Chapter

An Investigation of Virtual Reality Technology Adoption in the Construction Industry

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Abstract

While Virtual Reality (VR) technology has experienced a recent growth in interest and offers immense potential in a number of domains, there is still insufficient information on the acceptance and adoption of this technology among individual users. The purpose of this chapter is to examine the acceptance and adaptation of people using VR technology in the construction industry and to identify factors that prevent VR technology from being adopted more widely in the construction industry. Semi-structured interviews were conducted to approach this research problem among 15 students and academic staff members at two universities. The results of this research indicate that VR technology is acceptable to people who work in the construction industry. However, there are barriers to further adoption of VR technology, namely high VR hardware and software requirements, low affordability, and low accessibility. This research also proposes several resolutions to these barriers, including preparing facilities by construction industries and universities, providing software and hardware requirements for VR technologies, and decreasing the price of VR devices. The results of this research are of immense value to suppliers and companies affiliated with this technology. Further research is required to demonstrate the functionality of VR technology in the construction industry.

Keywords: Virtual Reality, adoption, barriers, construction management, construction industry

1. Introduction

Virtual Reality (VR) technology allows users to interact with different objects in a virtual environment [1]. Shen et al. [2] found that virtual simulation, through VR technology, creates significant advantages including cost savings, time-savings, and improvements in training efficiency and safety in areas such as healthcare, construction, and manufacturing. Sherman and Craig [3] define VR technology as a medium composed of computer simulations that sense the user's actions and positions and change or augment the feedback to the user's senses, creating the feeling of being present in the simulation, in other words, being mentally immersed. Some VR applications aim to combine virtual displays with the physical world to create more meaningful virtual presentations by providing the ability to interact with real-life

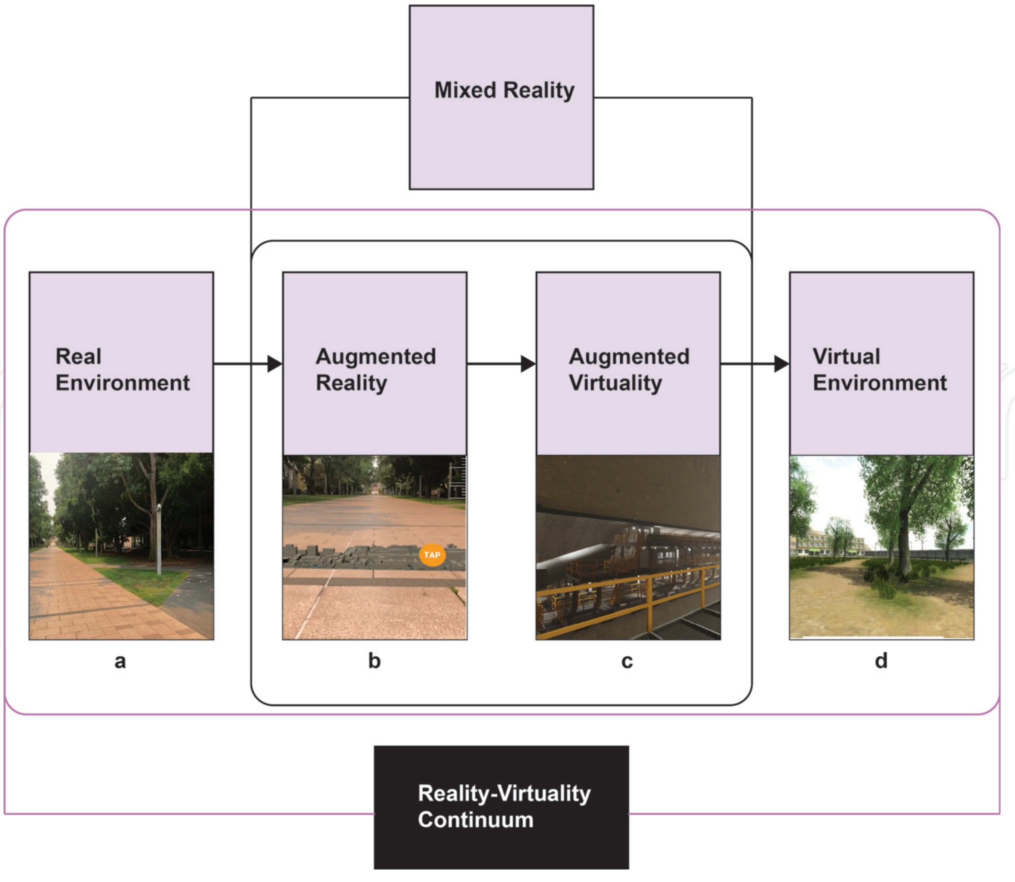

Figure 1.
Reality-Virtuality continuum that indicates the stages between real and virtual environment. (a): real environment (RE); (b) using mobile application to create Augmented Reality (AR) in real environment; (c) Augmented Virtuality (AV): virtual environment created from a real environment; (d): virtual environment (VE); Mixed Reality (MR): the combination of AR and AV.

stimuli and VR simulations. This is referred to as Augmented Reality (AR) and Mixed Reality (MR). AR allows the user to perceive the real world with overlaying virtual elements. MR presents the best qualities of AR scenario in an immersive interface to overlay upon reality [4]. **Figure 1** offers an illustration of the differences between VR, AR, and MR scenarios in the form of a Reality-Virtuality continuum.

The use of VR technologies has expanded in various industries in recent years [5–9]. One of these is the construction industry, although the adoption of VR technologies in construction has been limited. Some construction companies use AR to identify hazards and falling of their workers in their workplace [10, 11]. Based on the research of [10–13], there is significant potential for the wider adoption of VR and AR devices in the construction industry. VR may be helpful for training construction workers at low cost, with fewer safety risks, and faster methods in a virtual environment [12]. VR may also be a beneficial tool for architectures when building maquettes in the virtual environment, and may allow more creativity and time-savings [13]. Section 2.4 offers a detailed discussion of the application of VR and AR technology in the construction industries.

1.1 Outline of the chapter

This chapter provides information on the context of VR and AR technologies in the construction industry. This chapter aims to provide an in-depth understanding of the current and future opportunities of VR and AR technologies generally, and to examine the actual uses of VR technologies at present. The chapter is organized as follows:

- Problem statement, research goals, and research objectives will be discussed in detail.

- A review of the literature on VR technologies is presented, providing a summary of VR technology concepts as well as a review of the existing literature about the adoption of VR. The current potential barriers that affect the adoption of VR are also discussed.

- The research methodology is presented, involving semi-structured interview questions and a participant survey.

1.2 Problem statement

VR has existed for decades; however, only recently has VR technology attracted substantial and sustained interest in a number of domains. VR technology offers immense potential for various industries, such as manufacturing, construction, healthcare, education, and media [5–9]. Based on the research [14], only 7% of businesses currently use VR in their sector, but 23% of companies have a plan to use VR in the next 3 years due to an increase in consumer purchase intention and product value. **Figure 2**, taken from Google Trends, illustrates the recent trend of VR, AR, and MR technology interest in Australia. As **Figure 2** illustrates, the interest in VR, AR, and MR technology has been fluctuated in the past decade. In some years, visible in red, interest in these technologies has increased steeply. Interest in VR, AR, and MR technologies significantly increased in five different years, 2010, 2013, 2015, 2016, and 2017 [15, 16]. The reasons for some of these fluctuations are presented in **Figure 3**. For example, in 2010, AR technology was used for advertising purposes in the print media for the first time. This has

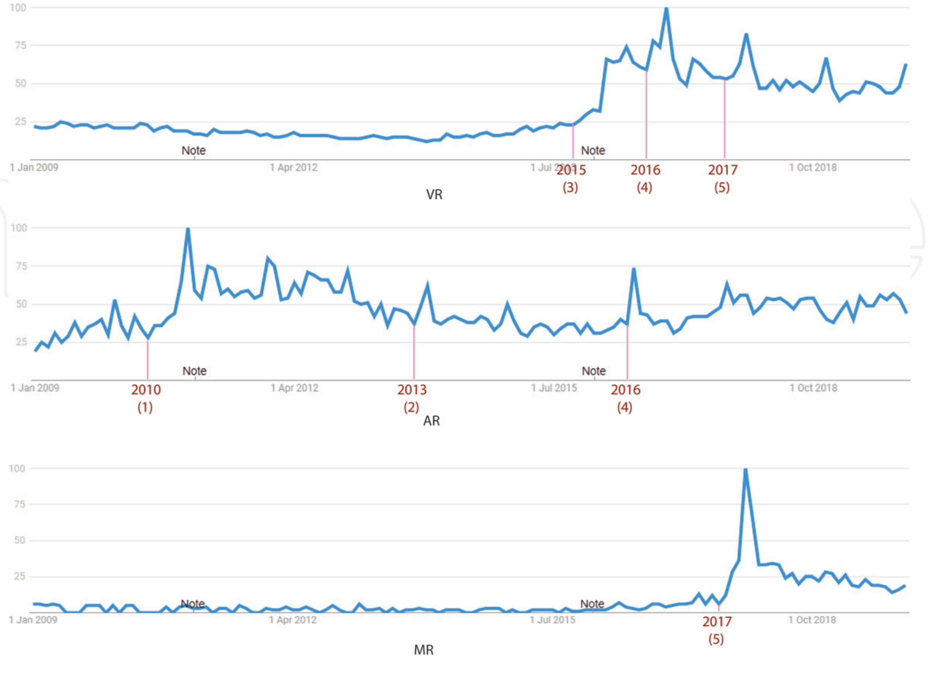

Figure 2.
VR/AR/MR interest trend since 2009 in Australia based on Google Trends. Note: the numbers one through five represent the years 2010, 2013, 2015, 2016, and 2017 with the growing interest of VR, AR, and MR.

dramatically increased the number of people who are familiar with VR technology [16]. In 2017, the first MR technology-related smartphone was introduced and released to the global market, the effect of that can be seen in the MR graph in **Figure 2** [4]. In addition, information obtained from CCS Insight about global shipments of VR and AR is displayed in **Figure 4**. As is illustrated in **Figure 4**, the global shipment of standalone VR and AR devices is on the rise. It is worth noting that the VR technology shift is higher than AR technology.

