VR Live in Architecture: Broadcasting Realtime Virtual Reality

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Abstract
Desktop broadcasting and Virtual Reality is an emerging medium which provides many opportunities in architecture, planning and design practices, including assessment for new architecture and interventions to existing buildings, heritage sites and, urban design. With the advent of real-time rendering and live streaming of Virtual Reality environments it is possible to interactively evaluate project vision by non VR experts. This paper discusses innovative developments on VR, and in particular applications from video-gaming technologies VR online publishing and live VR broadcasting. The paper reviews medium and evaluates software tools. The paper discuses on potential frameworks for further empirical research within the domain of environmental psychology. Five design projects are described, software attribute tables prepared and qualitative feedback presented. Although the paper mainly focuses on technology it concludes with evaluating empirical studies on people-environment and design utilising emerging VR authoring and broadcasting tools.

Keywords
Design, Live Streaming, People-Environment Studies, Architecture Visualisation

1 Introduction

Engaging with Virtual Reality in architecture and urban planning provides new and exciting opportunities as the technology has matured and will continue evolving. Much of the VR development has been propelled by video-gaming as it is one of the fastest growing industries, partly exacerbated by lockdowns during global pandemics in 2020 and 2021. Because of this, VR adoption is taking place at a rapid pace and both, cultural and technical barriers will continue to diminish bringing tangible and direct benefits to niche industries such as architecture and planning. With mass adoption also comes a drop in cost and improvements with user interface (UI), no codding or programming is now required to creating professional VR environments neither. Architects, designers, and urban designers can now author and broadcast virtual scenarios even if they are not 3D modelling experts. Licencing for authoring and publishing VR environments is now simple.

VR real-time stands for the ability to render buildings and design on-the-go rather than post processing. Cloud computing is unlocking the potential to generating high resolution and photorealistic VR renders taking away the problem of internal workstation CPU and RAM. Cloud computing allows for image processing non-dependent on the workstation. In the case of real-time VR is now possible to broadcast and share VR environments accessible on relatively small devices either, desktops and laptops with the capability to also connect VR glasses or a headset.

A user-friendly interface for VR postproduction and publishing is certainly a breakthrough for rapid adoption. Although much of the 3D modelling and BIM authoring tools require C++ and visual programming such as Python with parametric design tools such as Dynamo™ for Revit™ and

Grasshopper™ for Rhino™, Virtual Reality software has evolved in parallel mainly from videogaming technology. An example is TwinMotion™ that runs at the back of Unreal™ gaming engine by Epic™ games. TwinMotion™ is accessible with a small installation file and friendly user interface, it is also reasonable priced. Full installation of Unreal™ gaming software is optional.

On the affordability side, VR software is no longer acquired through expensive licencing for ownership but rather on a subscription and usage basis, making it affordable s small firms and even start-ups. Accessing the software which also runs on standard workstations (commonly used in architectural firms) provides the right scaffolding for the technology uptake. High-end graphic cards, CPUs and HD monitors and peripherals such as the 3D headset is optional but recommended once the practice is conversant with the technology. This scenario also enables start-ups and freelance practitioners to make use of VR without an upfront monetary burden. Up to recently only large firms could afford to have the VR experts inhouse or would outsource it to specialist. The argument here is that VR should be an integral part of the design process and integral to engaging with clients allowing at time participatory design to take place. On the other end of the spectrum, architects employed by large firms are now more likely to get approval to have VR software installed in the workstations making it part of the design workflow i.e., integrating with the standard BIM toolkit.

On the receiving end (such as a client accessing the VR scene for instance) technology has evolved to a point that once the VR has been published there in no need to have dedicated software nor specialised viewer or software installed but the VR can be accessed via a web browser, video streaming channel such as Youtube™ or social media channel such as Facebook™. It is also possible to access VR from various peripherals, from standard monitors and projectors for 360degree viewing to full immersive experience with headsets such as Oculus-Quest2™.

VR interoperability and post-production can be streamlined by operating on the cloud and accessing from various devices. Proprietary software vendors are increasingly aware of the importance of interoperability as well. This means that VR files can be accessed by various BIM and VR software applications. Saying that, software developers continue aiming to stablish captive markets and user-group loyalty. Achieving open standards for interoperability across software is still an issue to solve in the prevailing proprietary climate. This has been much discussed over the years (Aranda-Mena and Wakefield 2006). However, open standards for file exchange are available and increasingly in use. Virtual Reality with Twin Motion™ is possible with file exchanges via Datasmith protocol.

