

DETERMINATION OF COGNITIVE CRITERIA TO ENHANCE VISUALISATION DURING DESIGN REVIEW SESSION

Adlin Shaflina Azizo¹, Kherun Nita Ali¹, Noorminshah A. Iahad² and Chan Vei Siang³

¹*Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Johor Bahru, Malaysia*

²*Faculty of Management, Universiti Teknologi Malaysia, Johor Bahru, Malaysia*

³*Faculty of Computing, Universiti Teknologi Malaysia, Johor Bahru, Malaysia*

ABSTRACT

In the construction industry, it is a common practice to conduct a design review to uncover potential problems by comparing the designer's plan to the client's specifications before the construction begins. The design review involves cognitive process where conversation and debate help to cultivate effective decision-making. It also includes thinking and processing information to empower human communication. The designer's mental processes are crucial as they determine how designers address challenges and construct appropriate decisions. Hence, this study aims to investigate the cognitive criteria that can improve visualisation in the design review practice. This research conducted video interviews with a group of experts in the construction industry to elicit their feedback regarding the topic of virtual collaboration for quality assurance during the design review phase. The authors analysed the collected data using thematic analysis to develop cognitive criteria that improve decision-making during design review. The results uncover the possibilities of more future studies in this area. In conclusion, cognitive criteria with the aid of Virtual Reality (VR) have emerged as a potential solution for enhancing visualisation during the design review process.

KEYWORDS

Cognitive Process, Cognitive Criteria, Design Review, Visualisation, Virtual Reality

1. INTRODUCTION

Nowadays, the construction sector in Malaysia is embracing Industry Revolution 4.0 applications to reduce labour hours and achieve increased flexibility, efficiency, and quality production. Hence, design review during the design stage is critical to ensure that the design complies with all necessary operational, safety, environmental, and industry requirements. Design review is the process of reviewing the design according to the client's requirements to identify problems before the construction begins. In Malaysia, the construction firm still relies on traditional design review practices during the presentation stage of construction development. Thus, it is difficult to introduce a new intervention without exhibiting the advantages and limitations of its usability, especially for designers who follow conventional *modus operandi* (Czmoch & Pękała, 2014).

To achieve a better design review, the presentation of the design must be adequately assessed, and the design must be judged using reasoned and objective criteria rather than the designers' or developers' preferences. According to Balali *et al.* (2018), factors that will affect the project timeline during the regular design review session, such as changing orders, are due to a lack of understanding and communication between designers and stakeholders. As a result, the design review prizes high-quality visualisation and communication. Recently, the use of VR in design review is gaining momentum in integrating the workflow with 3D construction models and establishing a rapport between designers and clients. The VR environment allows the evaluation of unanticipated issues, typically caused by design mistakes, poor performance, and health and safety concerns in terms of time, costs, and resources (Goulding *et al.*, 2012). It can also assist designers in reaching a mutually agreed settlement with stakeholders to expedite the flow of construction activity (Du *et al.*, 2018). Hence, VR is capable of resolving difficulties regarding quality output during design review. However, it has inescapable obstacles and drawbacks that must be addressed (Fox & Felkey, 2017), including

technical hardware issues, user-friendly interaction design, and incorporation of various data types for advanced VR analytics.

Therefore, this study aims to investigate the cognitive criteria in VR to improve the design review process which is one of the critical elements in the construction domain. It identified the cognitive criteria through interview sessions with experts and thematic analysis. The contribution of this study anticipates a means for effective discussion and empowering decision-making among the clients and designers or architects. The organisation of this article is as follows: Section 2 introduces the background of this study; Section 3 presents the research methodology; Sections 4 and 5 report the results and discussion, respectively; Section 6 concludes the article.

2. RELATED WORKS

2.1 Design Review

In the construction industry, the term 'design' encompasses drawings, design details, specifications, bills of quantities, and calculations created for the purpose of a design, which allows the project team to focus on safety and health issues and other vital aspects of the project (“Guidelines on Occupational Safety and Health in Construction Industry (Management),” 2017). Design review is a critical part of the planning process (Mathers et al., 2013) because it allows the designers and clients to share information and assess the project's design based on requirements to detect flaws before the construction begins. Most reviews are in the form of presentation sessions in which the design team and client present the plan to the evaluation panel and engage in conversation to obtain the comments from panels (Mathers et al., 2013). As part of the standard design process, the review process also allows the project team to focus on safety and health issues.