As is suggested by the figures above, awareness and engagement with VR technology are increasing, but this upward trend is not constant and is oscillatory. The reasons for the variegating interest in VR are unclear. Despite significant investments in the VR technology advancement, there still appears to be a reduced desire to use VR technologies across several domains [1]. While, various research projects [1, 17–19] have investigated the barriers to the adoption of VR technology in different industries separately, there are few resources to address the acceptability and adaptation of VR technology in the construction industry. Identifying the barriers and factors encouraging the adoption and acceptance of VR technologies in the construction industry is thus a vital issue for VR technology suppliers as well as potential VR user groups and VR-related businesses.

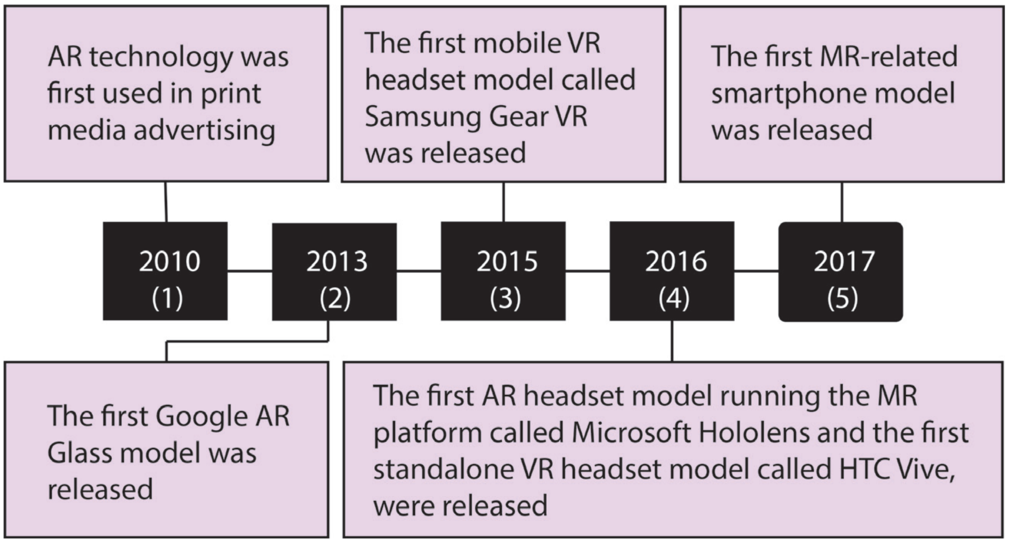

Figure 3.
Reasons for the growing interest of VR/AR/MR in five marked years illustrated in **Figure 2**.

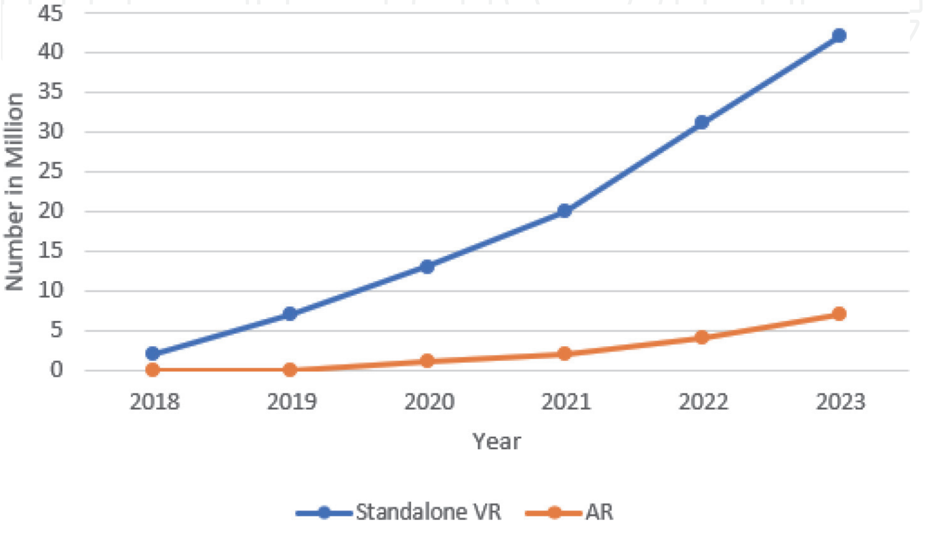

Figure 4.
Global shipments of VR/AR devices, data obtained from CCS Insight.

1.3 Research aims and objectives

There is no doubt that the interest in VR technologies is growing and VR technologies are being implemented in new ways across myriad domains. VR technologies are still in the early adopter stage and diverse applications for significant adoption are uncertain. Although VR technology can be a very applicable technology in the construction industry and there has been a lot of investment in this technology so far, VR technologies continue to be under-utilized in the industry. Some articles do identify some of the factors and barriers that affect VR adoption [1]. However, there are inadequate data to investigate VR adoption in the construction industry. Eliminating the barriers that hinder the growth of VR technology and developing the drivers for wider adoption are essential for wider application of VR technology in the construction industry. This chapter aims to examine the essential drivers and barriers to the adoption of VR technology in the construction industry.

The specific goals of this chapter are listed below:

- Indicate the current status of adoption and acceptance of VR and identify the opportunities of these technologies in the construction industry.
- Identify the barriers to the adoption of VR technologies.
- Identify the factors and drivers of adoption of VR technologies.
- Present solutions for eliminating VR adoption barriers.

2. Literature review

This section provides an overview of the literature discussing VR and AR technology, their applications in different areas, specifically in the construction industry. **Figure 5** illustrates the different VR platforms that we will discuss in the sections specified.

2.1 VR/AR technologies

The key terms and definitions related to VR technologies are presented in **Table 1**.

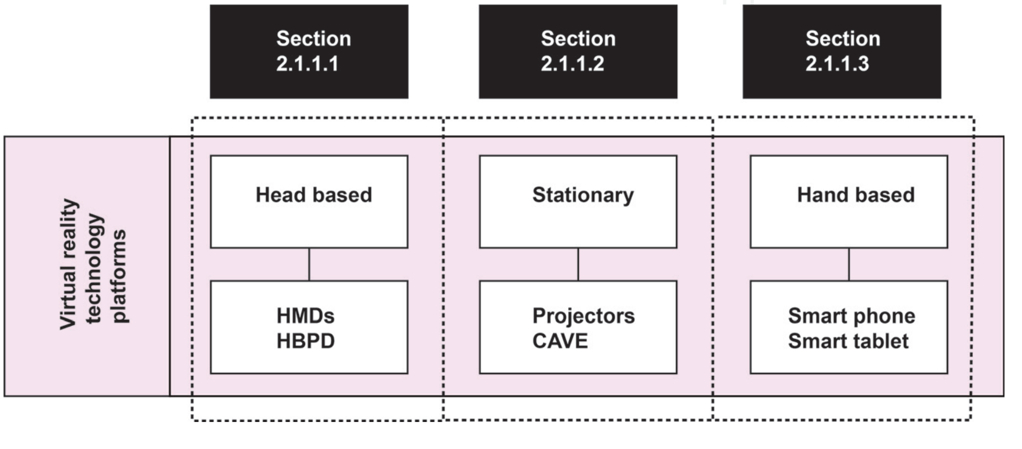

Figure 5.
Virtual Reality technology platforms. Note: HMDs: head-mounted displays; HBPD: head-based projector display; CAVE: the CAVE system.

Terms	Definitions
Virtual	Being or effect that is almost real, but not physically [20]
Virtual environment (VE)	A computer-generated environment within a simulation [21]
Reality	The state or quality of being real [3]
Immersion	The sensation of being present in an environment [21]
Virtual Reality (VR)	A computer-generated simulation of a realistic experience [22], where users interact practically and physically with the environment [23]. Also, a technology that produces the simulation via applying immersion theories into a virtual environment [24]
Augmented Reality (AR)	A similar concept to VR, where computer-generated content is added onto or embedded into the real-world experience so that both can be experienced simultaneously [22], a medium in which real-time interactive digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world [3]
Mixed Reality (MR) or (XR)	Incorporation of virtual computer graphics objects into a real-world three-dimensional scene, or the inclusion of real-world elements into a virtual environment [25]
Artificial Reality	Perceives a participant's action in terms of the body's relationship to a graphic world and makes responses that keep the illusion that his or her actions are happening within that world [3]
Mediated Reality	The concept of filtering reality, typically using a head-mounted video mixing display [26]
Cyberspace	A virtual network that exists to facilitate communication between users [27]
Telepresence	The ability to directly interact with a physical reality [27]

Table 1.
Key terms and definitions related to Virtual Reality.

Virtual Reality (VR) simulations are designed to create immersive worlds from which users have unique insights into how the real world works [27]. The critical elements in experiencing VR are participants, creators, the virtual scene, interactivity, and immersion [3]. First, participants are the most crucial foundation for experiencing this technology. The entire virtual scene happens in the minds of the participants and the experience in the virtual arena is tailored according to the participant's needs. The second most important element is the person who designs and implements VR technology as a creator. Third, immersion involves a feeling of being mentally or physically present in an environment. Mental immersion is the primary purpose of major media designers, while physical immersion is one of the characteristics of VR. Finally, interactivity is the response to a user action, which is essential for successful VR experiences [21].

Virtual Reality, Augmented Reality, Cyberspace, and Telepresence are the forms of computer-mediated interfaces of virtual and real worlds. Virtual Reality, Telepresence, and Augmented Reality are three classes of immersive media in a physical manner. Cyberspace, on the other hand, indicates mental immersion with other individuals. Augmented Reality (AR) mixes computer-generated information with the physical world. Mixed Reality (MR) is defined as an immersive technology that merges VR and AR [27]. Telepresence is defined as the ability to interact with a physical world without limitations on the size or position of the device utilized to transfer the user's command [27].

