Soliman-Junior, J., Awwal, S., Tzortzopoulos, P., Ayo-Adejuyigbe, M., & Kagioglou, M. (2022). Eliciting Requirements in Social Housing Retrofit Projects: Tools and Processes Within a Living Lab Setting. *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)*, 468–479. doi.org/10.24928/2022/0152

ELICITING REQUIREMENTS IN SOCIAL HOUSING RETROFIT PROJECTS: TOOLS AND PROCESSES WITHIN A LIVING LAB SETTING

Joao Soliman-Junior[1], Samira Awwal[2], Patricia Tzortzopoulos[3], Morolake Ayo-Adejuyigbe[4] and Mike Kagioglou[5]

ABSTRACT

Requirements' elicitation is a critical step in construction projects as it affects design development, construction, and ultimately, impacts on value generation. In social housing retrofit projects it becomes especially relevant due to the improvement character underlying such initiatives, which offers an opportunity to better address residents' needs, but also to consider the effects of disruption and cost implications. Despite different tools and processes being widely acknowledged by existing literature, their practical application in this type of project is often shallow and do not effectively support the definition of requirements that meet users' and other stakeholders' needs. This paper reports on preliminary findings from an ongoing research project focused on the use of living labs during the retrofit of 8 social housing dwellings in West Yorkshire, UK. It aims to better understand how different tools (i.e., Virtual Reality immersive cave, virtual walkthroughs, and value cards) are useful in the context of generating value within living labs. Key findings relate to the description of how tools were used in this context, as well as the participants' assessment of their benefits and limitations.

KEYWORDS

Requirements, Value, Social Housing, Retrofit, Living Labs, Tools, Virtual Reality.

INTRODUCTION

Social housing construction projects generally consist of top-down approaches (Karvonen, 2013) in which essential project drivers and requirements may not be clearly specified in accordance with the end-users needs. This process can result in a disconnection between

[1] Lecturer, Department of Architecture and 3D Design, Innovative Design Lab (IDL), School of Arts and Humanities, University of Huddersfield, Huddersfield, UK, J.SolimanJunior@hud.ac.uk, orcid.org/0000-0002-8089-8628

[2] PhD Student, Innovative Design Lab (IDL), University of Huddersfield, UK, samira.awwal@hud.ac.uk, orcid.org/0000-0001-7771-1511

[3] Professor, Department of Architecture and 3D Design, Director, Innovative Design Lab (IDL), School of Arts and Humanities, University of Huddersfield, UK, p.tzortzopoulos@hud.ac.uk, orcid.org/0000-0002-8740-6753

[4] PhD Student, Innovative Design Lab (IDL), University of Huddersfield, UK, morolake.ayo-adejuyigbe@hud.ac.uk, orcid.org/0000-0002-9600-7746

[5] Professor, School of Engineering, Design and Built Environment, Western Sydney University, Australia, M.Kagioglou@westernsydney.edu.au, orcid.org/0000-0003-3521-1484

housing provision and users’ requirements, impacting their life quality and wellbeing (Chaves et al., 2017; Crawford et al., 2014), and ultimately affecting the success of initiatives by undermining value generation (Kowaltowski & Granja, 2011).

Different participatory approaches have been explored by existing research and in practice to shift from traditional top-down initiatives to bottom-up approaches (Karvonen, 2013). In this context, the use of living labs highlights end-users' (i.e., residents) inputs and needs (Oliveira et al., 2013). Living labs can be generally defined as user-centred initiatives that focus on the collaborative development of innovative solutions in real-world environments (Leminen & Westerlund, 2017). In living labs, different stakeholders actively collaborate and co-create solutions (Eriksson & Kulkki, 2005). Existing research acknowledges their application in different contexts and initiatives (Soliman-Junior et al., 2021; Bridi et al., 2022). Their use in the construction and housing domains becomes promising especially when focused on retrofit projects (Bridi et al., 2022), as motivations of these initiatives are often diverse, resulting from cultural and societal evolutions, changing comfort needs and standards, and the advent of new housing systems and technologies (Karvonen, 2013).

In the UK, social housing retrofit projects are usually associated with energy and thermal performance upgrading (Swan et al., 2017). In this context, a considerable part of the retrofit works relates to replacing or adding wall insulation by modifying the external building envelope and replacing energy systems and equipment, mainly by switching gas systems to fully electrical. Retrofit projects are especially challenging and of high complexity as end-users often remain in their houses during construction, leading to a very disruptive situation in which construction works happen simultaneously with residents’ daily lives (Chaves et al., 2017).