2.1.1 Virtual Reality and Its Adoption in the Design Review

Virtual reality (VR) is a virtual experience that is similar or completely distinct from reality, where users can communicate and interact in a simulated environment while analysing and collecting data from the 3D construction model. VR technology has been adopted to the construction industry for more than two decades (Thabet et al., 2002). The main reason for its high adoption rate in various businesses, including construction, is that VR enables designers to better comprehend the workflow, facilitates development, and increases operator safety (Park et al., 2018; Ray & Teizer, 2012).

One benefit of VR is that it enables powerful adaptive evaluation based on a multitude of design parameters and presents the outcome in a simulated environment. According to Lucko, Benjamin and Madden (2008), VR simulation of building operations is practicable, safe, less time-consuming, and cost-effective. In addition, it permits precise monitoring of the operation's driving factors and the parameters can be changed multiple times instantly to obtain the statistical mean and variance readings for choosing the optimal design.

Additionally, the realistic experience of VR technology is advantageous to the construction industry (Brioso et al., 2019). Whisker *et al.* (2020), discovered that a full-scale 3D virtual model of a construction project can aid designers and learners in comprehending, learning, and gaining experience by evaluating designs for their constructability and create suitable construction plan for complex buildings or infrastructure projects. Immersive VR also enables stakeholders to experience the full-scale representation of a virtual facility prototype in a realistic and accessible way through immersion and a sense of presence, hence facilitating the collection of input and feedback during usability-focused design review sessions (Ventura et al., 2020). Thus, incorporating virtual technology into the design review can provide effective yet interactive discussion.

2.2 Cognitive Process

Thinking, reasoning, learning, and remembering are all the end results of the human brain's cognitive process, which are defined by the way the brain receives and handles information. All designers' actions when analysing data or information are acts of cognition. Furthermore, understanding the scope of their own cognitive abilities is an essential part of the design process. The term "cognitive processes in design," as defined by Tschimmel (2004), encompasses the thinking and interacting abilities necessitated for design which include perceptual,

creative, communication, learning, emotional, and collaborative processes. Therefore, it can overcome problems with reasoning, solution-seeking, conceptualization, and communication, as well as facilitate a more fruitful application of the creative design process by appreciating and accommodating individual differences in the cognitive process.

Nevertheless, most of the mental work involved in a design review can cause the developers' mental workload to increase, and thus, designers need to maintain open lines of communication to prevent cognitive burnout. Besides, it is inevitable that there are misunderstandings during the group discussion since every designer has a different degree of understanding. Another possibility is that the information supplied is only retained or comprehended at the time it is first encountered. Therefore, (Motte, Andersson and Bjärnemo (2004), argued the necessity to investigate the designer's cognitive process to better understand their abilities and explore the cognition weakness or limitation. Designers need to navigate the topics throughout the design review process, including coordinating with the developer to ensure clear and concise explanations.

In addition, the design skills and knowledges gained from studying fundamental processes, absorbing domain information, and examining previous satisfied examples can contribute to promising ideas before constructing the mock-ups for visualisation, comparison, and execution of the concepts (Gero, 1998). This cognitive process empowers humans to engage effectively with their environment and adapt to any circumstances. According to Gross and Medina-DeVilliers (2020), from a Bayesian perspective of cognitive process, individuals calculate the costs and benefits of a measure using their prior information and experience. Thus, consulting the experts can obtain a higher level of knowledge that can contribute to a more efficient identification of cognitive process compared to debate amongst peers.

2.3 Virtual Collaboration Quality (VCQ)

Advanced visuals can encourage people to interact and participate in discussion to reach a satisfactory decision. According to Hamrol (2015), the visual element is the centre of focus in most previous work. Hence, a VR system can promote advanced visual representation during client configuration, solving problems, and preventing communication crises. Besides, data visualisation is more effective in communication and understanding than writing or drawing (Cham et al., 2020). Meanwhile, dialogue can lead to decision-making or idea-exchanging (Gjerde, 2017). During the design review session, designers and clients discuss designs, ideas, and decisions through visualisation and dialogue. This research covers four aspects of Virtual Collaboration Quality (VCQ), including communication, decision, discussion, and visualisation, as depicted in Figure 1. These classifications determine the quality of cognitive process during the design review.