2.1.1 VR technology platforms

VR technology is a virtual scene that is generated by software in which the operator can feel and experience a virtual scene that reflects the real world. A head-mounted display (HMD) is a wearable device, which permits the user to explore the virtual area by moving one's head. The user can interact with individual controllers with the environment in many cases. Users can display video-recorded or computer-generated content with 360-degree cameras in VR. VR also can be categorized into three different groups based on their technology platforms: head-based, stationary, and hand-based [3]. Below, each of these platforms is described in detail.

2.1.1.1 Head-based

A head-based group such as helmet, HMDs, or HBPD does not allow users to see the outside view of the world. Users stand in front of the position tracking sensor and see the virtual world that is created by the computer system. The position tracking sensor recognizes where the user is looking and transfers that into the computer. Instead of wearing a headset, users can wear a projection system on their head and see the virtual world on the surfaces ahead of them. This is called a head-based projector display.

2.1.1.2 Stationary

A stationary group such as projectors and CAVE creates a location in space for users to feel the virtual environment without carrying any hardware. One of the most commonly used platforms is the CAVE system. CAVE system provides a space, such as a room that displays computer-generated imagery around it. Users are in the middle of this place and find themselves in a seemingly real environment.

2.1.1.3 Hand-based

Hand-based groups such as smartphones and tablets require users to hold and look at something like a mobile phone, monitor, or tablet in order to experience a virtual environment [3]. In some cases, headsets in the head-based group are capable of being mobile-connected. However, this type of technology restricts the user to using a mobile or tablet for being in a virtual environment.

2.2 Development of VR and AR

This section discusses the development of VR technology to highlight the crucial stages in creating the current generation of VR technology. **Figure 6** presents a continuum of the development and predicted future direction of VR technology [3, 15, 16, 28, 29].

As is illustrated in **Figure 6**, interest in and development of VR technologies has ebbed and flowed since initial experiments with reality-augmentation in the late 1950s. In the 1990s, when 3D gaming became more accessible and popular, there was a similar boom in interest in Virtual Reality. Gaming companies presented 3D videogames; movies similarly depicted virtual worlds and computer-generated environments. However, this technology is rudimentary and limited, with mediocre graphics, low computing power, time lags, and high prices. These products eventually failed because consumers were unhappy with these technologies and interest

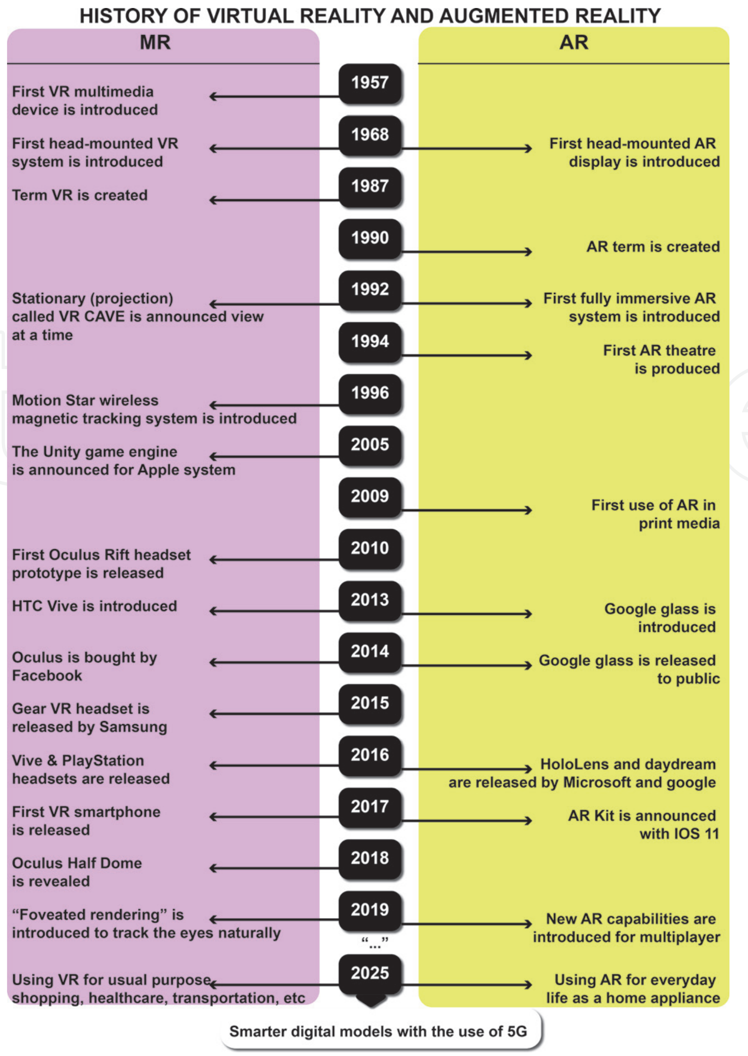

Figure 6.
Timeline of Virtual Reality and Augmented Reality technologies and the predictable future of them [3, 15, 16, 28, 29].

significantly diminished [30]. Since the 1990s surge in VR interest, new technologies have encouraged renewed interest and investment in VR platforms. Computers are powerful enough to make virtual worlds realistic, and mobile technologies have made higher quality VR simulations more available and accessible. New companies have become interested in this progress, and have invested significantly in new VR technologies [30]. For example, in 2014, Facebook made an investment of US$2 billion to buy the Oculus Rift, a VR headset from a technology-based company that combines a headphone with a microphone to help users feel more immersed in the virtual environment [31]. Since 2018, more than 225 VC investments in VR/AR have been made, raising $3.5bn inequity [30]. Flavián et al. [21] predicted that VR, AR, and MR sales in 2020 would grow to approximately US$ 61.3 billion, 21 times higher than VR, AR, and MR sales in 2016.

2.3 Potential sectors for VR/AR

There are various areas in which VR/AR technologies may deliver new potential to markets. VR technologies have sold well in the domain of personal entertainment, and statistics suggest that most investments have been made in these markets so far [30]. However, VR and AR technologies may offer further benefits in the architecture, engineering, and construction (AEC) industries. **Table 2** indicates the application of VR/AR technology in different sectors.

Sector	Application
Entertainment	Jung and tom Dieck [32] proposed a framework for visitors to use VR, AR, and 3D printing at a cultural heritage site to prepare a better experience for visitors. Mobile AR applications were used for tour guides. VR applications were used for simulating the inaccessible places. 3D printing was used for selling a small 3D souvenir. This offers cultural heritage sites new ways to attract visitors, encourage positive publicity, and enhance visitors' positive experiences, thereby encouraging future visits
Live events	Kim and Ko [5] conducted a case study to use VR as a media for spectators to see the sports match and make users feel like they are physically present at the event. By utilizing VR instead of 2D screen, the visitor's satisfaction increased. VR can increase the visitor's good experience by preparing more vitality, telepresence, and interactivity compared to the traditional method
Retail	Poushneh and Vasquez-Parraga [33] used an AR application for evaluating retail user experience by showing a different view of their designs to customers. AR can provide a new experience for customers to assist decision-making. This can affect customer satisfaction and their willingness to buy positively
Real estate	Ozacar et al. [34] created a VR real-estate application that delivers a computer-generated 3D simulation of realistic interior design of the on-sale unbuilt property. This VR application can satisfy the expectation of the property buyers or investors compared to 2D plans or renders
Healthcare	Hall et al. [6] evaluated the usability and acceptability of a 3D Virtual Reality technology to give health-related information to people with intellectual disabilities. This technology was used for a new way of healthcare-related learning. By utilizing a VR environment, people with intellectual disabilities could remember some features of that environment
Education	Chang et al. [7] indicated the use of AR in different fields of education such as chemistry, mathematics, spatial ability training, physics, geography, and surgical training in order to increase the level of quality and progress. AR technology can be useful by superimposing computer-generated virtual 3D objects over real environments
Engineering	Nee and Ong [8] found that AR has potential in different manufacturing activities such as robotics, product design, maintenance, CNC machining simulation, and facility layout planning. This technology offers high accuracy, desirable alignment with industrial standards, and fast response in the above-mentioned domains
Sport	Stinson and Bowman [35] utilized a VR system to present a virtual 3D scene for athletes training to feel a high-pressure training situation that can be helpful for athletes to become ready for a real job. This system could increase the anxiety in athletes' feeling compared to baseline condition and help them to be in a high-pressure situation like a real world
Architecture	VR can be useful in building and exploring 3D maquette models for architectures. It can help them in early design and ideation stages. Architects can create maquettes in a virtual environment by utilizing VR headsets. This can help designers to work more effectively, and at a faster pace compared to current CAD software [13]

Table 2.
Potential sectors for using VR and AR.

2.4 VR in the construction industry

VR and the development of virtual environments can shape the understanding of construction project stakeholders and their success in completing their projects. VR technologies can help improving the effectiveness and efficiency of detailed design, preparation and planning, and construction completion of a project. Increasing the understanding of the design intent, decreasing disruptions, and improving the constructability of the project can be achieved by reviewing and rehearsing the construction of the facility in a 3D immersive and interactive environment before the start of construction. **Table 3** indicates the application of VR technology in the construction industry.

2.5 Theoretical research framework

Several models have emerged that aim to explore the adoption and acceptance of new technologies. In **Table 4** these models are explained, and below, discussed in depth.

