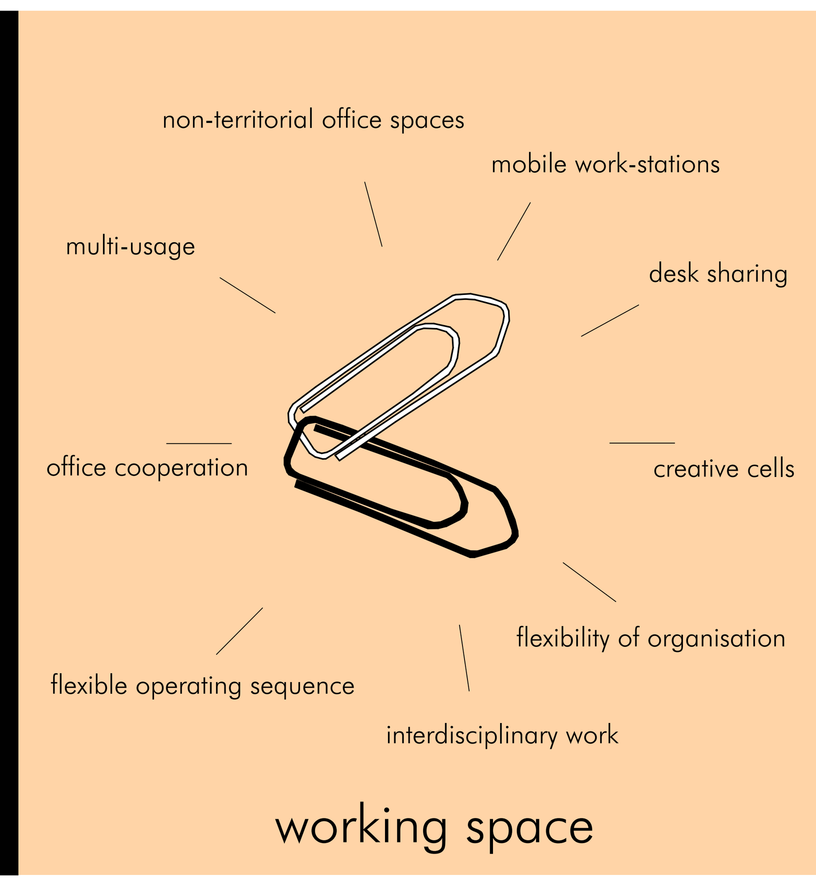
a new concept for housing and living

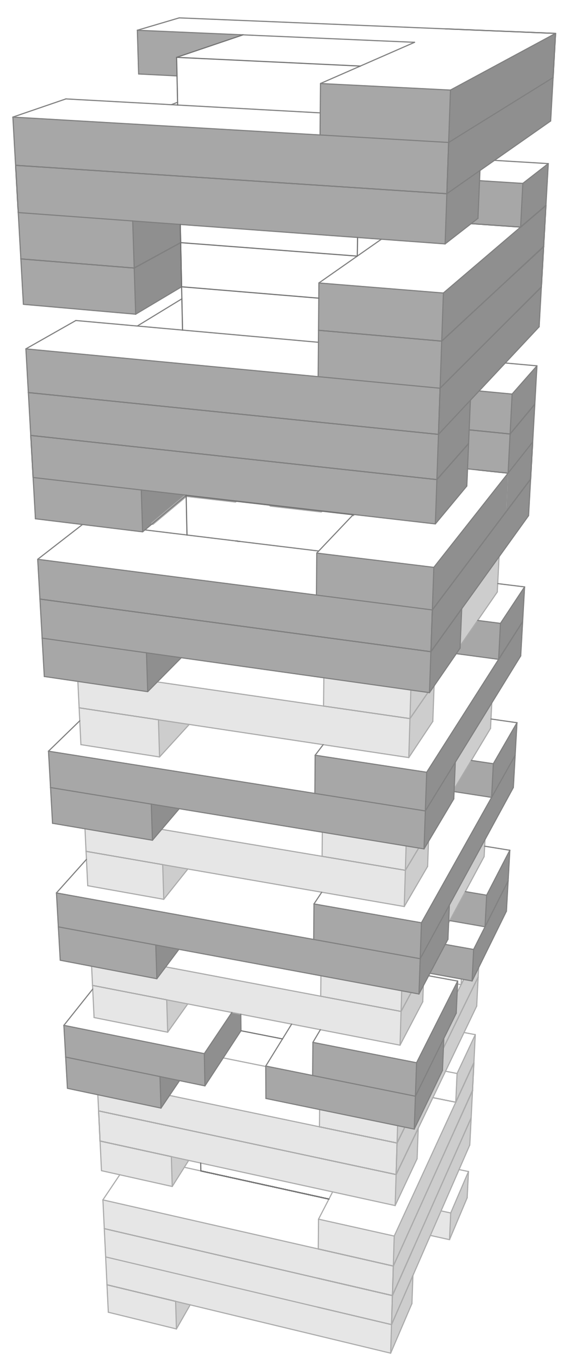
living

working

spare-time activities

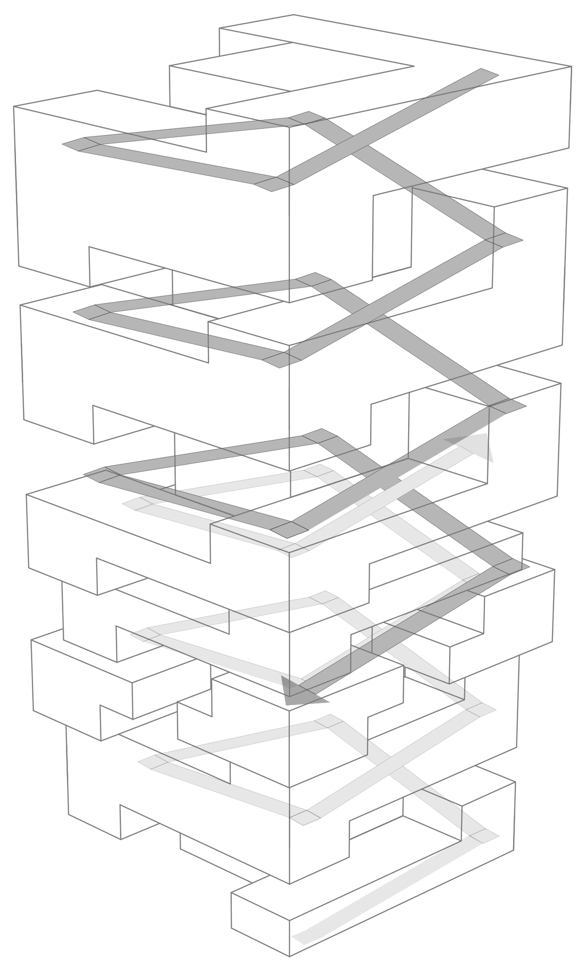




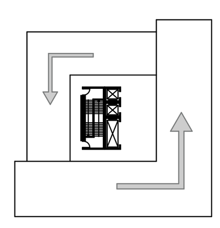


configuration type I:

skyscraper with 25-60 storeys



01 _ figure (double helix)



The infinite loop is a new type of building concept. It is a new combination of living and working. What has been separated through the time of functionalism is now united in a complete new method offering new possibilities and qualities.