Considering both design and construction stages in this type of project, understanding users’ needs and requirements is fundamental to improve value generation (Koskela, 2000). However, there is a lack of systematic approaches to ensure that end-users and other stakeholders are effectively understanding the information they receive, as well as adequately communicating their needs and requirements. This issue can be a source of disruption, mostly affecting end-users and therefore, potentially increasing dissatisfaction and impacting value generation. Such uncertainty is also understood as a major challenge in retrofit projects, alongside the lack of approaches to assess different design alternatives during the project development (Gholami et al., 2013).

This paper aims to better understand how different tools (i.e., Virtual Reality immersive cave, virtual walkthroughs, and value cards) are useful in the context of generating value within living labs. These tools have been used during living lab workshop sessions to support better understanding and requirements’ elicitation towards improved value generation in social housing retrofit projects. The paper reports preliminary findings of an ongoing research project focused on the use of living labs during the retrofit of 8 social housing dwellings in West Yorkshire, UK. This work is part of a larger research project named User-Valued Innovations for Social Housing Upgrades via Trans-Atlantic Living Labs (uVITAL). This initiative involves institutions from Brazil, England, Germany, and the Netherlands collaborating on user-valued solutions for social housing upgrades by using living labs.

It is structured as follows: after the introduction, the theoretical background associated with the paper is presented, followed by the research method. Key findings are described and discussed according to the different tools that were used in the workshops, leading to a closing section of discussion and final remarks.

THEORETICAL BACKGROUND

VALUE GENERATION IN SOCIAL HOUSING PROJECTS

In this research, the understanding of value generation aligns with Koskela's view of a process in which value is created from the fulfilment of customers' requirements (Koskela, 2000). In this paper, customers should be understood as all stakeholders which are part of the living lab, including end-users, designers, local government etc. From a design perspective, De Los Rios & Charnley (2017) discussed design's value role as a social construct, whereas Koskela (2000) highlights that the focus of value generation should be on the best possible and achievable value. Nevertheless, there is often a mismatch between users' expectations and designers' predictions of product usage (Hasdogan, 1996). This issue highlights the need for robust methods to capture needs and requirements, ensuring they are adequately managed and fulfilled during construction projects (Koskela, 2000).

In this context, surveys and post-occupancy evaluations are often used to capture and elicit users' requirements (as reported by Miron & Formoso, 2003). The same authors indicate a strong relationship between clients' values and requirements, supporting Koskela's view (2000), which demands a better identification and understanding of requirements. Therefore, managing requirements is a vital aspect that focuses on improving value generation of construction projects by capturing stakeholders' needs through a systematic approach of processing information, specifying requirements, and controlling their implementation throughout the design and construction stages (Baldauf et al., 2013).

LIVING LABS

Living labs are described by existing research as an umbrella concept-methodology which includes a diverse range of research methods, tools and approaches (Leminen, 2015; Tang & Hämäläinen, 2014). Across the different methodological understandings associated with living labs, there is generally a focus on user-centred and collaborative approaches used to create and evaluate an innovation (Bridi et al., 2022; Eriksson & Kulkki, 2005).

In terms of process, existing living labs developed within the housing context typically consist of four generic and iterative phases: definition, ideation, co-creation and evaluation (Bridi et al., 2022). They usually involve different actors, such as end-users, private and public organisations, as well as knowledge institutions (Steen & van Bueren, 2017) who collaborate directly together within the living lab.

Existing literature highlights that there are multiple definitions for living labs, leading to multiple applications in practice (Bridi et al., 2022). Despite the lack of conceptual clarity, which might suggest the existence of different ontological assumptions on the terminology (Soliman-Junior et al., 2021), different authors and researchers often highlight similar characteristics (Bridi et al., 2022), such as their focus on end-users and the use of collaborative processes to identify, co-create and implement innovations in real contexts (Leminen & Westerlund, 2017).

Early living lab applications understood the 'lab' setting as a real-life environment in which behaviour, performance or perceptions were analysed (Eriksson et al., 2005). Different understandings over time have led to a multitude of applications and, recent living labs have been proposed more dynamically. Some studies (e.g., Liedtke et al., 2015; Sharp & Salter, 2017; Lockton et al., 2017) use a series of workshop sessions that allow the development of required interactions and relationships between participants to support the development of a living lab environment. The research reported in this paper adopts a similar understanding, by conducting user-centred workshops sessions focussing on co-creation and development of shared understanding in a living lab setting.