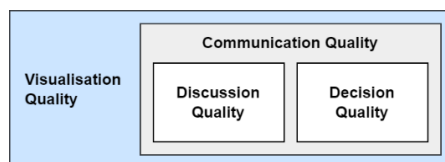


Figure 1 Virtual Collaboration Quality (VCQ) (Azizo & Ali, 2022; binti Azizo et al., 2022)

3. METHODOLOGY

To explore the cognitive criteria in VCQ during the conventional design review process, this study established a qualitative method by using an unstructured interview with an open-ended questionnaire for the experts in the construction industry to gather information and verify it (Berman, 2017; Creswell et al., 2011). Due to the Covid-19 pandemic, it is a necessity to use digital technologies (De et al., 2020) to collect the data via video meeting with industry experts. Since the goal of qualitative research is to construct knowledge from first-hand accounts of human experience and researchers need to follow a certain protocol to produce reliable and useful findings, this research chose qualitative research method for this investigation (Sandelowski, 2004). Five experts from the industry took part in the unstructured interview. Besides, the consultation and knowledge from the experts can improve the reliability of the interview results (Thakur, 2008; Wolfartsberger, 2019), because they had been involved in a wide range of experiences over the entirety of the construction process. Table 1 shows the information about experts invited for unstructured interviews.

Table 1. The details of experts of unstructured interviews

Experts	1 & 2	3	4	5	Total
Expertise	Architect	Architect (Government)	Civil Engineer	Quantity Surveyor	
Experience	> 10 years	> 10 years	> 10 years	> 10 years	
Total	2	1	1	1	5

4. RESULTS

This research conducted the thematic analysis by utilising NVivo software version 12.0 plus, a qualitative data analysis program that enables uncomplicated qualitative data analysis to aid researchers in acquiring a deeper understanding about specific research. All of the experts' feedbacks from the unstructured interview sessions was thematically analysed based on a six-step thematic analysis approach (Braun & Clarke, 2006), including (1) familiarisation with the data, (2) generating an initial code, (3) searching for preliminary themes, (4) reviewing themes, (5) defining and naming themes, and (6) summarising the thematic network in a mind map to easily identify the cognitive criteria in the design review (Mansor, 2021). According to Braun and Clarke (2006), thematic analysis is a suitable method for analysing the viewpoints of several respondents, uncovering similarities and contrasts, and delivering unexpected results. Figure 2 illustrates details of the thematic analysis.

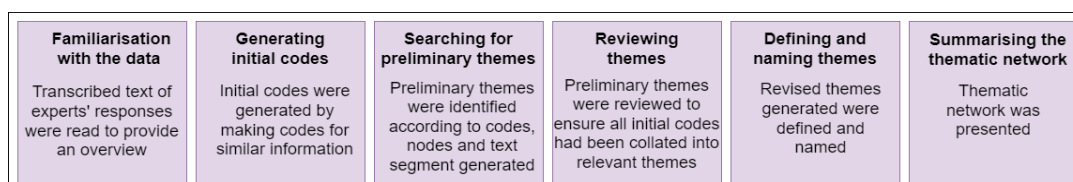


Figure 2. Phases of thematic analysis (Braun & Clarke, 2006; Mansor, 2021)

Azizo and Ali (2022) stated that incorporating an interview by involving three experts in the research can determine the cognitive processes. As a result, the interview outcomes showed the generation of initial codes that contain comparable information from all supplied data, including 'luxurious design', 'inviting design', 'grandeur design', and 'welcoming sense' that were combined under the code term 'quality of space.' Next, the initial theme for the 'quality of space' code was classified under 'vision and imagination'. Then, all preliminary themes were identified and described completely which encompasses 'design awareness', 'coordination', 'sharp discussion', 'firm', 'perceiving', 'understanding', 'teamwork processes', and 'evaluation'. In addition, under the 'visualisation quality' is the cognitive design that includes 'visual perception' theme (Sulaiman et al., 2020).