Scalability is another technological improvement in the VR space. Mobile computing is rapidly evolving, through smart phones, tablets, and laptops, and some of the hybrids such as phablets and laptops with touchscreens. This means that if the VR project started with designing 3D space for example in Formit™, as an early project concept *on-the-go*, same file can now be accessed from a workstation with a robust version of the same software application or imported into another application for further developed. File synchronisation (sync.) is often available. *Roundtrip* is when the native file has been altered by a third-party plugin off main BIM authoring application e.g., the main model is updated every time there is a calculation or update by the plug-in application.

The real-virtual continuum. We can refer to this continuum as an ongoing link between the virtual and the analogue world. In times of imposed social isolation and lock-down it has become clear that technology is a medium that allow us to operate, not as a substitute to our real physical world but as an addition to it and not only as ‘augmented reality’. Although virtual and immersive technologies are still in their infancy, they have now reached a level of maturity providing a gentle learning curve. We live in times when the benefit of adopting VR seem clear, and if not, at least piloting and playing with the technology, same technology being propelled by videogaming, should be a must in architecture practice. Afterall, this is already a practice gamechanger which will continue to evolve.

2 Architecture VR Live

Architecture VR Live is here defined as:

> *'[the] ability of broadcasting 3D Virtual Environments of building design and urban planning at conceptual, development and project review meeting stages via an internet video-streaming channel merging both, a (1) virtual environment production (2) synchronously' accessible real-time by a (3) co-located and inter-office group. Just in the same way a music band might be performing live to a face-to-face and online audience.*

This represents a breakthrough as the speed of rendering buildings and settings has increased. The *on-the-fly* ability to render and displaying virtual scenarios in motion (both as navigating through the space and as dynamic objects within it) is now possible through faster clod-based processing making. Making interactions with client, other designers, and stakeholders more fluid and enabled rather than obstructed by the technology where synchronous face-to-face and online design meetings and project reviews can take place.

Accessing VR can be through web browsers projecting on screens or peripherals such as VR glasses or headsets, there is still room for better studying the psychology of *(i) interactive* and *(ii) iterative* design collaborating options, either collocated vs. interoffice, synchronous vs. a synchronous. This presents an opportunity to scale up the design from concept into schematic bringing participatory design opportunities for instance. For example, a design practice based in Melbourne, Australia could import a Building Information Model (BIM) from a town council or planning office in Mexico sharing a basic 3D massing model in any standard file such as a Rhino™ import into TwinMotion for VR via Datasmith™ protocol for data exchange. In the case of Rhino-TwinMotion, all work can be synchronised with plug-in (also available for other commercial BIM applications such as Revit, 3DsMax, Rikcad, Archicad and SketchUpPro) which allows roundtrip updates from either the BIM or the VR ends.

The 3D building asset can also be imported into a gaming engine such as Unity™ or Unreal™ by Epic Games™ with high-end programming capabilities if need for further post-production for presentations under various formats such as high-resolution PNG images to, 360-degree navigable panoramas, to true VR scenes. Export of projects has also the ability to creating 4D time/process simulation for project construction or life-cycle simulation, for example in the case of looking a project development stages or lifecycle landscaping.

A business scenario would be a small practice further developing an early schematic design (even if hand-drawing) into a 3D model for further photorealistic visualisation including other entourage such as landscaping, people, and vehicles. This links to earlier work carried out by Heintz and Aranda-Mena (2012). Twin Motion™ has a plugin option from Quixel™ as a material, render and object library of high-resolution scans of real-world materials and objects including from terrain, vegetation, to vehicles, people and even light conditions and even light conditions and weather data (Quixel reported an object library of 15,907 digital assets when this paper was written.

3 Authoring and broadcasting VR

Here we introduce two stages to achieve a VR Live session, one is the authoring or the 3D environment and secondly to publish it. Both stages could be either sequential or synchronous depending on the intent i.e. creating a VR and then publishing it online for access to the team or co-creating the VR as part of concept development workshops, participatory design sessions or project review for instance. Although participatory design and immersive environments have been widely discussed in academic journals for some 30 years (Aranda-Mena et al. 2004) the technology is finally able to support the design process and not the other way around. Still, perception, communication, and people-environment applied studies in this area are still much needed though.

3.1 Authoring VR:

The base 3D preparation of a VR environment is carried out (authored) in BIM tools and then imported into VR software tool for post-production. BIM applications that are interoperable with VR platforms include Rhino, Archicad, Revit, Vector Works, 3DsMax, and SketchUp Pro amongst other well-established and commercially available products. During the preparation of this paper two master classes created 3D buildings utilising the above tools and some of the discussed attributes are presented here below:

Table 1: BIM for VR: 3D authoring tools

Interoperability and functional attributes of 5 BIM for VR 3D authoring tools across various protocols for file exchange. From basic 'save as:' to the export-import file exchange option to full synchronicity across tools and applications via an app.	Rhino	Formit	Revit	Archicad	Sketchup
Plug-in for parametric design. Full Grasshopper or Dynamo integration (***). Note that integration with Dynamo only takes place while running on the standalone Formit Pro version. on a laptop or desktop. Archicad and SketchUp Pro have some level of parametric design option that are built into the standalone applications.	***	***	***	*	*
Plug-in for Virtual Reality. Either via 3D file export (*) Datasmith exporter (**) or full data exchange integration and synchronisation (***).	***	*	**	**	*
Plug-in for energy analyses. Effectiveness with energy analyses tools such as Sefaira, Insight (Green Building Studio) or Grasshopper (Honeybee and Ladybug). All run with e+ data in .epw files (Energy Plus Weather format).	***	**	***	**	**
Flexibility for geometric modelling: Free-from design which is highly flexible (***) to a rigid or more constrained model (*).	***	***	*	*	***
Object and building data capture: Rich-data capture of building components (***) - only geometric and spatial information (*).	*	*	***	***	**
BIM file exchange: large and reliable import/export range (***) limited and faulty import/export range (*).	***	**	*	**	***
Market penetration (Australian context). Dominant product (***), established product (**) and emerging product (*).	***	*	***	**	**

The above table 1 indicates the level of interoperability and synchronicity for various commercially available BIM authoring applications. The list/descriptions aim at illustrating key areas of interest rather than being exhaustive and determinant. Today it is possible to produce Virtual Reality easily and sharing it online a standard desktop PC. This provides new opportunities for architects and built-environment professionals. Information exchange, user interface, file size, and the ability to modify, share and access VR projects on the cloud are amongst the main incentives for business uptake. File combability and interoperability is becoming seamless, and, in many cases, available plug-in ensure synchronicity between 3D authoring, analytical and VR tools. Current developments provide new opportunities for architects, planners and their clients and project stakeholders.

3.2 VR Broadcast

Once VR post-production is completed, preparation for broadcasting and model sharing can be organised in various ways. In this case we will discuss two effective formats: Twin Motion™ Cloud hosting and Open Broadcast Studio™ (OBS) which is written in C, C++, and Qt for User Interface (UI), the initial version appeared in 2012 and the latest version 27 (OBS 2021).

The Twin Motion™ Viewer offers a cloud-base application with a service to host VR environments which can also be easily accessible on the web. This provides an easy of sharing and accessible environment even for non-visualisation experts. On the receiver end all is required is a web browser allowing a client or non-expert stakeholder to have access to the VR scenario and can interact with its weather through a desktop, laptop, tablet, or even smart phone. This opens opportunities for engagement, feedback and iteration not seen before.

A second option is to use OBS in addition, or as a substitute, to Twin Motion™ cloud viewer. OBS is an opensource software that works on Windows™ or Apple™ operating systems. OBS also originated from the videogaming community some 10 years ago. OBS allows to broadcast custom or tailored scenes creating a 'Virtual' camera which can easily be set as the default camera for any broadcast application such as YouTube™, Twitch™ or Face Book™. It can also work as the default (virtual) camera for any teleconferencing applications such as Zoom™, MS Teams™, WebEx™, Skype™ or similar.

OBS enables an architect or presenter to switch in between scenes while on face-to-face and online live meetings presenting thus various project with a *high-level of control on views and formats*. The broadcasting also offers options for comments and interaction with client. OBS scenes setup in combination with real-time VR offer what we refer here as VR Live.

A worked example on setting up scenes say, on a design review meeting with client include:

- **Welcome Scene:** webcam 1 presenter; pre-recorded video of project/model. Also, with sound and voice mixer. OBS has filters and VST plug-in for sound and voice-over editing.
- **Main Meeting Scene:** webcam 1 presenter; webcam 2 physical model or material library; webcam 3 aux It could be a remote camera or link with client or builder on site, for example. Note, webcam 3 is in addition to the standard webcam view available within any of the standard teleconference apps).
- **Live VR Project Scene:** webcam 1 presenter; share Twin Motion™ application; share web browser and options to activate/hide web cameras 2 and 3.
- **Whiteboard Scene:** webcams, 1, 2, 3. and a view of shared virtual board such as Miro™, Canva™ or MS OneNote™. Hear each meeting participant can login and notate on the virtual whiteboard by typing on postITs or directly sketching notations using a stylus if joining via a table or touch screen laptop.

OBS scenes and sound dashboards: Transitioning scenes is important, OBS has the facility to set a full screen with preview of various scenes before they go *'on air'*. If using a touchscreen PC, the presenter can simply touch the pre-view window to switch across scenes, if not, a simple point and mouse click can do the trick, as a third option, it is easy to set a remote interface using a smart phone or tablet with an app such as Touch Portal™, this would provide a smart way to include various in-situ meetings participants.