VIRTUAL REALITY

Virtual Reality (VR) supports visual management in the design and construction of building projects (Orihuela et al., 2019); it entails visualising environments through immersion for effective interaction with end-users (Sherman & Craig, 2018). VR is identified as a tool that can be used together with other technologies to enhance decision making, improve communication, coordinate clients' requirements in the design process and promote collaboration among stakeholders (Orihuela et al., 2019; Woksepp et al., 2005). Another efficient output of VR includes error forecast, reduction of negative iterations, and avoiding delays resulting from inadequate project understanding (Orihuela et al., 2019). These VR attributes are associated with the various interventions of lean tools and lean principles to achieve integrated and collaborative design, early engagement of stakeholders, budgeting, information and communication using visual management and BIM (Ladhad & Parrish, 2013; Vrijhoef & Dijkhuizen, 2020).

Previous studies identified the importance of using tools and techniques to improve efficiency in managing social housing retrofitting projects (Kemmer et al., 2013; Woksepp et al., 2005). The exploration of VR spans through architectural modelling for proposal and generation of the virtual environment, engineering, and construction to reduce project cost, solve quality problems, and ensure adequate delivery time (Orihuela et al., 2019).

VALUE CARDS

Value cards were originally proposed by Kowaltowski & Granja (2011) aiming to better understand how social housing residents expressed and prioritised their needs. In this context, the cards can be understood as a tool for recognising values through users' perceptions and improving project decision-making (Carvalho et al., 2020). They are an example of a game that can be used to improve communication and understanding among stakeholders in different projects.

Kowaltowski & Granja (2011) show that using value cards provided a shift from satisfaction levels to the introduction of the concept of desired values, which can be seen as an important tool to assess building performance and improve the design and construction process in social housing retrofit (Kowaltowski & Granja, 2011). The use of this tool can also be linked to lean research, as it is easy to use and there is an opportunity to capture requirements and values (Soliman-Junior et al., 2021).

RESEARCH METHOD

This paper is motivated by the following research question: how different tools (i.e., Virtual Reality immersive cave, virtual walkthroughs, and value cards) can be useful in the context of generating value within living labs? It is part of an ongoing research project focused on the use of living labs during the retrofit of 8 social housing dwellings in West Yorkshire, UK. This project aims to improve value generation in social housing retrofit projects by advancing on social innovations. A series of workshop sessions are part of the research design, and, so far, two events were carried out and led to the preliminary findings presented in this paper. They included representatives from a Local Authority (public stakeholders), which is responsible for the dwellings being retrofitted and for the construction project, as well as social housing tenants (end-users), who are the current occupiers of the houses and remained living in them during all stages of the project.

These two sessions have been organised as workshops, in which participants were introduced to living labs, describing the characteristics of such initiatives and how they were expected to engage with them. In each of the sessions, different tools were used with different participants aiming to improve their understanding of the ongoing retrofit project and to support requirements' elicitation. They include the use of: (1a) a Virtual Reality (VR) immersive cave, in which participants explored Building Information Models of both existing and retrofitted dwellings, simulating both current and designed scenarios; (1b) a real-time rendering software (Enscape) linked to BIM models, which allowed enhanced visualisation and quick design optioneering; and (2) value cards, which consist of a methodology developed by (Kowaltowski & Granja, 2011) to prioritise different needs according to individual preferences and perceptions.

It is important to highlight that such tools were chosen at this stage because they provide different approaches to support requirements' and values' elicitation, either due to their visual and immersive features (1), which have been key drivers from the major project; as well as because they provide a structured approach to prioritise requirements that has not been explored in this context yet (2). Conversely, the above does not mean that other tools could not be used or adopted in this stage. In fact, there is a variety of tools used in different living labs reported by existing research, such as visual boards to support a better understanding of the proposed renovation (Boess et al., 2018), as well as the use of traditional prototypes (Lockton et al., 2019) for example. Because of the nature of the project, we decided to use the tools discussed above. Furthermore, it should be noted that the cost element has not been directly explored in the workshops, although cost implications and inferences emerged during the proposed activities.