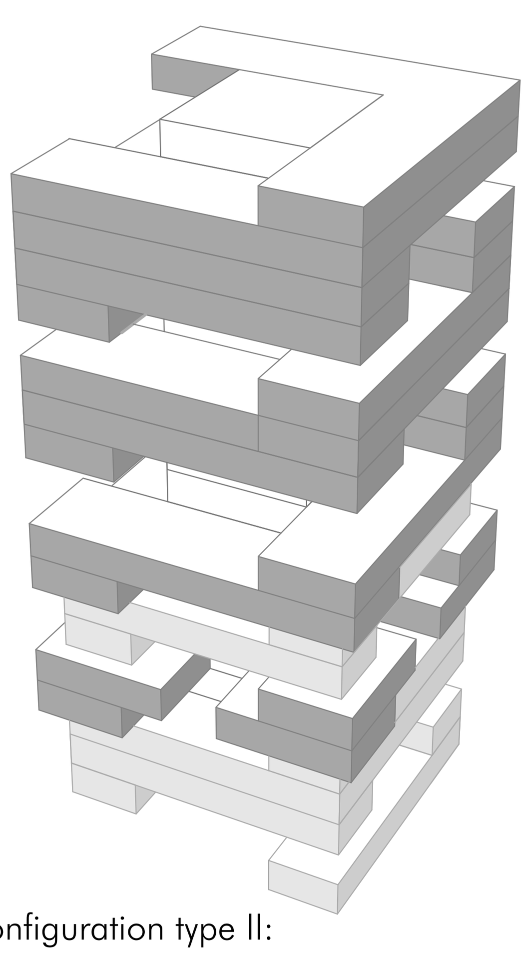
In this new urban building the barrier between working and living is blurred providing some very positive effects. Combining different uses in one building makes it appear more vivid. Moreover it has a positive synergy-effect enabling the inhabitants and employees to support each other. Additionally, long-distance car drives to the workplace will be omitted, which is advantageous in an economically and ecologically way.