Audio: sound quality in design reviews and presentations is often overviewed, especially when the focus is generally so strong on aesthetic outcomes. Sound clarity is very important, and sound quality can really enhance a virtual experience. The author explored and tested many software tools to improve sound quality while Live VR meetings or for pre-recorded VR scenes (sound files can be easily embedded in VR scenes). Here three tools that are open source. See links in reference list.

VoiceMeter: (VB-Virtual Mixer: Banana version). This is a virtual standalone audio mixer and synthesiser of all sound inputs and outputs. It is a highly convenient tool that enables a great level of control on the input and output of sound sources and the mixing of them. There are 5 input channels (three for hardware and two virtual) and two output channels. For example, a typical setup would include an external microphone, headphones microphone and perhaps a web-cam mic. Then, there are to virtual inputs, once would be a PC as playback device and finally a virtual channel which can be any dedicated application, for example only sounds from YouTube. In this way you can mute any channel or mix sounds during the presentation. There can also be pre-set controls.

VST plug-in for OBS: (Virtual Audio Technology): is a virtual synthesiser and an excellent tool to improve sound quality, it can work as standalone (Reaper) or as a plug-in software app within OBS. It provides a set of 9 sound dashboard that range from sound filters to cut-off background noise, equalizer, noise gate, compressor, expander, gain, and other tools to boost sound for pod and broadcasting. Although a great tool, it takes time to calibrate and pre-set filters, this is because every voice is different, and some testing is required. Also, the environment surrounding the presenter also has an impact, if setting up the filter to block background noise. One filter that was found very useful is the noise-cancelling filter. To set this you must create a *noise profile* of the room, save it, and the filter will subtract such noise profile from the presenter voice. So, for example if the noise profile includes the sounds of typing a noisy keyboard, when the filter is activated it cuts off those sounds. The more background noise to eliminate the more artificial (robot-like) the voice of the presenter sounds.
Nvidia™ Finally, the most effective filter to block background noise is the NVIDIA™, which requires the PC to have an GTX™ Nvidia™ graphic card for noise removal. Which means that to instal the application the GTX graphics card must be installed. There is an option for installing this as plug-in within OBS. Nvidia is the most effective application found for sound boos and noise suppression as the software uses Artificial Intelligence to process the sound ie. identifying your voice and filtering what is what is not yours. Nvidia claims that even a vacuum-cleaner can fade away!
The ability to inhabit designs and spaces as fully immersive VR experience without even having the software installed in a mobile phone or laptop is certainly a game-changes. It is now possible to livestream VR projects and host them on the cloud. This significantly brings new opportunities for clients and their architects, whether meeting remotely or face-to-face, ultimately of benefit to improving design decisions, design outcomes and thus better shaping our *real* environment!

4 VR Live: Case projects

This section presents five scenarios to pilot-test VR in architecture, urban design, and workplace research. The design philosophy of the G-Lab architecture studio is beyond the scope of this paper however, it has been described in Aranda-Mena (2016, 2017).

4.1 Live VR_01 UNESCO heritage sites

This project is currently being prepared as a complete paper submission for the 49th CIB_W78 conference on Information Technology for Construction, Melbourne June 2022. The work is done by the author in collaboration with the UNESCO Chair at Politecnico di Milano. The studio has undertaken projects in Europe, Northern Africa, the Middle East, Latino America, Asia, and Australia and currently preparing projects in Rhino for design interventions, Grasshopper™ (GH) for energy and economic appraisal and TwinMotion™ for VR immersive experience design evaluation. A list of world heritage sites ranging from Villa Adriana near Rome; to Petra in Jordan; to Tell Mozan in Syria to Milano, Bologna, Verona and Mantova in northern Italy (Orbit Inova, 2021).

4.2 Live VR_02 Urban scale: Designing a 20-minute city competition

The fist VR scenario is an urban project proposal in Melbourne, Australia. It is a competition entry by the G-Lab to regenerate a northern suburb known as Croydon, after 1961 it was set as an independent shire and in 1971 proclaimed a city, with a planning principle as a ‘green new town’. Half a century later Croydon is lacking charm and identity. An open competition requested the rethinking of an area around Croydon South’s shopping street. The G-Lab project proposal extended the original scope of the project generating a *’green boulevard’* along a creek connecting the South with Croydon Civic Centre and the train station (see central image in Figure 1). The green boulevard is expected to increase pedestrian and cycling traffic as to reduce car dependency. By connecting

various *'anchor-elements'* through urban interventions such as landscaping, lighting, art, and street furniture. This is expected to re-energise Croydon neighbourhood with increased liability and vibrancy tapping into recreational activities, sports, people movement, arts, and events. From energy and sustainability by capturing solar and kinetic energy to be self-sufficient for public and street lighting needs. 15 individual designs and buildings were all modelled in BIM (e.g., in Revit™, Rhino™, Archicad™, Formit™ and SketchUp Pro™) and Insight™, Sefaira™ and Grasshopper™ Honeybee™ and Ladybug™ for comfort, lighting and sustainability energy analyses.