In both sessions, after the exploration of the tools, a 'discussion and evaluation' exercise was undertaken in which participants were asked to describe how tools were useful in better understanding design and construction information and how they helped to express their needs, as well as what could have been different in the retrofit project if such tools and processes were used at earlier stages. It is important to highlight that these sessions could not be synced with the main project programme because of Covid-19 restrictions which delayed face to face interactions, and this consists of a limitation of this study from a methodological perspective. Hence, this research has been developed retrospectively in contrast to the retrofit project.

RESEARCH FINDINGS

This section includes key findings emerging after the development of two workshop sessions within the social housing retrofit living lab. It is structured according to the key tools that have been explored during the sessions, discussing how they have been used from a process perspective, highlighting how they supported requirements' elicitation, as well as the participants' perceptions on their use and effectiveness to improve understanding, elicitation, and communication of needs and values.

VIRTUAL REALITY (VR)

Virtual reality has been used in different ways during the workshop sessions. As discussed in the previous section, the VR immersive cave and the real-time rendering software were used to provide different types of immersive visualisations of BIM models. The BIM models, in that context, were used as a source of information to the VR tools in place and consisted of the alternatives that were explored by participants, representing both the existing and designed scenarios (figure 1).

Figure 1: BIM models of existing (left) and designed (right) scenarios

From a living lab process perspective, the use of VR tools can be introduced at different stages. In the reported process, they supported the 'definition' and 'ideation' phases, in which the existing model of dwellings was used to aid requirements' elicitation; as well as to assist design optioneering and evaluation in 'co-creation' and 'evaluation' phases, through rapid design modifications and what-if explorations.

In the first case described above, examples of emerging requirements relate to the overall aesthetics of the houses, and how some specific elements (e.g., fences, external wall render, and roof chimneys) are not pleasant from that perspective. The existing timber fence in front of the houses was particularly a topic of discussion, which impacts the perception of the garden area, and does not allow the beauty of the garden to show through. One of the participants highlighted that it also affects their mental health because they are very proud of their garden and wish others could see it in that way.

Conversely, when virtually immersed in the proposed designed model (figure 2), participants revealed requirements mostly related to privacy and aesthetics. Examples of participants' elicitation of requirements and values from the workshops are presented below:

- *"What is this here in the front, is it just a normal fence? And what is the fence here in the back garden? Are we getting this tall fence in the back garden? I just had new panels for the fence in my back garden before the retrofit. It costed me a lot of money, and I would appreciate having something as nice there now.* (Inference from researchers: but why do you want tall fences there?) *I've placed these panels there because I've got a hot tub and I need privacy."*
- *"Oh, it looks so good!* (Right after stepping into the cave). *I am going to look at my house only, so that is mine* (pointing at the house with the controller). *I have chosen teal for the colour on the window frame, and I do not like the yellow you have here at the moment, as it comes out like a mustard colour."*
- *"I want a back door with a glass panel and mailbox on it, similar to a front door as I had before. I do not like how this door is at the moment."* (Referring to the solid panel door).

The use of Enscape, which is a real-time rendering tool linked to the BIM model on Revit supported the exploration and testing of different design options, enabling rapid design modifications and what-if explorations (e.g., changing colours of façade elements, adding and removing canopies, changing door types). This tool allows participants to walk through the BIM model by using VR equipment or simply running as a desktop add-in to modelling tools.

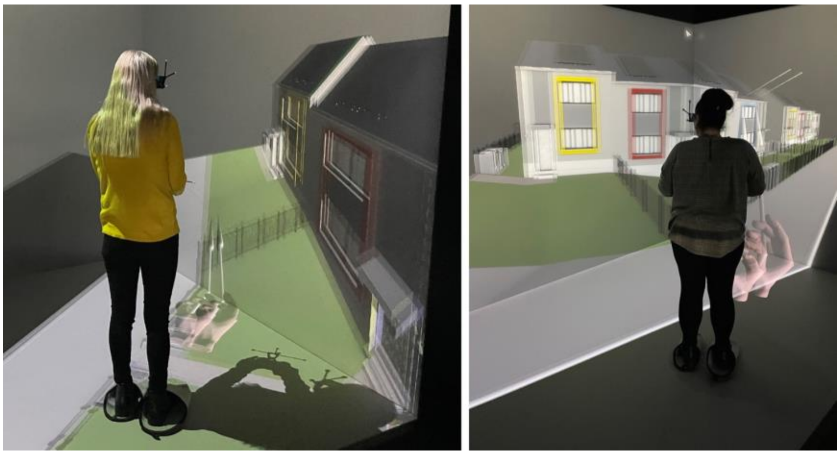

Figure 2: Participants using the VR cave to explore BIM models

One of the benefits of Enscape reported by participants is that it provides a much more realistic perception in comparison to the models explored in the VR cave, as materials, textures and effects are visually enhanced and more accurately represented (as seen in figure 1). It also supports testing different weather and climate settings and e.g., how the model is impacted by shading and sunlight at different times of the day. In the workshop sessions, participants suggested one example of application would be to aid the definition of the position of solar panels to be installed as part of the retrofit works, concerning tree shading and maximising sunlight, as seen in figure 3.