Lastly, this study created a thematic mind map to show the general theme-codes network link. The thematic network is a multi-actor organisation that combine existing knowledge on a focused issue for consultants, clients, and more. It is a method used for analysing text material thematically and illustrating the network's relationship graphically (Attride-Stirling, 2001). The use of colour encodings is as following: orange represents the initial codes, pink represents the codes, blue represents the preliminary themes, green represents revised themes, and white colour represents the VCQ's major parameter. Accordingly, the authors classified the ten codes into five revised themes from the five preliminary themes. Figure 3 provides a mind map summary of the additional data according to Braun and Clarke (2006) that utilise the thematic analysis.

5. DISCUSSION

The five revised themes are grouped under four VCQ's major parameters where 'visual perception' is under 'Visualisation Quality', 'synthesising' is under 'Communication Quality', 'knowledgeable' and 'leadership perspective' are under 'Discussion Quality', and 'decision making' is under 'Decision Quality'. During the design review, understanding the design specifications by all stakeholders is the first and most crucial step

toward effective and quality communication. Hence, cognitive performance for all designers and stakeholders during the discussion is pivotal to reach an agreement from any problems. Furthermore, understanding the cognitive criteria can assist in the adoption of VR in design review to improve the design review process. According to Paes and Irizarry (2018), an immersive VR system improved decision-making during design review by improving the user's cognitive performance in expressing and comprehending the design ideas. Hence, the cognitive performance of designers and stakeholders throughout the dialogue is critical to obtain a consensus on any topics. In a nutshell, high-end technology can improve the efficacy of design reviews by assisting the stakeholders considerably in understanding their design and reducing cognitive strain (Frederiksen et al., 2020). Thus, the study of cognitive processes is necessary to enhance the use of VR in design review. The following sections explain the four VCQ's major parameters in detail.

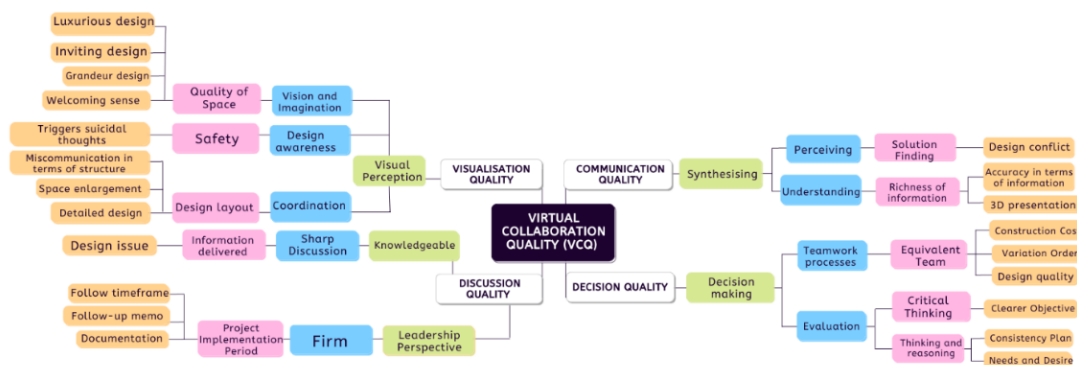


Figure 3. Summarisation of the thematic network mind map

5.1 Visualisation Quality

Visualisation is crucial in design review. As mentioned by Expert 1, the design review prizes the first visual impression of the building's entrance whether it has a welcoming and inviting presence that attracts the people to visit. Yee et al. (2012), indicated that visualisation improves decision-making where they are used internally to articulate findings and keep empathy for the client or context, as well as a communication tool with project stakeholders. By visualising the complete scale of architectural design (Liu et al., 2020), immersive VR can help with the decision-making process (Soust-verdaguer et al., 2021). Visual perception entails viewing, absorbing, and recognising an object or surrounding, and then, arranging the information mentally. Alhadad, (2018), argued that visual perception encodes the properties of the visualised information in the working memory. Through the design review process in VR, designers and stakeholders or clients are more aware of the building's structure or uncover existing problems in the design.