The future location of the building is planned to be in an attractive urban context. To provide an optimal exposure and ventilation on each side, it has been designed with square floor plans and is placed in an autonomous position. The height of the twenty-storey tower reveals beautiful views over the city. Furthermore, the extraordinary design and the representative appearance makes it very easy for the inhabitants to identify with their new living and working place.

The building structure is based on the principle of an infinitely enlargeable double helix, offering a configuration type with many different variations. The spiral movement of both loops, which are concentrated at the beginning, start to disintegrate in an intermediate zone.

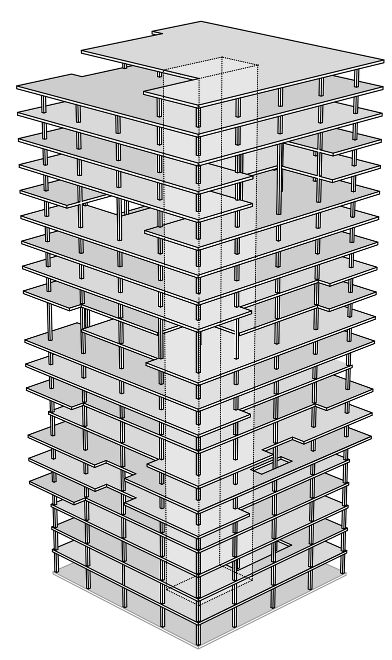
A skeleton construction and the use of moveable walls allow the highest grade of flexibility. Non-territorial structured office spaces offer multi-usage and interdisciplinary working. The residential areas are dominated by open living space and partially two-storey zones with galleries. Transformable community zones are placed in between. Based on an adaptable partition system it is easy to organize space perfectly and fulfill the residents needs. The infinite loop is a place of social interaction between neighbours and colleagues and to counteract the anonymity of the big city.

Last but not least, the inner concept appears as well at the outside in form of a mixed-use tower.
Life and work - interlocked and combined in a loop.

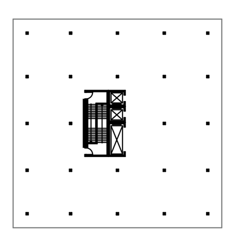


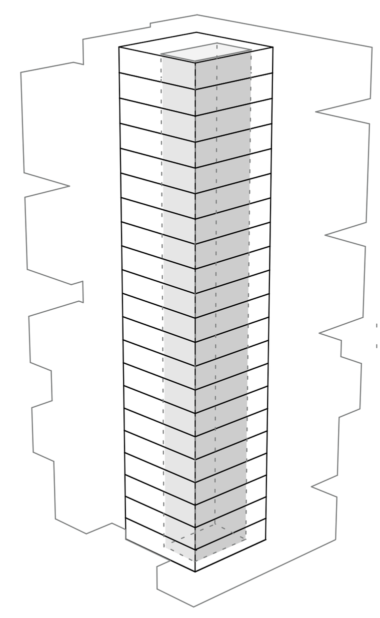
configuration type II:

tower/multi-storey building with 20 storeys

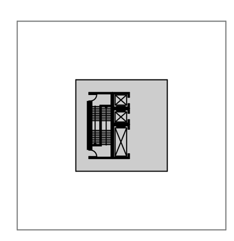


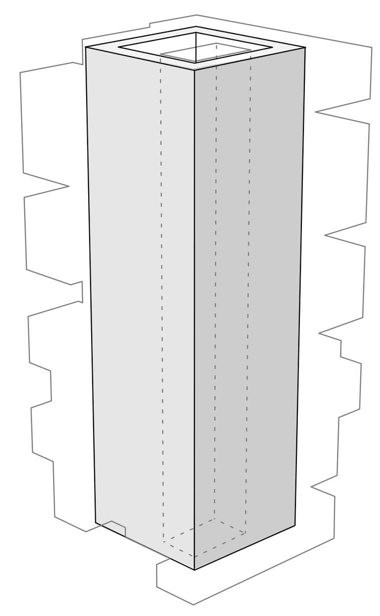
02 _ supporting structure



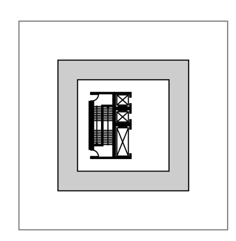


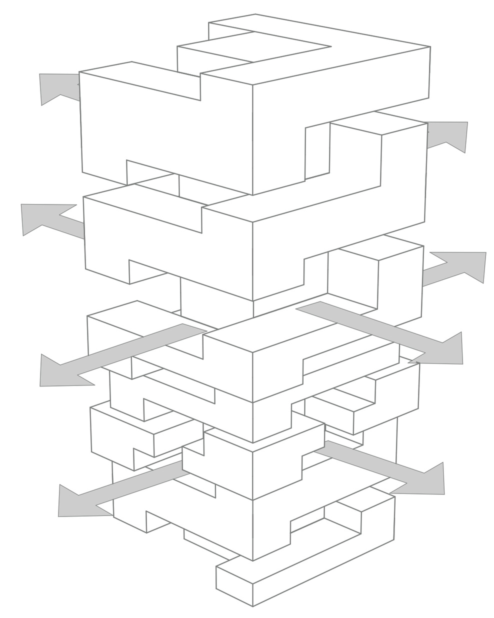
03 _ core of vertical circulation



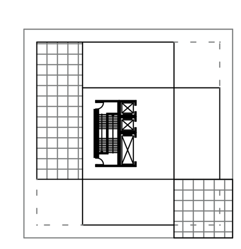


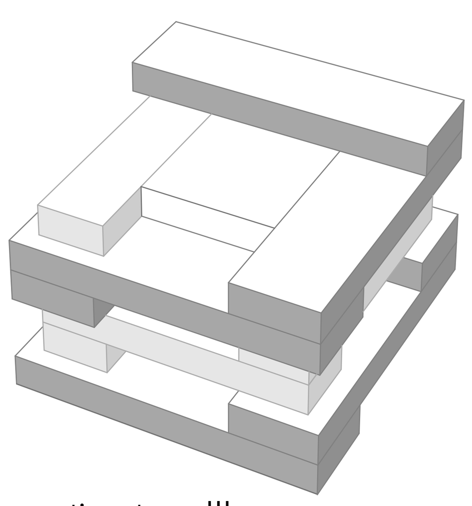
04 _ service zone





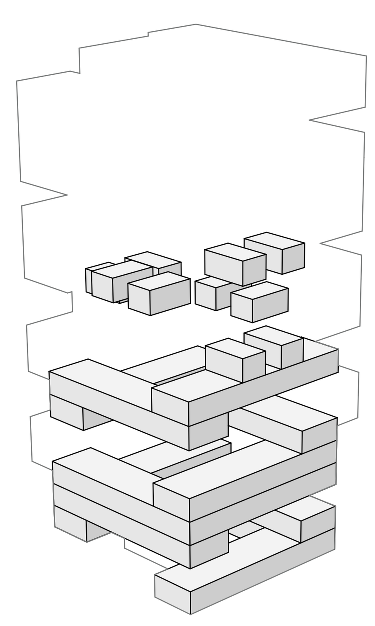
05 _ view and open spaces



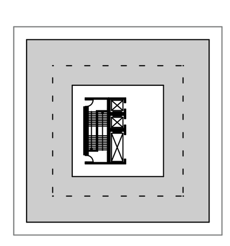


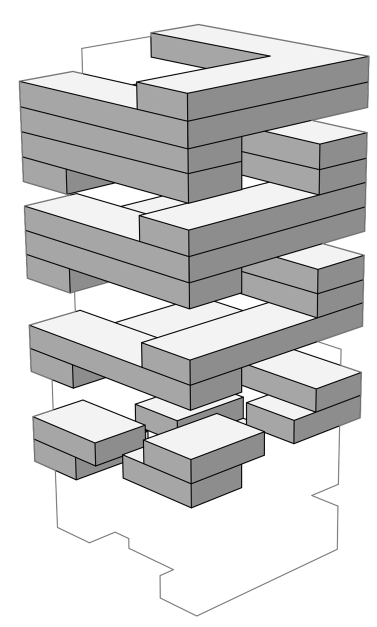
configuration type III:

town house with 6-8 storeys

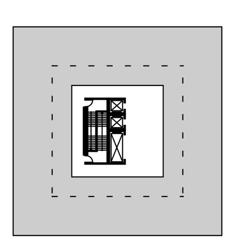


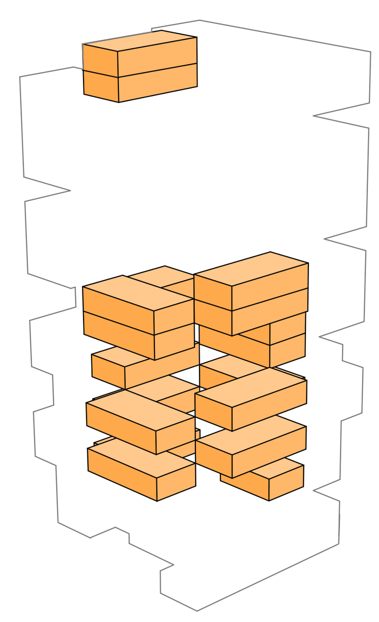
06 _ working



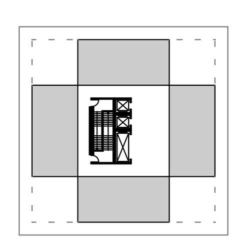


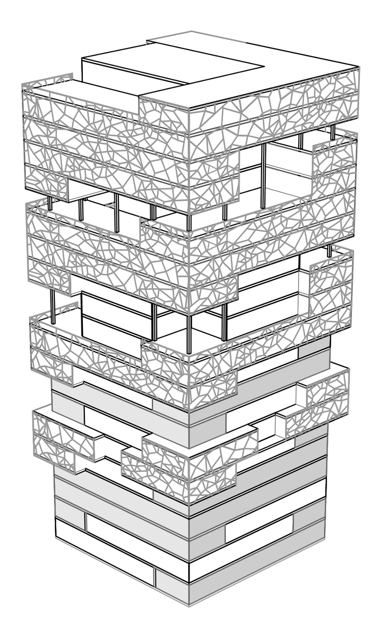
07 _ living



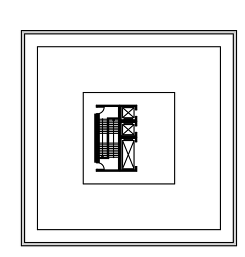


08 _ spare-time activities





09 _ facade



infinite loop

a new concept for housing and living