Figure 3: Different times of the day simulated on BIM models through Enscape

VALUE CARDS

Value cards have been used in the workshop sessions as a tool to capture participants' preferences of attributes and values related to different categories of social housing retrofit. These categories consist of: layout and remodelling, thermal comfort, accessibility, maintenance, security, privacy, sustainability, and environmental quality (examples included in figure 4). The cards have been developed based on information emerging from the other sources of evidence that are part of the project and are not included in this paper (e.g., participation in retrofit project meetings, development of interviews with project stakeholders and social housing residents).

A set of 45 cards was developed in the UK, illustrating design requirements and values. In the first round, participants were asked to order cards from the same category, according to their priority. In the second round, participants were asked to prioritise based on the first chosen cards from each category, ranking the most important cards overall. The value cards were used in the living lab process as part of the 'definition' phase, which is predominantly focused on understanding participants' needs, requirements, opinions, and constraints. This tool enabled participants to inform about their preferences and priorities considering the categories described above in a straightforward exercise.

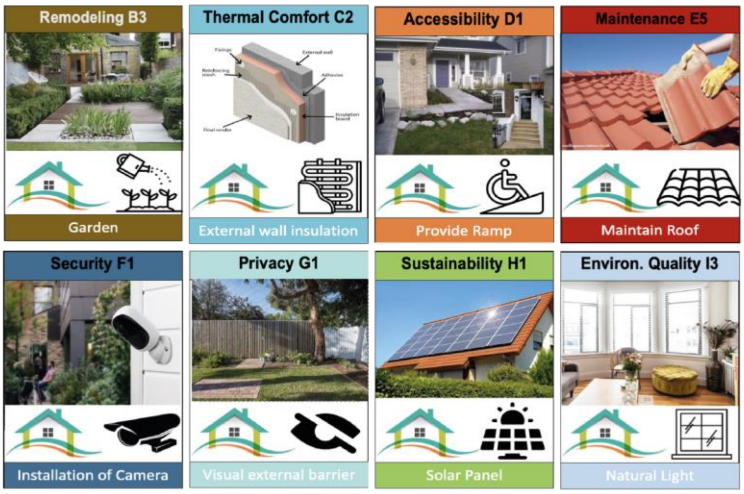

Figure 4: Examples of Value Cards as a tool to infer desired user value

During the use of this tool in the workshop sessions (figure 5), different needs, requirements, and values emerged, and they relate to various categories, such as security, privacy and thermal comfort:

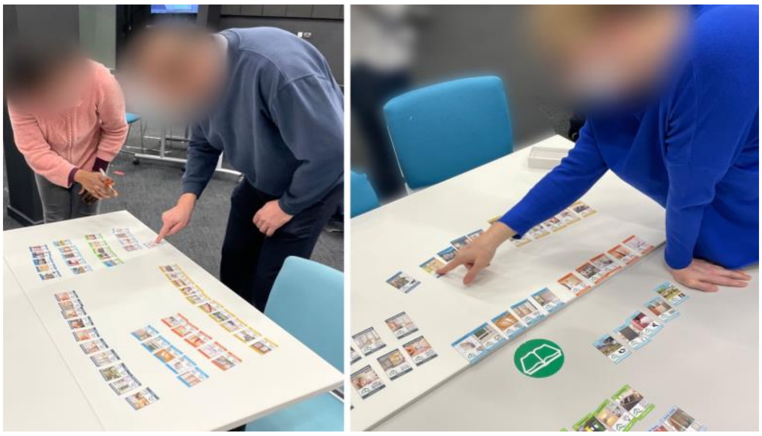

Figure 5: Application of the Value Cards with living lab participants

Examples of these requirements are described below, based on comments made by the participants while using the tool.