The theoretical framework used in this research considers the adoption of new technologies and employs the UTAUT model. This model assumes that performance expectancy, effort expectancy, social factors, facilitating conditions, and trust are the primary constructs in the adoption and acceptance of new technology among users. Performance expectancy is the most critical factor in utilizing modern technology. There are significant expectations for new technologies and uncovering the perceptions of users regarding the usefulness of VR technology is essential for meeting the demands of future users of VR technology. Effort expectancy considers the required effort in implementing and learning how to use new technologies. This construct can represent the ease of use in technology. Social factors consider

Section	Application
House building	Building a Virtual Reality system that allows architects to be immersed in a virtual environment for planning and building cities [36], investigating the use of VR technology for the simulation of on-site tasks in architectural practices [37], and utilizing VR for pre-sale housing system to decrease the project costs, quality risks, and delivery time. This system allows the user to experience the design of the unbuilt house [38]
Construction safety and training	Creating a Virtual Reality simulator of heavy mobile crane operations that can be employed for user training by doing the lifting process in the virtual world before the real project [12]; developing a framework to create training simulators of heavy construction machinery to improve productivity, safety, and quality perspective [9]; developing VR and MR learning and education program to evaluate the power of VR and MR to facilitate the knowledge acquisition [39]; developing a VR safety training program that is related to electrical hazards in the US construction environment [40]; and utilizing VR system to experiment the user's social behavior in the hazardous situation [41]
Project planning	Using a VR application in the construction job site for site layout planning, evaluation of construction site logistics planning, and collision detection [42], and utilizing VR and AR as a prototype tool to do the site planning, support construction layout, and rationalization of the logistics for increasing the productivity and decreasing the operating cost [43]
Augmented VR	Using a mobile AR to support monitoring and documentation of construction site improvement to visualize progress information [44]. Utilizing AR in the case of problem saving, design alternatives and decision-making through a design review activity [45]. Utilizing augmented 360-degree panoramas help users increase their hazard identification in the construction job sites [10]. Utilizing AR to deliver design layout to the electrical construction practitioners in a faster way with less mental and physical demand requirements [46], and utilizing the AR glasses for the users who are working in an assembly construction line [47]
Analyzing tool	Developing a framework to increase the efficiency of maintaining and developing gas and oil facilities by utilizing AR [48]

Table 3.
Using VR in the construction industry.

Model	Explanation
Technology Acceptance Model (TAM)	The TAM is mostly used in the field of Information Technology. The model assumes perceived ease of use and perceived usefulness are the most critical constructs influencing people's attitudes toward using new technology [49]
Unified Theory of Acceptance and Use of Technology (UTAUT)	The UTAUT model is one of the most widely used models for adopting new technologies. The model evaluates four primary constructs: (i) performance expectancy, (ii) social influence, (iii) effort expectancy, and (iv) facilitating conditions [50]
Real Estate Stakeholders Technology Acceptance Model (RESTAM)	The RESTAM is employed in the real estate online platform, considering 11 constructs: (i) information quality, (ii) service quality, (iii) system quality, (iv) playfulness and usability, (v) perceived enjoyment, (vi) perceived usefulness, (vii) self-efficacy, (viii) user satisfaction, (ix) perceived ease of use, (x) actual use, and (xi) behavioral intention to use [51]

Table 4.
The adoption of new technology.

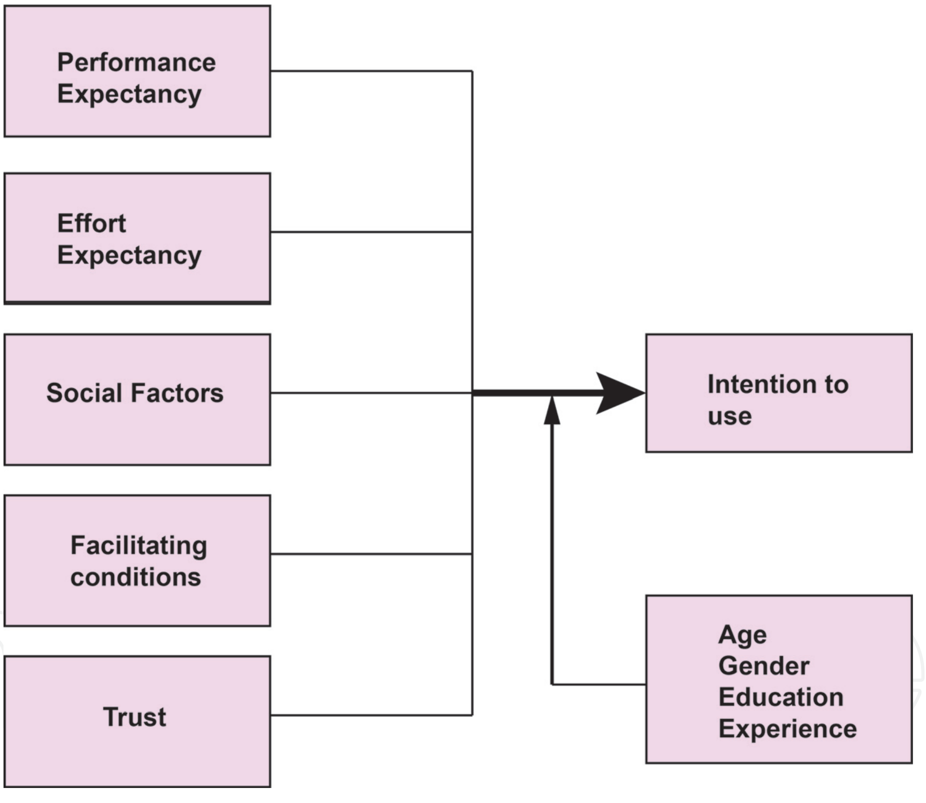

Figure 7.
Important constructs to the adoption of new technologies.

people's thoughts about adopting new technologies in other companies in the same industries. Facilitating conditions considers the functions of modern technology to simplify the existing conditions rather than complicate them. Trust involves identifying security and privacy risks and hazards of new technologies. The effects of these sub-constructs are evaluated during this research.

Figure 7 illustrates the relationships between the identified construct to the adoption of new technologies alongside other factors including age, gender, education, and experience. This figure is adapted from the UTAUT model [50].

2.6 Barriers to the adoption of VR technology

In this part, the obstacles to VR-based technologies are explained in light of the existing literature. Fernandes et al. [52] investigated the aspects that affect the adoption of VR among top UK construction firms in the public sector. The authors found the factors that affect VR by researching other resources; then, they organized these factors into various categories. The authors collected data from 33 top UK construction firms by distributing questionnaires. The results of this study indicate that the senior management support, champions of the technology within a company, degree of business competition, internal needs, the participation of users, and organizational resources are the most critical factors affecting the adoption of VR in the UK construction sector. Laurell et al. [1] identified the barriers to the adoption of Virtual Reality through social media. The author chose HTC Vive and Oculus Rift as empirical cases. The data were collected through all published user-generated posts in Swedish social media channels such as Facebook, Instagram, various blogs, and Twitter. The result of this study suggests that network, technology, price, and trialability are the most critical barriers to the adoption of Virtual Reality respectively. Glegg et al. [17], Paulo et al. [18], and tom Dieck and Jung [19] evaluated the effects of VR and AR adoption on the healthcare, tourism, and national parks sectors respectively. Stockinger [53] considered the current and future state of the VR and AR technology; however, the only participants of this study were VR experts. This sample may not be representative of the wider population, of industry actors and investors, with regard to knowledge of VR technology and its capabilities. Likewise, Whyte [54] only used experts as its participants to investigate users' contributions to the VR as new technology. Therefore, to fill the existing gap in the current research mentioned before, this research considers the perspectives of participants who have varying levels of expertise in VR technology.

3. Method

In the following section, the approach and reasoning for the selected method is outlined in more detail. The process of choosing contributors, collecting and analyzing data is also discussed.

3.1 Qualitative research

A qualitative method was selected for this research involving semi-structured interviews. In the qualitative method, information is collected, interpreted, and suggestions are made at the same time. Because individuals answer the questions, the themes that can arise may be dissimilar than expected. Qualitative approaches provide significant freedom for the examiner to highlight the outcomes of the study and the legitimacy of the gained data [55]. In order to realize and explore a broader phenomenon, qualitative methods are utilized by asking questions that allow participants to provide detailed and open responses. Developing and adopting new technology is one of the areas that needs qualitative research to gain better data from a broad selection of participants [55]. Ethics approval was sought and obtained from the Built Environment Faculty of the University of New South Wales.

Participants were asked to conduct the VR program, which was followed by a face-to-face interview. Participants used a VR program that was provided for the purposes of this study. The program was a Tunnel Boring Machine (TBM) simulator that allows users to see and interact with various locations and parts of the TBM. A laptop, an HTC Vive headset, and two handheld controllers were used to perform this simulation. Users can view the machine in real time through a headset, as well as being able to navigate through different parts of this machine via controllers. All the relevant information that the users needed to know to use the technology on their own was provided. **Figure 8** illustrates the HTC Vive headset that was used in this research. **Figure 9** shows a participant while taking part in the simulation exercise.

3.2 Case studies

Case studies were utilized in this study. This approach involved examining subjects and evaluating this new technology based on the identified construct such as performance expectancy, effort expectancy, facilitating conditions, trust, and social factors. The goal of the case studies-based approach is to examine a situation or an event from the perspective of the individual [56]. The case study approach aims to obtain different categories and themes, not to test hypotheses or prove relationships. In this sense, case studies involve an interpretive approach. Case study data were collected by doing interviews with participants [56].