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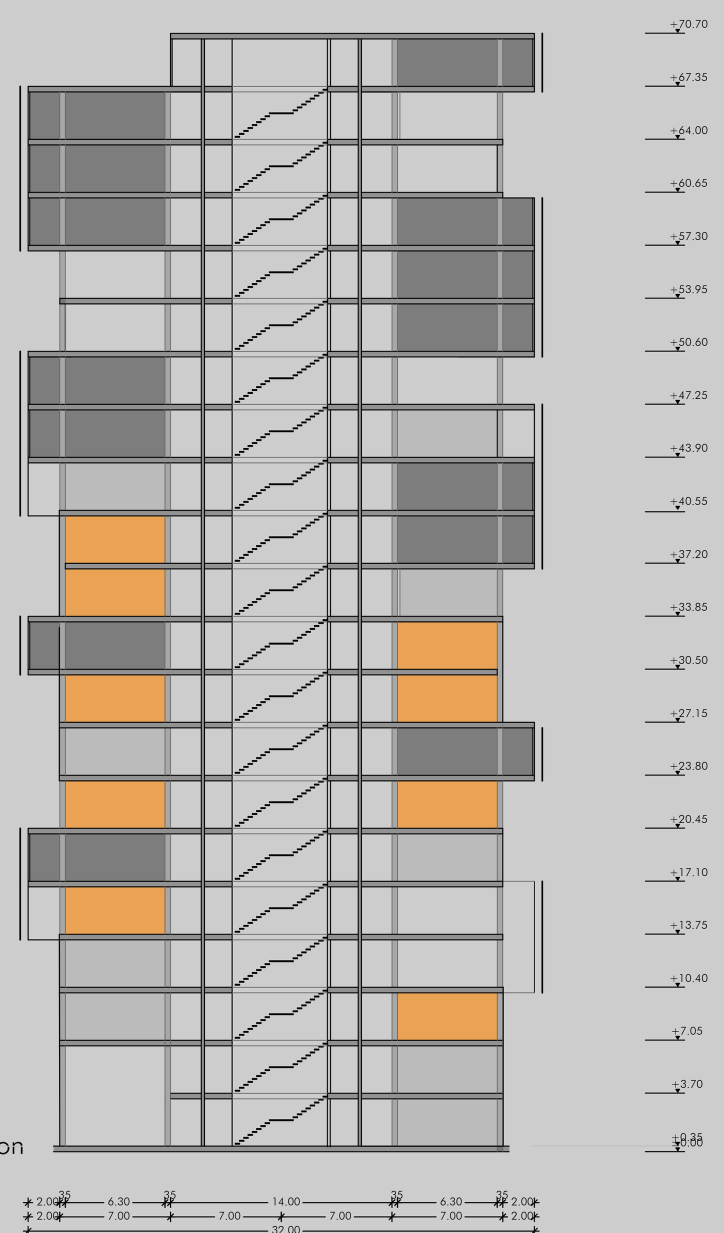
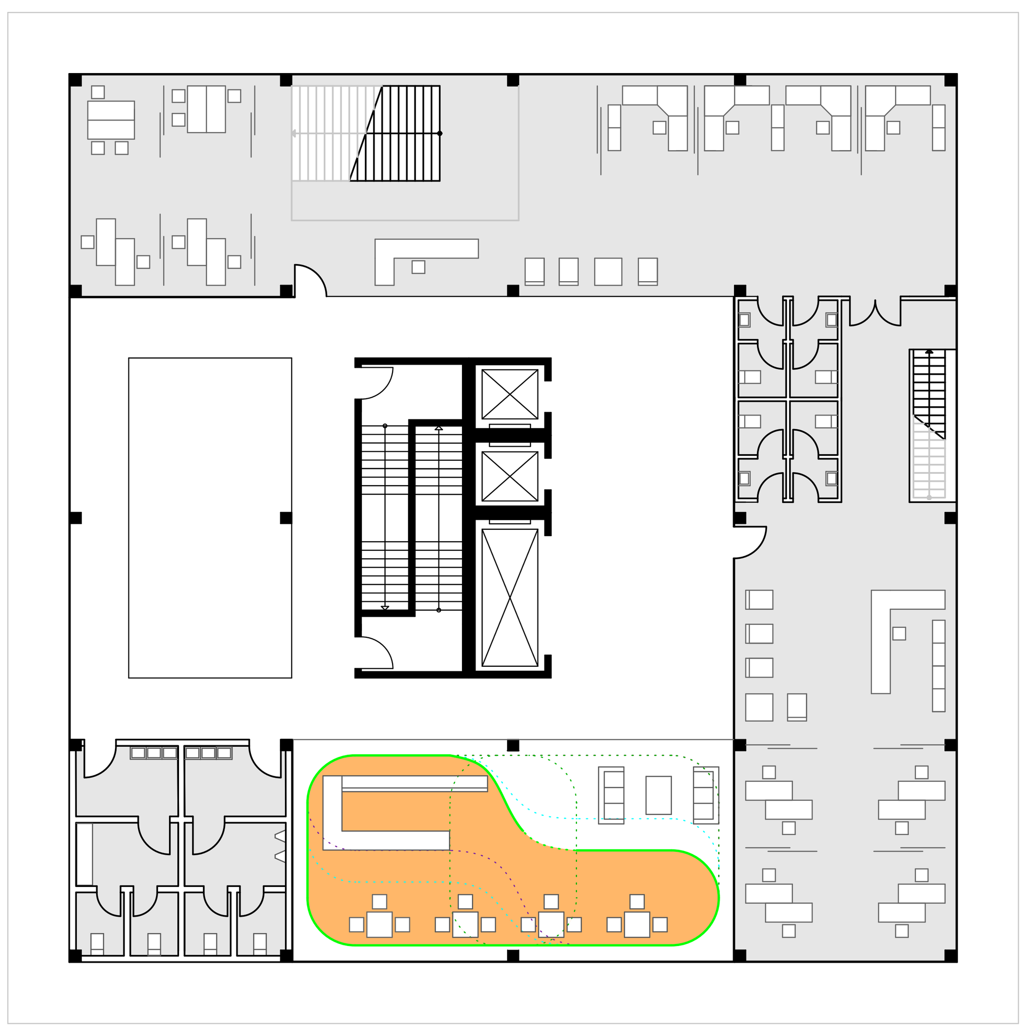
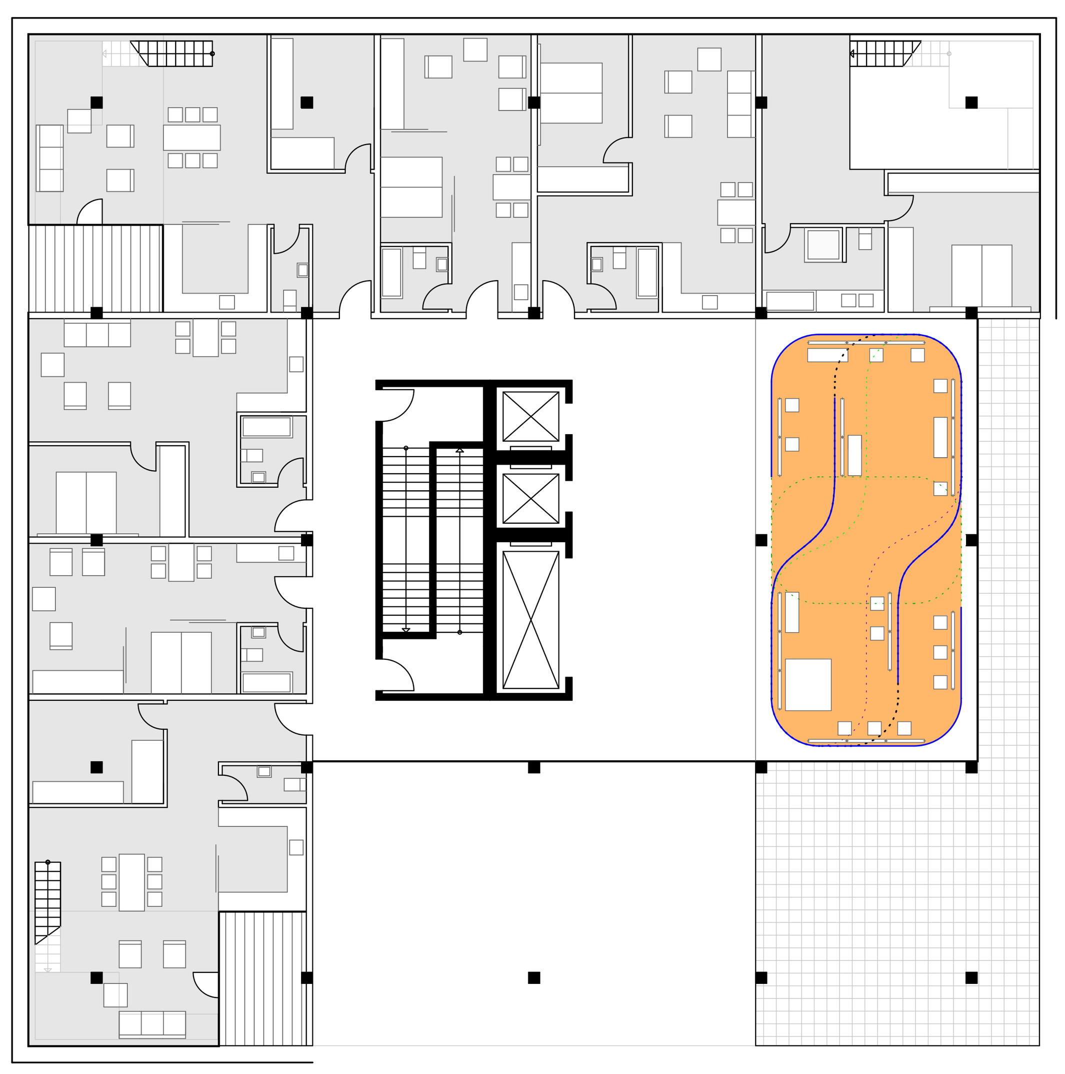