- Security: participants highlighted that the installation of an external motion-enabled light system was needed, as some areas around the houses and in the back garden become very dark relatively early in winter. They also prioritised the installation of cameras (CCTV system) because of local burglary in the area, as well as door security, through the installation of new doors and locks which are easier to use.
- Thermal Comfort: workshop participants prioritised the installation of external insulation systems as well as replacing doors and windows. One of

the participants later associated such changes with reducing the household running costs, when prioritising the cards in the second round. Their reasoning was to first replace doors and windows, because '*there is where we lose most of the heating'*, and then install solar panels to *'save even more money on energy bills'*.

DISCUSSION AND CLOSING REMARKS

During the 'discussion and evaluation' exercise, participants assessed the tools that were explored during the workshops according to a set of questions. These questions were later used to foster a discussion on how tools supported better requirements' and values' elicitation, their benefits and limitations. A summary of this assessment is presented in figure 6, followed by a description of key points highlighted by participants in that regard. It is important to highlight that this paper reports preliminary findings from the living lab process and, therefore, a more comprehensive living lab evaluation has not yet been developed and is planned for a future workshop. Nevertheless, participants provided a positive feedback based on the activities and tools reported in this paper, which is described below.

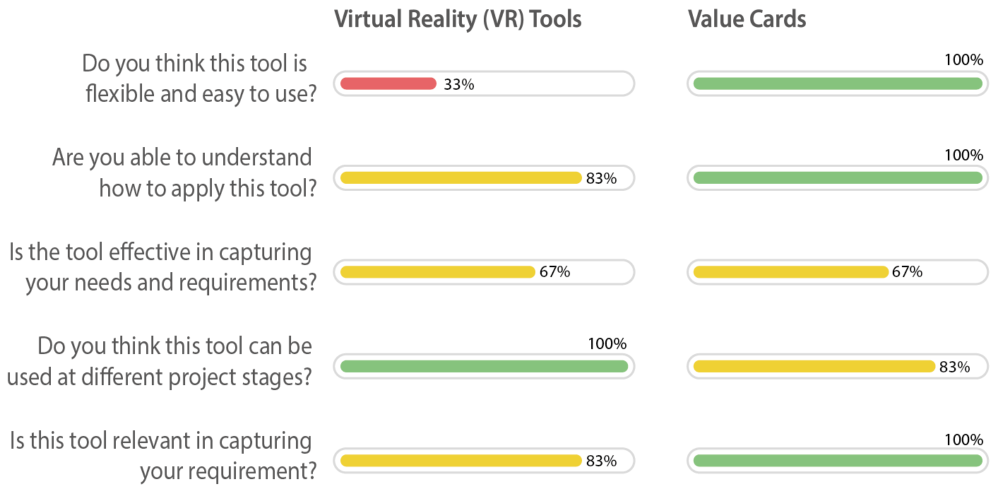

Figure 6: Participants' assessment of tools used during living lab workshops

The workshop participants highlighted that using VR and especially the immersive cave is not very simple nor flexible and that some further training might be required to successfully explore this tool. It is important to highlight that at times when the workshop sessions were undertaken, there were some limitations associated with the software that supports the VR cave. This temporary issue compromised the visualisation of materials and textures, resulting in some of the BIM model elements appearing 'flat'. Considering the living lab context, and especially the requirements elicitation intent, this becomes a potential challenge, as it can decrease the participants' perception of the virtual environment, not allowing needs and opinions to emerge.

Whereas some participants had difficulties in using the VR cave, others were more familiar with this type of system, mostly due to its similarities with video game consoles. In this context, workshop participants highlighted they could relate the virtual experience with the real environment and felt immersed in that context. They suggested that this tool could be used as part of different living lab phases aiming to improve stakeholders' understanding of the project and of its next stages, fostering communication, and enabling emerging needs to be discussed and addressed more appropriately and transparently. During the exploration in the cave, VR helped elicit both technical and clients' requirements, and the different BIM-related tools helped analyse how the proposed design was responding to them, as well as how participants perceive such requirements.

When comparing the two different VR tools that were used in the workshops (i.e., VR cave and real-time rendering software linked to BIM models), participants generally preferred the latter. This is because it was perceived as more efficient and easier to use, allowing a richer visualisation of materials and textures in the BIM models. It was also suggested that because it better supports design optioneering, it can potentially be used with larger audiences to address their emerging opinions more efficiently.