3.3 Semi-structured interviews

Semi-structured interviews were selected in order to provide subjects with more freedom when answering questions and allow participants to provide information relevant to a number of VR applications and experiences. Completely structured interviews for this study could not be a useful approach because, as mentioned in

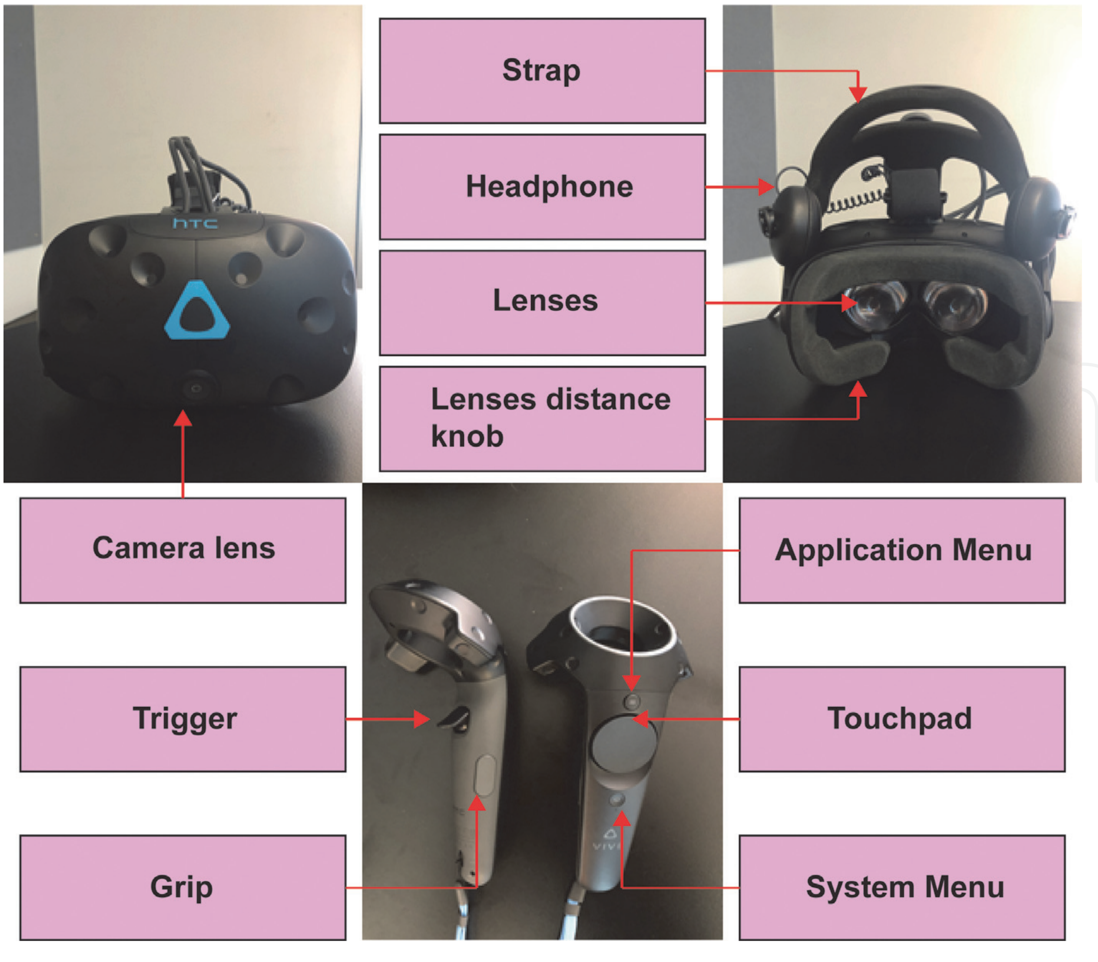

Figure 8.
Different components and parts of HTC Vive headset and controllers that are used in this research.

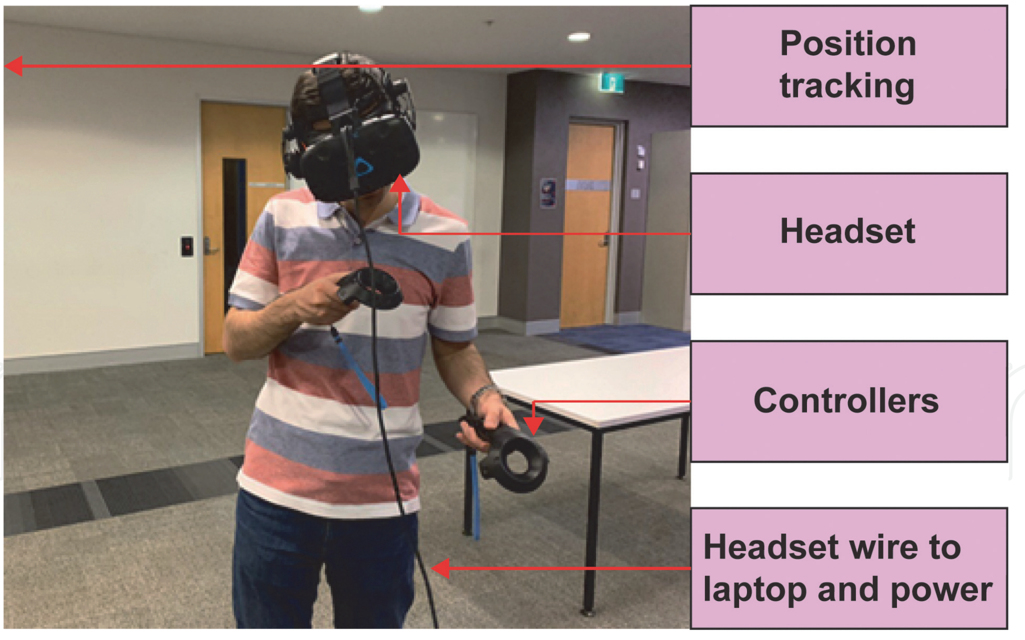

Figure 9.
Research participant experiencing Virtual Reality.

the literature review, there are many areas in which VR technology plays a role and the ways users experience and interact with VR technology are often difficult to predict.

3.4 Sampling

Interviewees for conducting this research chosen from academic staff and students at the University of New South Wales and the University of Wollongong from the built environment and construction faculty. Some interviewees used VR in their daily work, while others were relatively new to the technology.

3.4.1 Sample size

The size of the participant pool was determined by other similar research projects. Studies such as [54, 57], which are closely related to the subject of this research, used 11 and 10 participants, respectively. So, it can be inferred that this is the usual and ordinary number of participants used in such analyses. In this study, 15 participants were assessed. Out of the 15 participants, 4 were from the University of New South Wales and 10 were from the University of Wollongong, the academic staff member participant was from the University of New South Wales. The participants had work experience and education in construction.

3.5 Data collection

All participants engaged in this study with informed consent. Students who were interested in participating in the study filled out the consent form from the Built Environment Faculty of the University of New South Wales. To perform this research with academic staff, researchers emailed with the information about the research. Additional information and the consent form were sent to academic staff members on how to conduct the interview process, and the necessary coordination made to provide the appropriate time for doing the interview. All 15 face-to-face interviews were conducted among participants who were students and academic staff (14 students and 1 academic staff). Participants had varying levels of experience with VR technology. Interviews lasted about 20–30 min.

Semi-structured interviews were conducted as follows. Initially, participants were given basic information about the purpose and subject of this research. Second, participants shared their experience of using VR technology. The participants were then asked questions related to the adoption of VR technology. During the face-to-face interviews, the participants' voices were recorded as well as some notes taken. After each interview, all the participants' comments and ideas were written and saved as a Word document. All the audio recordings for this research and their transcripts were saved. After conducting all the interviews, these files were easily accessible for the analysis part. In the following section, choosing the appropriate software for qualitative research will be discussed.

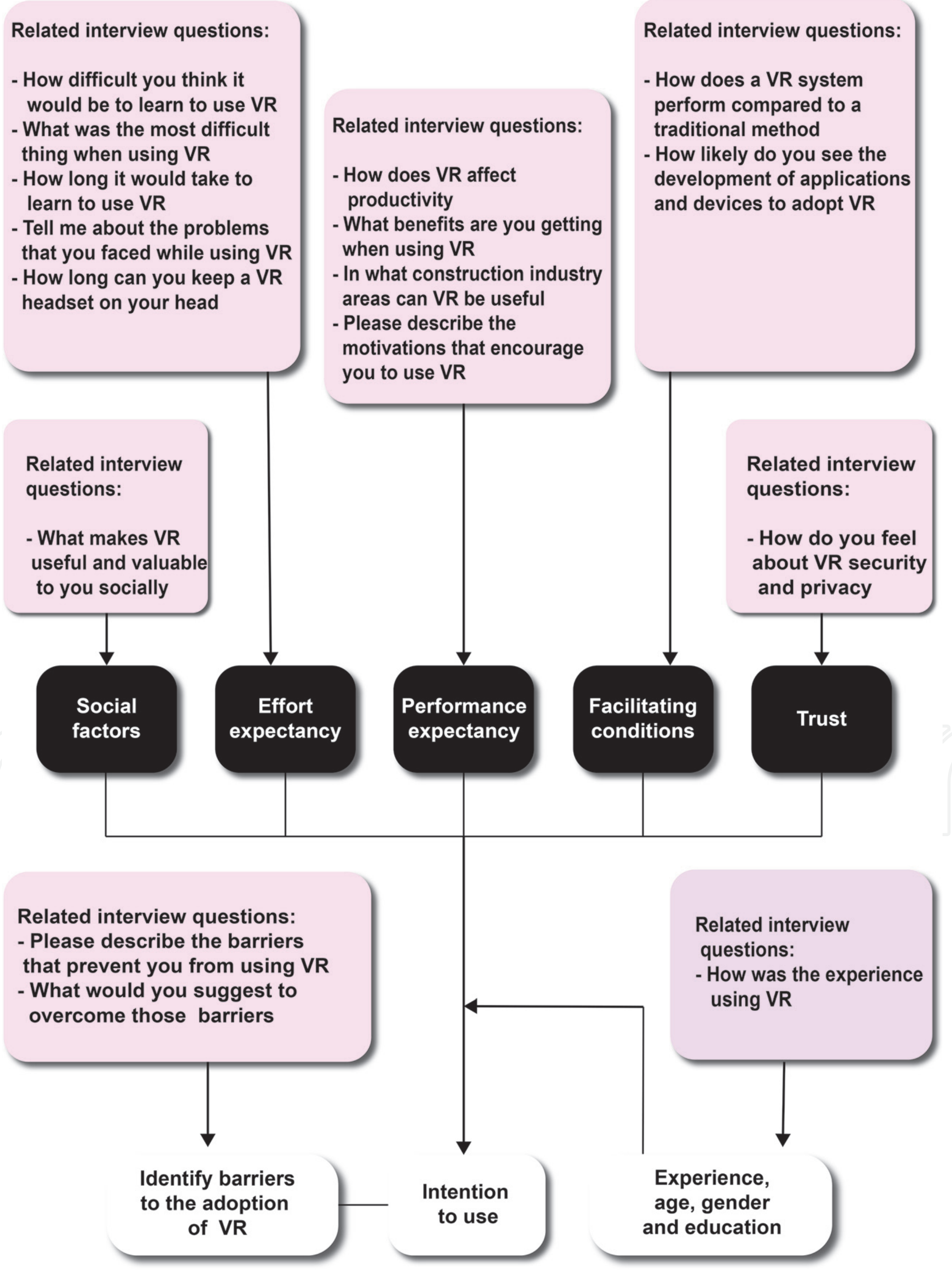

Figure 10.
The purpose of interview questions.