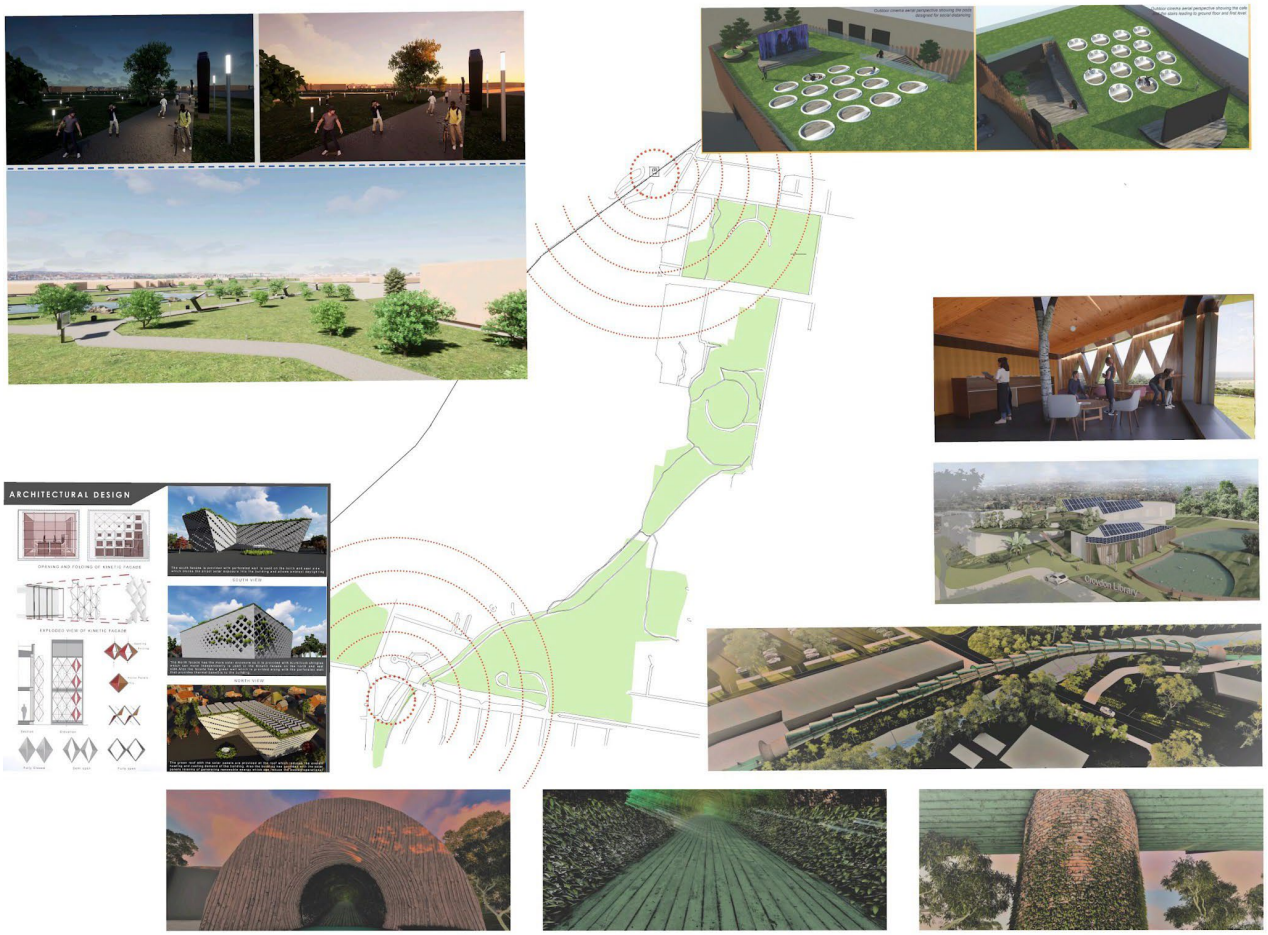

Figure 1. Screenshots of Virtual Reality project developed in TwinMotion™ with dynamic renders

The above Figure 1 is a short selection of individual designs prepared for 15 sites across the location. Site specific designs are used to integrate into the surrounding environment and increasing pedestrian and cycling activity. Engaging with *biophilic design* (Hayles and Aranda-Mena 20218) in the case of the 'Green Promenade'. The user centred design aims to connect people with the open spaces, where they work, live and play, by introducing higher density living and incorporating walkable, bikeable, bus and rail mobility linking Croydon Civic Centre and rail station with Croydon South shopping strip. All 15 individual building projects were incorporated via Twin Motion™ thus creating a Virtual Reality master plan. A summary of identified benefits of Live VR and real-time rendering include (starting from top left corner of the above image and moving clockwise):

- Ability to design public lighting and show changes at various times of the day and seasons of the year. There is no need to wait lengthy time to see the effects of light grid design. Here it is also possible to effectively identify risk areas (black spots) such as day, dusk, and night-time.
- Design of green roofs. In this case a rooftop cinema. Realtime rendering validating panoptic (horizontal angle) and isoptic (vertical angle) field of view from any seating position.