While assessing the use of value cards, participants mentioned they are very simple and easy to use, and they have a familiar format that can be transported to different places and replicated within different contexts and projects. They highlighted that this tool prompts discussion and reasoning on upgrading priorities and that even outside the living lab setting, it should be used during initial project stages as part of a 'consultation pack' with end-users. Conversely, they agreed that the cards are not suitable for late living lab stages, when the design is more developed and evolving requirements emerging from the use of the cards could be difficult to be incorporated, leading to a potential dissatisfaction and ultimately, affecting value generation.

Participants also suggested that both VR tools and the value cards support eliciting requirements and values to some extent, and they complement each other in that process. They suggested that whereas VR tools help participants to get immersed in the virtual environment, being mostly related with the visual sense, the prioritisation exercise which is part of the value cards deals with different types of reasoning and, therefore, allows other perceptions and needs to emerge. In that sense, the different categories that are included in the value cards support participants to expand their reasoning to a broader set of requirements in contrast to the VR tools, which rely on their individual perceptions only.

While the value cards have been more widely accepted and the benefits arising from their use were more directly identified, participants also appreciated the VR tools and suggested they have a great potential in the context explored by the research. It was also acknowledged that both tools within a living lab setting prompted discussion and fostered collaborative decision-making. They improved participants' understanding of each other's needs in the project, ultimately helping to reduce conflicts and misinterpretations of requirements, hence collaborating towards improved value generation in social housing retrofit projects.

ACKNOWLEDGEMENTS

This paper reports on partial results from the uVITAL project, funded by the Trans-Atlantic Platform for Social Sciences and Humanities and Economic and Social Research Council (ESRC) (ES/T015160/1). The authors would also like to thank the Innovative Design Lab (IDL) for their financial support.

REFERENCES

Baldauf, J. P. , Miron, L. I. G. & Formoso, C. T. 2013, Using BIM for Modeling Client Requirements for Low-Income Housing. In:, Formoso, C. T. & Tzortzopoulos, P., *21th Annual Conference of the International Group for Lean Construction*. Fortaleza, Brazil, 31-2 Aug 2013. pp 801-810

Boess, S., Silvester, S., De Wal, E. & De Wal, O. 2018, Acting from a Participatory Attitude in a Networked Collaboration. *ACM Int. Conf. Proceeding* Ser. 2, 1–6, doi:10.1145/3210604.3210642.

Bridi, M. E., Soliman-Junior, J., Granja, A. D., Tzortzopoulos, P., Gomes, V. & Kowaltowski, D. C. C. K. (2022). Living Labs in Social Housing Upgrades: Process, Challenges and Recommendations. *Sustainability*, *14*(5), 2595. https://doi.org/10.3390/su14052595

Carvalho, A. C. V. de, Granja, A. D., & Silva, V. G. da. (2020). Use of a card game tool to capture end users' preferences and add sustainability value to social housing projects. Ambiente Construído, 20(1), 7–20. https://doi.org/10.1590/s1678-86212020000100360

Chaves, F. J., Tzortzopoulos, P., Formoso, C. T. & Biotto, C. N. (2017). Building information modelling to cut disruption in housing retrofit. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability*, *170*(6), 322–333. https://doi.org/10.1680/jensu.16.00063

Crawford, K., Johnson, C. E., Davies, F., Joo, S. & Bell, S. (2014). *Demolition or Refurbishment of Social Housing? A review of the evidence*. UCL Urban Lab and Engineering Exchange.

De los Rios, I. C., & Charnley, F. J. (2017). Skills and capabilities for a sustainable and circular economy: The changing role of design. *Journal of Cleaner Production*, *160*, 109-122.

Eriksson, M. & Kulkki, S. (2005). State-of-the-art in Utilizing Living Labs Approach to User-centric ICT Innovation - A European Approach. *State-of-the-Art in Utilizing Living Labs Approach to User-Centric ICT Innovation*, *15*.

Gholami, E., Sharples, S., Shokooh, J. A., & Kocaturk, T. (2013). Exploiting BIM in energy efficient refurbishment – a paradigm of future opportunities. *Proceedings of PLEA 2013 – 29th Conference, Sustainable Architecture for a Renewable Future*, Munich, Germany, pp. 1–6.

Hasdogan, G. (1996). The role of user models in product design for assessment of user need. Design Studies, 17(1), 19-33. https://doi.org/10.1016/0142-694X(95)00007-E

Karvonen, A. (2013). Towards systemic domestic retrofit: a social practices approach. *Building Research & Information*, *41*(5), 563–574. https://doi.org/10.1080/09613218.2013.805298

Kemmer, S., Koskela, L. & Nykänen. V. (2013). Towards a lean model for production management of refurbishment projects. ApRemodel Project. VTT Technology 94. Espoo, Finland.