Figure 10 illustrates the purpose of interview questions that fit the needs of the survey to adopt new technology.

3.6 Data analysis

After all the interviews were completed, Word files provided after each interview were transferred to NVivo software. To perform the analyses, transcribed participant interviews were coded using the NVivo software. Thematic coding used in this research was based on the participants' responses. The final coding structure is available to see in **Table 5**.

ID	Factors	Codes
1	Application development	More effective
2	Difficulties	Depends on application
		Feel uncomfortable
		New technology confusing
		No difficulties
		No spatial awareness
3	Most difficulties	New technology
		No difficulties
		Setting up hardware and software
		Using headset and controller
		Working with some applications
4	Benefits	Be in a virtual place
		Ease of learning
		Involve different area
		Safety
		Time and cost saving
5	Problems	Application and program
		Feel uncomfortable
		Limited area of moving
		Setup correctly
		Using headset and controllers
		No problem
6	Usage area	Building construction
		Education
		Mining
		Site planning
		training
7	Barriers	Affordability
		Emotional and mental issue
		Hardware
		Not accessible
		Software
		No barriers

ID	Factors	Codes
8	Keep headset	Depends on the application
		Less than 30 min
		More than 30 min
9	Overcome barriers	Improve hardware
		Improve software
		Mix with traditional
		Reducing price
		University or industry facility
10	Drivers	Be in virtual space
		Different usage area
		Ease of learning
		New technology
		Not falling behind technology improvement
		Reliable
		Time and cost saving
11	Privacy	Depends on the application
		Privacy risk
		Same as other technologies
		No privacy issue
12	Socially	Communicate with others
		Depends on the application
		Flexible working conditions
		Share knowledge and information
		No benefits
13	Compared to traditional	More difficult
		More helpful
		More interactive and real
		Same
14	Experience	Better understand in learning
		Enjoyable
		High performance in future
		Interesting
		New experience
15	Productivity	Ease of learning
		Time and cost saving

Table 5.
Final coding structure.

4. Findings

After completing data collection and analysis, the results were divided into different categories according to the factors discussed in the research framework.

This section will explain participants' responses related to each factor as well as the barriers that prevent VR technology from being accepted by the participants.

4.1 Performance expectancy

This factor examines the usefulness of VR technology in the construction industry. To illustrate the value of this technology, participants answered four different questions including the effects of VR on productivity, benefits of using VR, different uses of VR, and drivers that encourage the use of VR. In the following section, participants' conversations regarding each question are reviewed.

4.1.1 Productivity

When participants were asked to comment on the effect of VR technology on productivity, all participants had a favorable view, saying that VR technology could significantly increase productivity, especially in the context of construction training. It is no longer necessary that actors, such as engineers, go to the original construction site to familiarize themselves with devices and machines. Below, one of these responses is provided:

> *"Education is where I think it does. Education and training. I think to try conveying the same thing through as I was saying, books, and lectures; you just cannot do it as quickly as you can with your hands-on things. The example is if Michael Jordan was doing a seminar on basketball, where no one played basketball" (participant number 4).*

Also, other participants felt that VR technology could impact productivity by time- and cost saving.

> *"In terms of productivity, I should mention that, for example, there is no need to be in the site because of course, it will be more cost extensive, and you can just use it in a room and you will see the Industrial site and whatever and it will save more time, cost and of course it will lead to higher productivity" (participant number 14).*

So generally, they thought that VR technology could have an impact on reducing costs and time as well as enhancing the ease of learning for construction engineers.

4.1.2 Benefits of using VR

When participants were asked to comment about the benefits that they were getting while using VR, most of them mentioned that it was an excellent opportunity for them to be in a virtual world, which offered opportunities related to time and cost savings and safety. Below, one participant's response regarding this question is provided:

> *"Well, of course, you can be somewhere in a virtual world which can be difficult to be there in reality or dangerous or even impossible because of restrictions. And that you can be anywhere you need to be with no matter of cost and time" (participant number 15).*

Participants also postulated that VR could help them to have a better understanding of a different area of knowledge.

> *"Well, I think VR technology involves many other technologies in different disciplines like computer science and or, construction management or other knowledge, so it has encouraged me to learn more knowledge in terms of other disciplines. So, I think this is a benefit I am getting" (participant number 3).*

4.1.3 Different usage areas of VR

Once participants were asked to think about an area of the construction industry in which VR can be helpful, all identified construction training and education as the first area. Below, we look at one participant's response regarding this question.

> *"One of the main ones that as a mining or civil engineer working in underground, or excavation like mining or tunnelling, which is not easy to get there by engineers. It means you cannot even get there. So, it helps engineers. Engineers in this field or technicians to get a better understanding of what is happening underground. Because We have a lot of problems when we go underground and when we want to start working there, so we must just do a lot of introduction, a lot of inductions to engineers for the first time. So, it gives us gave them a chance just prepared for the dangers" (participant number 10).*

Some participants also named other areas of the construction industry such as site planning, mining, building construction could be affected by VR technology.

> *"Sometimes, for example, for some construction site [s] that still on the progress on their construction that they are not ready but we want to present it for the clients for the stakeholders it would be interesting and also attractive, it will make them satisfied to you know, have a look at the future construction port construction site, how we will be the shape how are the features and these things that are the most part used" (participant number 14).*

4.1.4 Drivers encouraging the use of VR

When participants were asked to provide ideas about the drivers that would encourage them to use VR technology, most participants mentioned that being immersed in a virtual space where they cannot be in reality is the key driver for VR adoption. Some participants thought that VR is a new technology and they like to use that and if they do not use that they lag behind technology advances:

> *"I think in the last few years, it is the same as that. If you do not get into VR, you are going to fall behind businesses and the research and other areas like that. When you need big emotional things like emotional experiences or complex learning and teaching kind of situations where movement is important to you, I think then it is good. But I do see that in a lot of cases, AR will probably be more useful" (participant number 4).*

Furthermore, some participants mentioned another time that VR eased learning, that VR technology has different usage areas, and it offers time and cost saving and reliability. Hence, these are the essential drivers that encourage the use of VR in the construction industry.

4.2 Effort expectancy

This factor examines the level of ease of using this technology in the construction industry. Participants answered five different questions including identifying the difficulties of learning to use VR, time spent on learning, problems arising during use, and the amount of time that they can hold the headset. In the following section, participants' conversations about each question reviewed.

4.2.1 Difficulties of learning to use VR

Once participants were asked to share their ideas about the number of difficulties that they encountered to learn to use VR technology, almost half mentioned that there were no difficulties to learn how to use VR technologies. One answer regarding this statement is as follows:

> *"I think for people who know about basic thing about VR they can do it and no need to be deep and I think it is easy to learn" (participant number 11).*

Some participants thought that learning to use VR is relatively easy, but depends on the sort of applications.

> *"Not difficult at all. It was fundamental; it depends on the application itself. But for example, from what I saw, it had like few only like, buttons and few others like, stuff to do. It was straightforward. It was like; you just must try and error. You can learn a lot about to know how to use the whole application. So, it depends on the application" (participant number 13).*

Other participants felt confused because VR technology is a new technology that they had not used. Other participants felt uncomfortable because they have difficulties with spatial awareness. Participant number 4, who is a member of academic staff, offered some insight into this difficulty:

> *"There is a flat statistic of about 10% of the population who just will never feel comfortable. It is something to do with the physical. Functionality arises or something like that. So that flat statistic already says 10% is going just never to get a no matter how long put it on."*

We can conclude that some people had difficulties with using this technology that could be solved over time, while others will continue to feel uncomfortable.

4.2.2 Most important difficulties with learning to use VR

Participants were asked to give their opinion on the most crucial difficulty that they experienced when using VR technology. Some participants had problems with handling the controllers. Others felt that headset was heavy to use, because of the kind of headset that was used in this research. Again, some participants felt that VR is a new technology. Below, two participants' responses regarding this question are provided:

> *"Because VR is like a new technology for us as both students like our generation like most of the time that we are using VR so might be like having different feelings about the headset also the controller because I have never used the controller before. It is like our real life is still take some time to learn it was quite simple like I can actually learn in five minutes and pretty straightforward" (participant number 2).*

> *"Well, I think the most difficult things might be I think it might be people. Some people might be reluctant to learn new technology in they do not want to try new things. Because they feel unsafe or hard to learn new technology. So, I think this might be one of the difficulties for learning VR" (participant number 3).*

So generally, some difficulties in using VR were observed, but it is worth pointing out that these issues were considered to be easily overcome with further training and exposure to VR technology.

4.2.3 Time spent learning

Participants were asked to indicate how long it took to learn to use VR technology alone. Almost all participants acknowledged that it only took a few minutes to get to know everything. One answer from participants is as follows:

> *"It is a couple of seconds it depends on how you adapt yourself and how fast you are" (participant number 12).*

4.2.4 Problems arising during use

Some participants mentioned that problems using VR depend on the application that they need to use, because, if it is complex, using controllers will be difficult. Correctly setting up the system may be another issue checked before starting the application. One aspect that some participants mentioned about using VR was the limited area of moving. We can see one participant's response to this question.

> *"For me, as you saw, I have a problem that I cannot control my body. When I am using a headset, and I need to be restricted to an area just to prevent any kind of hurt because I might hurt myself and I am going to be using VR. I have no idea where I am. So, I start moving around" (participant number 10).*

Other participants mentioned that they did not encounter any problems while using this technology. Essentially, some problems that participants faced when using VR technologies require further research.