- Maximising views to surroundings from within government and community buildings. It is also possible to change time of day and weather conditions and see the impact to the indoor space. Rendering done real-time and connected with client and community Live.
- Landscape study of the main library with green surroundings, lake, and water features. This is a flood-prone area, and it is possible to model on-the-fly water level across rain and dray season bringing elements of *water-sensitive urban design*. Same image shows *photovoltaic* design for library roof. Twin Motion provided elements of solar incidence but more importantly, a way to view the impact for PV panels optimum tilt (to maximise sun exposure) on the overall design as seen from various angles.
- Green Spine foot and cycling bridge built recycled materials, natural and sustainable materials. The bridge has an element of element and protection which also isolate from views into the busy traffic road underneath. Both, field of view and acoustic ques, can be tested within Twin Motion™ to maximise outcome from user perspective and not only its aesthetic qualities from the road and other advantage viewpoints. The three bottom images are detailed views of the bridge including support, path and access point if seen from right to left.
- The last image shows the architectural design for a civic building and office spaces. The proposal incorporates kinetic design and Twin Motion can simulate various openings of the façade panels according to openness and closure user requirements or as activated by weather sensors. This will be further discussed under Live VR_03 M: Kinetic Façade.

The benefit of Twin Motion™ includes a tool to integrate all design files into a single VR file. The Twin Motion™ viewer allowed the team to see their designs into the larger urban context. It also allowed the ability to model people, cycling and train Motion™ under various frequency (speed of movement) and density conditions e.g., distance between pedestrian or number vehicles on the road. Variables could be modified according to time of the day, peak hours, or day of the week. Finally, it allowed better understanding of the interaction of buildings with greenery and urban furniture allowing the design team to explore variables, in particular long-term time variables. For example, the relationship of the green spine, roads, and property development. The ultimate ambition of this project was to create a 15minute city in which residents could operate their daily activities within 15minute walk – and with this contributing to place-making and quality of life of the residents.

4.3 Live VR_03 Civic Scale: Designing a Railway Station

In a recent study the author applied VR Twin Motion™ on a study for biophilic design as part of a Master Thesis supervision (Byrnes 2021). Biophilic design considerations for a train station in Melbourne, Australia in which real-time VR presented *'transitionary'* greenery scenes in a way that it was possibly to evaluate future outcomes of the landscaping across seasons in the year and vegetation growth in a 30-year life cycle. Live VR can provide realistic understanding of how greening and vegetation changes over seasons, time of the day and climate conditions, more importantly is the positioning and arrangement of vegetation in new or existing environments which is a new development only possible with real-time rendering. This presents the potential not only to show clients the outcome but the impact of design decisions over the life cycle of the project and the effect that this might have on evaluating project success and futureproofing. There is also potential to see the impact of designing with evergreen vegetation versus deciduous vegetation, both are equally good options but deciding factors are better placed to project conditions and site specificity. For instance, evergreen is good, but it might block much needed winter sun penetration. Whereas deciduous can let plenty of winter sun into the building but it would not particularly contribute to improving the visual or aesthetic aspect of a building thus the architecture takes then fore ground and thus important to evaluate via VR scenarios. Lastly, Twin Motion™ provides a realistic lighting and shading rendering in the VR scenes and this is important as evaluation on occupant comfort, daylight, glare, thermal comfort and even views i.e., to understand the impact of vegetation from the inside-out of the building across time and seasons.

If comparing with rendering tools such as V-ray™, 3DsMax™ or Maya™, one often need to wait hours to see and evaluate the render i.e., a single static rendered image. Lumion™ rendering is like Twin Motion™ but without the benefit of connecting directly with a gaming engine such as Unreal™ for further and more powerful postproduction process for high-end visualisation, interface, and interactivity, albeit utilising more specialised visual programming and scripting in C++.