5.2 Communication Quality

Communication is the process of communicating information or knowledge between peoples through speaking, writing, viewing, or reading the media, nature, or other sources. Expert 2 stated that the accuracy of information is crucial to provide an efficient workflow because the contactor does not need to create a physical prototype if the visual is presented accurately. Hence, effective communication can facilitate productive discussion and decision-making. Communication can also produce hypotheses that can be tested which lead to experiment planning, changing hypotheses, and concluding a result. Synthesis is the process of making a new argument and a new point of view. It is one of the most important cognitive processes (Wang, 2015) for making good conclusions from communication. Besides, Paes and Irizarry (2018), asserted that a thorough understanding of design requirements by all designers and developers is the first and most crucial step toward effective communication in a design review scenario. Therefore, immersive VR was demonstrated to enhance communication between specialists and clients by bridging the construction site into the discussion room (Tibaldi et al., 2020).

5.3 Discussion Quality

Discussion is the method or procedure of discourse that leads to valuable results in conclusion. Typically, the discussion process leads to decision-making or the exchange of opinions concerning the discussed subjects (Gjerde, 2017). Thus, knowledge of cognition is essential because it comprises information about oneself as a learner, knowledge about learning approaches, and knowledge about when and why to employ a certain strategy. Bundeswehr and Padagogik (1982), stated that cognitive knowledge is related to a person's understanding of his or her own cognition. To guarantee that the debate is relevant to the issue at hand, it is necessary to possess the appropriate expertise. Moreover, Expert 1 said that the leadership perspective is a good quality and guiding concept that can achieve the goal and serve as a model for others to emulate. According to Eden and Leviatan (1975), which is referenced by Lord and Emrich (2000), most respondents feel that the leadership factor is essential to their everyday lives. Moreover, the impact of communication between designers and stakeholders or clients is significant to design negotiations, deliver an idea or thinking, and make decision. During the design review, designers use their understanding of the design to argue with other designers and discuss which facts and data are most beneficial.

5.4 Decision Quality

The designers and stakeholders meet during the design review meeting to examine the construction project's planning and the repercussions of project failure. Quality decision-making must occur during the meeting to reach a plausible conclusion. The reviewers must maintain a democratic balance of power to prevent unfavourable decisions that could affect the project's costs and time (Gjerde, 2017). Therefore, decision-making is one of the most basic cognitive processes in human behaviour, in which a preferred alternative or course of action is selected among a variety of alternatives based on predetermined criteria (Lee & Ostwald, 2020; Wang et al., 2004). Several factors that influence decision-making, such as past experiences, various cognitive impediments, the ability to engage and sunk performance, individual differences in age and socioeconomic status, and a sense of personal responsibility, can influence a decision-making process (Dietrich, 2010). The cognitive process of the designer's decision-making and problem-solving skills is also engaged in the growth of design concepts, according to Sun and Yao (2011), Individual behaviour is a significant aspect in the study of decision-making in psychology because an individual's reaction can influence their decision-making.

6. CONCLUSION

The findings of this study contribute to the expanding body of information regarding the cognitive criteria utilised by designers during traditional design reviews. It is crucial to organise the design review into revised themes based on cognitive criteria of the VCQ to enhance the design review experience. By developing a quality design review process, time and money can be saved because it can help produce effective decision-making amongst designers. A paucity of research on cognitive processes in VR-related architectural research, such as spatial or behavioural, visual perception, and other cognitive processes (Paes et al., 2017) may contribute to the knowledge gap in this area. The results from the unstructured interviews with construction experts can also be incorporated into new technologies, including VR, to compare the effectiveness with traditional methods in generating satisfied design review decisions. Hence, the authors anticipated that it could improve the productivity of designers in a construction project by analysing their cognition during design review, thereby maximising the use of VR for visualisation and, ultimately, contributing to the improvement of the construction industry, especially in Malaysia. For future work, the authors will create a questionnaire according to the revised VCQ thematic network and conduct an experiment on a group of construction experts to use the traditional method and VR technology in the design review. The outcome of this future study aims to identify the feasibility of VR technology in the design review process and how it affects the cognitive process of designers.

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