4.2.5 The amount of time the headset holds

Interviews found that almost half of participants were willing to keep the headset on for an extended period, but others believed it was difficult for them or the type of program they were using should be so attractive that it makes them eager to keep that. One sample answer is provided below:

> *"The one that I tried with you brought is for us, that was pretty and good the headset was comfortable but from the point that we are human, I think for me, maybe 25 to 30 minutes. I am going to need to feel safe, I mean, the real reward but I think that can gradually increase the thing but if the headset we put them be so much*

uncomfortable. That is going to be annoying or make you headache or earache" (participant number 6).

4.3 Social factors

This factor examines the participants' thinking about adopting VR technology in other companies in the construction industry. Participants were asked about their ideas regarding the issues that make VR useful and valuable to them socially. Most participants thought that other businesses in the construction industries could also use this technology and be at the same virtual place, it would be important and valuable for them to have communication with each other during experiencing a scenario. Participants also thought that it would be useful for sharing and transferring their knowledge and ideas in a flexible working condition. Two sample answers are provided below:

> *"One of the most important things is that how can we contact other people if we can make a connection, contact with other peoples around the world. So, it is going to make it so reliable and easier to get a lot of information and getting knowledge from all around the world, for example about one specific part. So, it is going to make it more enjoyable and more reliable. If we have other people involved in one field of interest" (participant number 9).*

> *"It can be beneficial because I am sure that it can improve efficiency. But if we do not know the user, I am not sure how it can use if you want to know the idea of different people. It is complex or risky. You are not sure who they are. It depends on the goals and what you want to do I am sure that some people use that for online gaming maybe it can be good" (participant number 7).*

4.4 Facilitating conditions

This factor examines whether VR technology facilitates the existing methods such as those used in education and training. To illustrate this situation, participants were asked to share their ideas about comparing VR technology with traditional methods and developing VR applications and devices.

4.4.1 Comparing VR technology with the traditional method

Once participants were asked to talk about their ideas about comparing VR technology with the traditional method, most compared using the headset and controllers with using the mouse and keyboard. However, some participants compared VR technology with lectures and books in educational and training purposes. One sample answer is provided below:

> *"Honestly, I do not think there is a huge difference, where it comes in is the kind of spatial awareness thing. So, having a 360 view on a computer and YouTube, for example, is pretty much the same thing as a headset. However, the level of immersion goes up when you have everything down, and it is right up against your face. But I would say it is still similar that there is not that much difference at the moment between the situations where it is probably good to have a mention that I think is in training things, for example, I think that is when it helps me. It is hard to translate tacit knowledge. And I think VR is a good way of allowing you to have the experience, without that, you cannot read a book and learn a lot of things. Yeah, that is the kind of fills that gap" (participant number 4).*

Some other participants felt that using VR headset and controllers can be more useful. One participant's response is provided below:

> *"I think when you use the VR technology, you feel better that you feel that you are literally in that situation or in that place. So, it helps you to understand the environment. Like you are there. But when you use the keyboard, and you just follow it on screen, yeah, it does not give the same feeling and it helps you to remember what you see in a better way because you feel it" (participant number 8).*

All participants thought that using VR technology could be more effective than previous methods.

4.4.2 Development of VR applications and devices

All the participants agreed that developing VR applications and tools can improve the adoption and acceptability of VR technology because this can help VR to promote requirements more than before. One sample response is provided below:

> *"I think it is a part of our future, you need to accept it. I think within the next five or ten years, it is going to be mandatory for each engineer to know how to use this If they want to find a proper job. It is much less money and time-consuming to train people in this way, rather than to take them to real facilities. And it is no experience-wise it is. It is much more useful. It is much more fun to be in a three-dimension environment rather than just sitting at a desk and using keyboards and mouse they need to look if you want to encourage someone to use it. The first thing you need to do is to make them use it for five minutes. Because once they experience it for the first time, they realize that, there is a significant difference between, sitting at a desk and using desktop and keyboards and using a VR. And because we are visual people, the whole visual experience is fundamentally different and better when you are using VR. So, there is a huge room for improvements" (participant number 5).*

4.5 Trust

This factor examines the security and privacy hazards of new technology. For analyzing this factor of VR technology, participants were asked to talk about the privacy and security of VR. Almost half of the participants mentioned that the protection and confidentiality of VR are the same as other technologies. One sample answer is provided below:

> *"I think this technology is just like the rest of the software that depends on the internet and doesn't make much difference so overall I think it's a safe technology" (participant number 15).*

Some other participants thought that this technology could be problematic regarding safety and privacy, but it depends on the applications. One sample answer is as follows:

> *"I think when you are playing VR, they are somewhere to stand near you because you cannot see the surroundings, and you might have some safety issues. For our privacy issue depends on the software developer" (participant number 1).*

4.6 Experience, gender, age, and education

There are several sub-factors such as experience, gender, age, and education that need consideration to give a precise and accurate view of the adoption of VR technology. After the interviews, it appears that the gender and education factor did not affect any of the above situations, but the age and experience factors may be relevant.

Regarding the age factor, it is worth noting that participants believed that some people, especially older people, were not willing to learn new technologies and certainly learning new technologies can be harder for them. One sample answer is as follows:

> *"Elderly people are going to have many more problems with using that. It is going to be a total difference, you know, experience with them. To be honest, I cannot suggest anything, when you are dealing with older adults. One way or another they need to cope with it. It is a part of living in 2020" (participant number 5).*

Regarding the experience factor, participants who did not have previous VR experience found this technology to be a new, interesting, and enjoyable experience. Still, those who had more experience had a closer look at this technology and thought that this technology is a better way of learning and this will be used more in the future. Two sample answers are as follows:

> *"It was very interesting because I never used VR in that way. We use it for games, but I never used it with work industry related stuff. So, it was very interesting, and I thought like, you could not use it a lot in this field. But now I think there is a lot of things that you can learn from that" (participant number 13).*

> *"It was good. I was somehow familiar with the whole concept of using VR. But the thing was that it was my first time to use it for the specific purpose that if you are using it, it was interesting because I never had any kind of experience of being in that specific situation. And I enjoyed it. It did not last too much. It was something like 10 minutes" (participant number 5).*

4.7 Barriers to the adoption of VR

Participants were asked to express their views on barriers that impede the adoption of VR technology in the construction industries.

Several participants identified a lack of access to this technology as one of the critical barriers. They believed that this technology was not available and accessible to everyone, because of the high cost of the device and because this technology relies on a high-powered computer system that may not be widely available. One sample answer is as follows:

> *"Might be the equipment because like this kind of equipment is not common. You know for your own house. Also, like the computer that we need. Like it might be the computer with a better processor. Like we should not run just the big applications. You need a more powerful computer which is not accessible for some of the students" (participant number 2).*

Some other participants thought that the emotional and mental issues of some people who cannot use headset are the main barriers to the adoption of this technology. One sample response is as follows:

> *"Some of the population feel uncomfortable while wearing VR headset. It is related to the emotional and mental issues of them which is not about the duration of using that" (participant number 4).*

4.8 Overcoming current barriers to adoption of VR technology

One of the goals of this research was to recommend solutions to overcome the barriers to adopt VR technology. To accomplish this goal, participants were asked to suggest a way of removing and overcoming the barriers that they mentioned in the previous section. All suggestions made by these participants will be explained in this section.

4.8.1 Improve hardware

One of the factors that were considered by the participants as a barrier to the adoption of VR technology is the hardware used in this technology. It may be worth mentioning here that we did not use the latest headset and controller models in the market; instead, we used the available models, which had high power. It was concluded that over time the hardware available for this technology would improve and this can help a lot in adopting VR technology in the construction industry.

4.8.2 Improve software

Another factor in preventing the adoption of VR technology is the high-powered software needed to use such technology as computers with powerful resolution and the frame rate. The computer needs strong graphic processing unit power to be able to handle the VR applications. Indeed, one of the barriers that seem to be hard to fix is this factor because such computers are not available to everyone and suppliers of this technology need to find a solution to this obstacle to make this technology more acceptable in the construction industries.

4.8.3 Mix with traditional

One of the barriers raised in the previous section was the mental and emotional issues that some people have regarding new technologies. One solution that can help people use this technology is to mix VR technology with already established systems. Using the keyboard and mouse instead of using the headset and controllers is an example of that. This solution may help people to use this technology without any uncomfortable circumstances and it can also help older people to adopt technology more efficiently.

4.8.4 Reducing price

A critical issue that prevents the adoption of this technology among different people is the high costs associated with VR technology. Over time, it seems that there is a declining trend in the price of this technology. As such, this barrier is likely to be overcome naturally as VR technologies are produced more cheaply.

4.8.5 University and industry facilities

One of the solutions suggested by the participants of this research can help a lot in adopting and familiarizing different people with VR technology. This suggestion is that universities and construction industry centers provide this technology for use among their students and engineers respectively. This may solve both the problem of not having access to technology and the fact that people do not have to pay a lot of money to buy this technology and the associated software.

4.9 Summary

In this section, the responses from different participants in the context of the factors of the study were evaluated. **Table 6** offers a summary of the findings for each interview question. Fifteen questions were asked of participants of the study, and according to the participant's responses to each question, several codes were assigned to answers. The percentage column represents the percentage of participants who responded to the relevant issues by referring to each code. For instance, all participants agreed on the first question that VR technology can be instrumental in the construction industry. In answering question 6, 36% of the participants believed that VR technology could be beneficial and useful in the construction education section and 28%, 21%, 11%, and 4% of the participants, respectively, have referred to building construction, training, mining, and site planning as proper sections for application of this technology. An example column on the far right of the table provides an example of the participants' response to each question and code.