Koskela, L. (2000). *An exploration towards a production theory and its application to construction*. VTT Technical Research Centre of Finland.

Kowaltowski, D. C. C. K. & Granja, A. D. (2011). The concept of desired value as a stimulus for change in social housing in Brazil. *Habitat International*, *35*(3), 435–446. https://doi.org/https://doi.org/10.1016/j.habitatint.2010.12.002

Ladhad, A., & Parrish, K. (2013). The Role of Lean Practices for Zero. *Proceedings of the 21st Annual Conference of the International Group for Lean Construction*. 895–904.

Leminen, S. (2015). Q&A. What Are Living Labs? *Technology Innovation Management Review*, *5*(9), 7.

Leminen, S. & Westerlund, M. (2017). Categorization of Innovation Tools in Living Labs. *Technology Innovation Management Review, 7,* 15–25. https://doi.org/http://doi.org/10.22215/timreview/1046

Liedtke, C.; Baedeker, C.; Hasselku , M.; Rohn, H.; Grinewitschus, V. User-Integrated Innovation in Sustainable LivingLabs:An Experimental Infrastructure for Researching and Developing Sustainable Product Service Systems. *J. Clean. Prod. 2015, 97,106–116.*

Lockton, D.; Bowden, F.; Matthews, C. Powerchord: Exploring Ambient Audio Feedback on Energy Use. In Living Labs: D*esign and Assessment of Sustainable Living*; Keyson, D.V., Guerra-Santin, O., Lockton, D., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 297–308. ISBN 978-3-319-33527-8

Miron, L. I. & Formoso, C. T. 2003, 'Client Requirement Management in Building Projects' In:, *11th Annual Conference of the International Group for Lean Construction.* Virginia, USA, 1-.

Oliveira, Á., Brito, D., de Oliveira, Á. & de Brito, D. A. (2013). Living Labs: a experiência Portuguesa. *CTS: Revista iberoamericana de ciencia, tecnología y sociedad*, *8*(23), 201–229.

Orihuela, P., Noel, M., Pacheco, S., Orihuela, J., Yaya, C., & Aguilar, R. (2019). "Application of Virtual and Augmented Reality Techniques During Design and Construction Process of Building Projects. *Proceedings of the 27th Annual Conference of the International Group for Lean Construction,* 1105-1116. https://doi.org/10.24928/2019/0220.

Sharp, D.; Salter, R. Direct Impacts of an Urban Living Lab from the Participants' Perspective: Livewell Yarra. *Sustainability 2017,9*, 1699

Sherman, W., & Craig, A. (2018). Understanding virtual reality: Interface, application, and design. 2nd Ed Indiana, United States. Morgan Kaufmann. ISBN 978-0-12-818399-1

Soliman-Junior, J., Awwal, S., Bridi, M. E., Tzortzopoulos, P., Granja, A. D., Koskela, L. & Gomes, D. (2021). *Living Labs in a Lean Perspective*. 484–493. https://doi.org/10.24928/2021/0176

Steen, K. & van Bueren, E. (2017). *Urban Living Labs: A Living Lab Way of Working*. Institute for Advanced Metropolitan Solutions.

Swan, W., Fitton, R., Smith, L., Abbott, C., & Smith, L. (2017). Adoption of sustainable retrofit in UK social housing 2010-2015. International Journal of Building Pathology and Adaptation, 35(5), 456–469. https://doi.org/10.1108/IJBPA-04-2017-0019

Tang, T. & Hämäläinen, M. (2014). Beyond Open Innovation : the Living Lab Way of ICT Innovation. *Interdisciplinary Studies Journal, Vol.3*(4).

Vrijhoef, R. & Van Dijkhuizen, M. (2020). "Lean Toolbox Approach for Effective Preparation of Housing Refurbishment Projects using Critical Success Factors." In: Tommelein, I.D. and Daniel, E. (eds.). *Proceedings of the 28th Annual Conference of the International Group for Lean Construction, 181-192. https://doi.org/10.24928/2020/0138.*

Woksepp, S., Olofsson, T., & Jongeling, R. (2005). Design Reviews and Decision-Making Using Collaborative Virtual Reality Prototypes ; A Case Study of the Large-Scale MK3 Project. *Proceedings of the 13th Annual Conference of the International Group for Lean Construction,* 145-152.