cross section



2rd floor plan scale 1:200



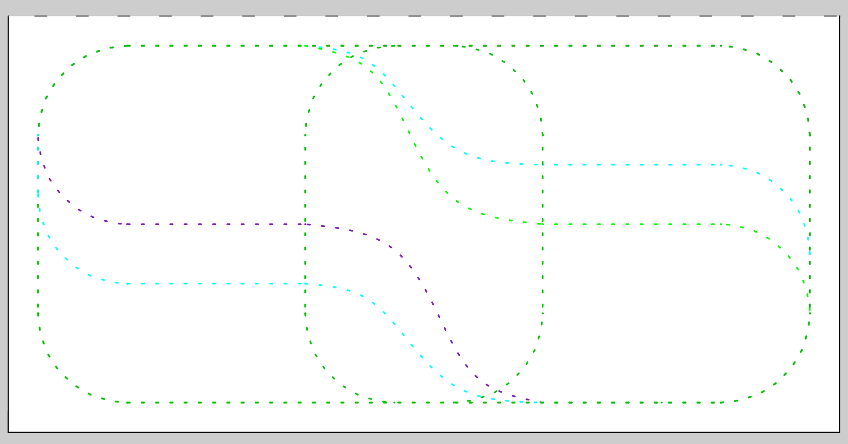
19th floor plan scale 1:200

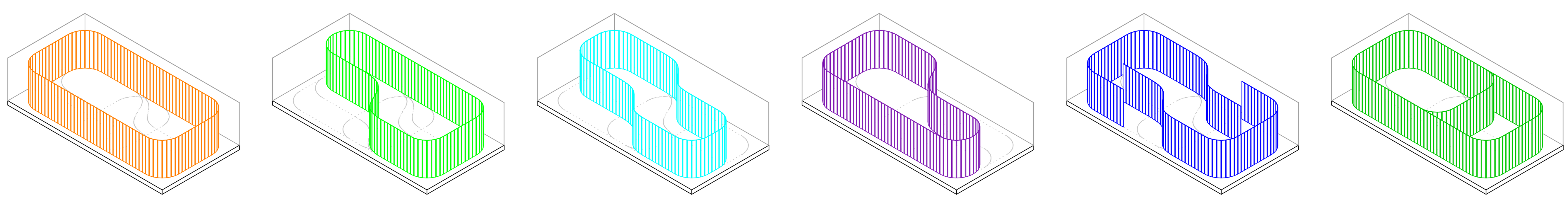
MOVEABLE WALL

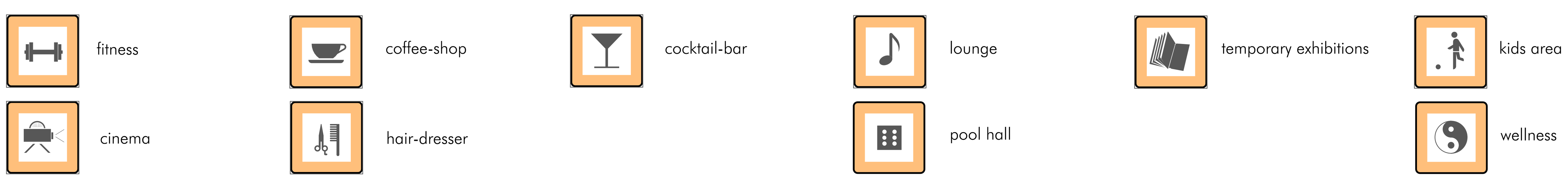
With this multifunctional partition system, rooms can be divided flexibly in just a few seconds. By means of a rail system, the convertible panels can be adjusted very easily and exchanged without big effort. So the moveable wall reacts to the different needs and offers variable spaces.

This system is used for the community zones to create different situations for the modular spaces and to adapt to the respective use.

This drawing shows the overlay of the possible cladding positions.







This publication contains the PROCEEDINGS OF THE 16TH INTERNATIONAL CONFERENCE "OPEN AND SUSTAINABLE BUILDING - O&SB2010", ORGANISED JOINTLY WITH TECNALIA. MAY 17-19, 2010 BILBAO (SPAIN).

The papers address issues ranging from health care to housing, building technology to design methods, and represent research and practice by experts from Asia, Europe, North America and South America. In addition, the winners of the 2nd International Open Building Student Competition "Detaching form Architecture" are presented, along with the challenge issued to the students. An international jury of architects reviewed more than 70 entries in coming to a list of winners.

The book is introduced by a *Challenge to the Open Building Movement*, authored by Dr. Stephen Kendall, Professor of Architecture at Ball State University in the USA, one of the joint coordinators of the CIB W104. It offers a brief history of the CIB W104, its primary focus and principles, and outlines a number of challenges facing the design, construction and long-term management of a sustainable, open building stock.

Fundamental support has been provided by the CIB W104 Open Building Implementation Commission of the CIB, INTERNATIONAL COUNCIL FOR RESEARCH AND INNOVATION IN BUILDING AND CONSTRUCTION. These proceedings contain the latest developments, published after review by these two organizations.