4.4 Live VR_04 Building scale - Designing a Kinetic Façade System

Facades and building envelop continue to shape the way humans interact with the environment, not only in terms of the aesthetic look of buildings but also to improve interior comfort and energy optimisation. Kinetic designs require modelling of materials and structures and their mechatronic motion (Burry et al. 2013). In this way real-time VR allows motion rather than the traditional static rendering tools. Applications such as Unity™, Unreal™, Lumion™ and Twin Motion™ provide an effective way to simulate movement and exploration in the environment in first person through a VR experience. Movement of kinetic façade system can be set and activated for opening and closing. The avatar in the VR space can operate the façade shutters or any operatable element and then investigate the resulting level of shading. An element with kinetic that could be incorporated are Photovoltaic panels thus creating a more dynamic Building Integrated Photovoltaic (BIPV) (Aranda-Mena and Fong 2020). In commercial projects, façade panels and elements are modelled physically including (i) visual and (ii) performance muck ups costing an average of $70K AUD each time. Realtime VR can provide a cost-effective way to run early prototyping and simulations with the potential to significantly improve design and project outcomes.

4.5 Live VR_05 Interior Design Scale: Individual Workspaces for Organisations

Office and workspaces have been turned upside-down since the start of the pandemic in early 2020. As the working from home is here to stay, many office spaces are engaging with hybrid *modus operandus* or ways of working for their staff. In this way the design of workplace and office environments has become less tangible and more fragmented (Finch and Aranda-Mena 2021). Places like Melbourne Australia, the city with the world record for the longest with hard lockdown of over 250 days since March 2020, after Buenos Aires. Melbourne now provides a good example how workplace could have re-set for good. In other words, real-time VR can provide and excellent tool to identify effective workplace design for individuals rather than teams or organisations. In other words, turning the up to recent one size fits all model into a more humane bespoke model in which employees can design their workspaces according to their working preferences and styles. The author of the paper is trailing VR to reflect personal needs and preferences to identify workspaces within and outside the employee premises. For example, what would be possible to do for redesigning the office space and the home office.

Also, using VR in combination with immersive photography to create a virtual library of new and existing spaces that could be available to employees such as libraries, co-working spaces and even parks and coffee places that would have a level of support for office workers. Organisations are also looking to provide more options on satellite offices often close to home. This last section closes the loop of the 15-minute city presented above. Living, working, and playing within 15-minuest walk from home (Aranda-Mena 2019). This model is also more sustainable, reducing the commute time and stress that goes with it. The environmental needs and preferences can easily be tested by the interior architect and ergonomist through the VR library, variations of it or new designs from afresh. This obviously can also be an area where practice and academic research overlaps thus contributing to our understanding of motivation, wellbeing and thriving individuals.

Finally, individual clients and organisations often ignore the value of enhancing workspace-aesthetics with art and nature – which now can be real-time rendered in tools such as Twin Motion™ and designs trailed and tested with increased degrees for confidence. However, scientific studies

reveal that both factors significantly contribute to employee well-being and measurement of occupancy satisfaction. On a neurological level emotional response to aesthetic dimension arise by reading from all five senses. Stimulating positive emotions at work are difficult to measure, still we know they exist (or not). Most organisations focus on measuring change and output, however, looking a design intervention with VR can provide a more accurate understanding of the person and the environment around him or her. As the instrumentality of the workspace i.e., what is needed to 'get the job done' prevails and the focus is on 'doing' rather than on being or feeling.

5 Conclusions and Further Research

This paper has introduced and positioned VR technologies within the architecture and planning domain. Arguing for an add-value practice and business propositions because of technological maturity which is now accessible to a wide market from small start-ups to corporate design firms. The above five case sites demonstrate VR applications on various project typologies. Strengths and weaknesses are drawn and have set the scene for follow up studies and publications. Thirdly, in this we provide a hands-on guidance to kick-start a VR project takin into account both, authoring of VR and broadcasting VR, references with further examples as provided. Finally, a definition of 'VR Live for Architecture' has been elaborated. Future studies on the emerging human experience, especially on user-centred design approach with recommendations for architects and planners on proving professional practice will be further developed.

This paper has re-visited Virtual Reality technologies with a fresh eye, looking into current development of the technology and applications for the practice of architecture and people-environment research. A descriptive and procedural section accounted for the setup of VR Live via broadcasting channels in VR format such as YouTube. The technical section also guided on the set up of Open Broadcast Studio (OBS) in combination with Twin Motion™ (TM). The following table summarises identified attributes across design scenarios and technological capability. This can assist researchers, architects, urban landscape, and interior designers to better set up and stage their virtual environments and their research design.

Table 2 VR Opportunity versus Project type: a summary of case projects and identified attributes

Identified Opportunity	Live VR_01 UNESCO sites	Live VR_02 Urban Scale	Live VR_03 Civic Scale	Live VR_04 Building Scale	LiveVR_05: Scale Building Interiors
Greenery motion	*	***	***	**	***
People motion	*	***	***	**	***
Traffic motion	*	***	***	*	-
Site staged change	***	***	***	*	*
Soundscape/noise	*	*	**	**	***
Dynamic light/shade	*	**	**	**	***
Dynamic glare	-	-	-	**	***
Weather/climate	***	***	***	**	*
Rainwater motion	***	***	***	*	-

From the above Table 2 indicates how VR (via Twin Motion™) was used both, as the *repository* for each building and as the tool to complete the urban design, integrating thus all buildings into a site more commonly referred as the master plan. Proposed new buildings and upgrades to master plans include: a housing states, a public administration building, UNESCO heritage interventions, planning, and urban landscaping projects have been summarised and synthesised according to scale/opportunity relationship.

A qualitative study of the above Table 2 and survey data is to be presented at the 49th CIB_W78 conference on Information Technology for Construction, Melbourne June 2022. On the technological

end, if looking at Rogers' Diffusion of Innovation Theory and Moore's Chasm theory it can be concluded that VR technologies and uptake have move onto a safe and stable for adoption. Full empirical research on business drivers for VR industry uptake will be carried out, now is clear that a *plato* has been reached like that of BIM uptake in business at the turn of the 21st Century (Aranda-Mena et al. 2006), in the VR space uptake might be more rapidly because of rapid of the wider market videogaming. Other enablers such as wider broadband Internet availability and social media move into VR with Meta™ from Facebook™ for instance. Meta (of Metaverse) is FB's newest company brand introduced in October 2021. This flags the expectation that VR will continue evolving in the same trajectory described in this paper. Future stages of this work will delve into the psychological response such as (1) human-computer interaction (2) people-environment studies and (3) decision-making all within Kelly's research framework of Personal Construct Psychology.

6 References

Aranda-Mena, G, 2001. Using Repertory Grids to Measure Changes in Risk-Taking Behaviour. AVRII and Construction Virtual Reality, Conference Proceedings, Chalmers, Gothenburg, SE.

Aranda-Mena, G., Sher, W., Ward, P. and Gameson, R. 2004. Towards nD modelling: current needs and expectations of virtual reality in architecture, engineering, and construction. Universitat Politècnica de Catalunya, Escola Técnica Superior d´Arquitectura de Barcelona, Catalunya

Aranda-Mena, G., Sher, W., Gameson, R. and Ward, P. 2005. Evolving Trends in nD Modelling Architectural Engineering and Design Management Volume 1, Issue 2, Pages 111-126. T&F.

Aranda-Mena, G., and Wakefield R., 2006. Interoperability of building information — Myth of reality? in book of proceedings: eWork and eBusiness in Architecture, Engineering and Construction Edition1st Edition First Published 2006 CRC Press eBook ISBN9781003060819

Aranda-Mena, G., Wakefield R., and Lombardo, R. 2006. A diffusion theoretic approach to analysing e-business up-take in small building enterprises 2006/5/3 Journal of Information Technology in Construction (ITcon). Volume 11, Issue 11, Pages149-159

Aranda-Mena 2016. The G-Lab: A Global Green Architecture Studio Proc. of the 33rd CIB W78 Conference 2016. Oct. 31st – Nov. 2nd, Brisbane, Australia

Aranda-Mena 2017. BIM Integration in Architecture Studios: The G-Lab Milano. The 41st Australiasian Universities Building Education Association Conference, pp.527-539; AUBEA Melbourne, Australia, 3-5, July 2017

Aranda-Mena, G. 2019. Mileu d L'interior: Innovation Districts are not new. Proceedings of the International Conference on Changing Cities IV: Spatial, Design, Landscape & Socio-economic Dimensions, Book of Proceedings. University of Thessaly, Greece

Aranda-Mena, G., and Fong, T.P., 2020. Building Integrated Photovoltaic for Architectural Façades in Singapore. Journal of Sustainability Research, 2.

Burry, J., Aranda-Mena, G., Alhadidi, S., Pena De Leon, A. and Williams, M. 2013. Design Trade-off: sailing as a vehicle for modelling dynamic trade-off in design. In Designing the Dynamic by Melbourne Books. 1st Edition January 2013.

Finch, E. and Aranda-Mena, G. 2021. Creating the Emotionally Intelligent Home-Office, Australasian Universities Building Education Association; 44th AUBEA, Deakin 27-29 October

Hayles, C. and Aranda-Mena, G. 2018. Well-being in vertical cities: beyond the aesthetics of nature. International Conference of the Architectural Science Association, p331-338, Melbourne.

Heintz, J. and Aranda-Mena, G. 2012. Business strategies for architectural firms: type versus capabilities. Proceedings for the CIB_WBC 2012. Pp.594-606 Montreal Canada.

Orbit Innova. 2021. Circular Design for Architectural Heritage, Building and Urban Renewal, UNESCO https://orbitinnova.blogspot.com/ (accessed December 2021)