ID	Codes	Percentage	Example
1	More effective	100	"… It can be more effective in different areas …"
2	Depends on application	16	"… It depends on the application itself …"
	Feel uncomfortable	5	"… Felt uncomfortable when wearing a headset …"
	New technology confusing	21	"… Felt confusing because VR technology is the new technology …"
	No difficulties	53	"… No need to be deep and I think it is easy to learn …"
	No spatial awareness	5	"… Felt uncomfortable because I do not have any spatial awareness …"
3	New technology	25	"… Some people might reluctant to learn new technology …"
	No difficulties	12	"… I can learn in five minutes and straightforward …"
	Setting up hardware and software	6	"… Setting up software and hardware is the important part …"
	Using headset and controller	38	"… Having different feelings about the headset also the controller …"
	Working with some applications	19	"… It depends on the sort of application …"
4	Be in a virtual place	30	"… Somewhere in a virtual world which can be difficult to be there in reality …"
	Ease of learning	26	"… It has encouraged me to learn …"
	Involve different area	9	"… Involves many other technologies in different disciplines …"
	Safety	13	"… Somewhere in a virtual world which can be difficult to be there in reality or dangerous …"
	Time and cost saving	22	"… Be anywhere you need to be with no matter of cost and time …"

ID	Codes	Percentage	Example
5	Application and program	25	"… It depends on the application that we need to use …"
	Feel uncomfortable	20	"… I have no idea where I am …"
	Limited area of moving	15	"… I have a problem that I cannot control my body …"
	Setup correctly	5	"… Correctly setting up the system can be another issue …"
	Using headset and controllers	30	"… Using controllers will be difficult …"
	No problem	5	"… I did not feel any problem …"
6	Building construction	28	"… For some construction site that still on the progress …"
	Education	36	"… Engineers in this field or technicians to get a better understanding …"
	Mining	11	"… As a mining or civil engineer working in underground …"
	Site planning	4	"… Construction port construction site …"
	Training	21	"… It gives us gave them a chance just to prepare for the dangers …"
7	Affordability	13	"… Because of the high cost of the device …"
	Emotional and mental issue	9	"… Some people who cannot use headset …"
	Hardware	17	"… You need a more powerful computer …"
	Not accessible	9	"… lack of access to this technology …"
	Software	17	"… Need a better processor …"
	No barriers	35	"… There are no barriers …"
8	Depends on the application	18	"… It depends on how you adapt …"
	Less than 30 min	29	"… It is a couple of seconds …"
	More than 30 min	53	"… I did not feel any inconvenience …"
9	Improve hardware	12	"… There is a room for much improvement …"
	Improve software	39	"… Having computers with powerful processors …"
	Mix with traditional	12	"… Mix it with its previous versions …"
	Reducing price	12	"… Seeing a declining trend in the price …"
	University or industry facility	25	"… Universities and construction industry centres provide this technology …"
10	Be in virtual space	31	"… Be in a place that we cannot be there …"
	Different usage area	17	"… I do see that in a lot of cases …"
	Ease of learning	9	"… VR ease the way of learning …"
	New technology	17	"… Experiencing new technology …"
	Not falling behind the technology improvement	9	"… You are going to fall behind businesses …"
	Reliable	4	"… It brings reliability …"
	Time and cost saving	13	"… It brings time and cost-saving …"

ID	Codes	Percentage	Example
11	Depends on the application	18	"… It depends on the software developer …"
	Privacy risk	12	"… You might have some safety issues …"
	Same as other technologies	23	"… This technology is just like the rest of the software …"
	No privacy issue	47	"… I think it's a safe technology …"
12	Communicate with others	33	"… Contact with other peoples around the world …"
	Depends on the application	6	"… It depends on the goals and what you want to do …"
	Flexible working conditions	6	"… It is going to make it more enjoyable and more reliable …"
	Share knowledge and information	11	"… Make it so reliable and easier to get a lot of information and getting knowledge …"
	No benefits	44	"… It is complex or risky …"
13	More difficult	6	"… It could be more difficult than traditional …"
	More helpful	19	"… You cannot read a book and learn a lot of things …"
	More interactive and real	69	"… You feel that you are literally in that situation or in that place …"
	Same	6	"… I do not think there is a huge difference …"
14	Better understand in learning	29	"… There is a lot of things that you can learn from that …"
	Enjoyable	12	"… It was delightful because I never used VR in that way …"
	High performance in future	4	"… It will be more useful in the future …"
	Interesting	38	"… it was interesting because I never had any kind of experience …"
	New experience	17	"… learning new technologies can be harder for elderlies …"
15	Ease of learning	65	"… As quick as you can with your hands-on things …"
	Time and cost saving	35	"… It will save more time, cost and of course it will lead to higher productivity …"

Table 6.
Summary of the findings.

5. Discussion

The purpose of this research was to demonstrate the acceptance and adaptation of VR technology in the construction industry. To achieve the research goal, it was essential to examine VR technology based on different factors provided from the theoretical research framework. The research identified several barriers that hinder the adoption of VR technology in this sector. Various factors that drive different people to adopt and use this technology were also discussed. Finally, this research proposed various suggestions for removing barriers to further adoption of VR technologies in the construction industry.

Performance expectancy, effort expectancy, social factors, facilitating conditions, and trust were identified as the factors that determined the acceptability status of VR technology based on the theoretical research framework. Performance expectancy examines the usefulness of VR technology in the construction industry. By analyzing this factor, the results indicate the usefulness of VR technology in the construction industry. VR technology offers immense potentials for productivity. This technology is applicable in different parts of the industry and these features encourage people to use VR. Effort expectancy examines the ease of using this technology in the construction industry. In the effort expectancy factor, the results illustrate the high level of ease of using VR technology in the construction industry; there are some barriers to this factor. From the participants' point of view, it seems that the degree of difficulty of using this technology is not great, but due to some factors such as anxieties related to using new and unfamiliar technologies, it can be concluded that the required effort expectancy factor is not fully met by VR technology. Social factors include the participants' opinions about adopting VR technology in other companies. Based on the participants' responses, VR technology worked well on social factors in the construction industry and most of the participants feel excited that they can have a connection with others in the virtual environment. Facilitating conditions consider the ability of VR technology to be adopted into the construction industry. The results show that a high percent of participants agreed on the good performance of VR technology in facilitating conditions. Finally, the trust factor examines the security and privacy hazards of VR technology in the construction industry. Most of the participants agreed that VR technology could be like other technologies and there is not any hazard regarding the privacy issue. Still, there are some obstacles related to this factor to the performance of VR in the construction industry and some participants mentioned that the level of privacy hazard is related to the sort of the application.

There are some sub-factors that may also affect the adoption of new technology. These were age, experience, education, and gender. The results indicate that the gender and education factors were not affecting the adoption of VR technology in the construction industry, but age and experience factors can influence the adoption of this technology, because the level of experience makes people more focused on the technical issues of VR technology, which can affect the adoption of VR technology. The age factor can influence the learning and using of VR technology. A clear example of this factor is related to the elderly people. Some are not interested in using or learning new technologies.

The results of this study indicate that there are some barriers to adopting VR technology in the construction industry. These barriers include affordability, emotional and mental issues, hardware and software issues, and accessibility. Affordability relates to the high price of this technology. Emotional and mental issues refer to people's inability to use VR technology. Hardware issues relate to the computer requirements for using this technology. Software issues were related to the required high level of improvement in the VR technology and simulation applications. Accessibility of this technology suggests that VR technology is not available for all individuals. Each of the above factors needs to be addressed by VR technology-related companies and industries.

After identifying factors that prevent people from adopting VR technology, the participants also made suggestions for overcoming these barriers. These suggestions are as follows: improving VR hardware and software in construction sector; mixing VR technology with traditional learning methods to help some people who cannot shift suddenly from traditional methods to VR technologies; reducing the price of VR-related devices; and preparing VR technology facilities for engineers and students by construction industry companies and universities respectively. By addressing these issues, the process of adopting VR technology in the construction industry may accelerate, and VR technologies may become more common in the construction industry.

6. Conclusion

Based on the Findings section, the performance expectancy factor was analyzed based on the participants' responses for VR technology, which demonstrates the efficiency and usefulness of this technology in the construction industry. The effort expectancy factor was analyzed based on the participants' responses, demonstrating that the VR technology is relatively easy to use. The social element was analyzed based on the participants' responses related to the construction industry, which indicates the usefulness and effectiveness of this technology. The facilitating condition factor was analyzed based on participants' responses, which illustrates the high efficiency of VR technology in facilitating conditions. Generally, it seems that most of the participants felt that there is no serious threat to the security and privacy of VR technology. Based on the results on age, experience, gender, and education factors, it seems that gender and education factors do not have a significant impact on people's intentions of using VR technology. Still, age and experience factors do have some influence. Affordability, hardware, software, accessibility, and mental issue are some other factors identified as preventing the wider adoption of VR technology. However, improvements in hardware and software, reductions in price, and more availability of university and industry VR facilities may remove the barriers.

6.1 Limitations

There were some limitations to this study, including the following: first, due to the limited time available for conducting this study, few interviews were conducted for this study while many more interviews need to be undertaken to produce statistically meaningful results. Although other similar studies have had approximately the same number of participants, the accuracy of the results increases as the number of participants increases. Secondly, this research was conducted at only two universities in Sydney, Australia: the University of New South Wales and the University of Wollongong. This represents a relatively limited and narrow pool of potential participants, who may have greater exposure to VR technologies due to their socio-economic status, the wider availability of VR at Australian universities relative to the rest of the world, and a generally younger and more technologically savvy cohort. Third, before conducting all interviews, participants used one sample of VR technology, which indicated that they used only one type of application and program. The results may be different if participants were using other programs. Various programs have their target audience. Some programs may be less appealing than others; participants should be familiar with different types of programs so that they can give more accurate comments. Finally, the latest version of the VR headset and controllers was not used in this study, which may affect the results. With the advancement of VR technology, there have been changes in the applications, headsets, and controllers of VR technology since this study was undertaken.

6.2 Recommendation

Given the current state of VR technology and its associated hurdles, there is still much to be done on how to develop this technology. In the case of specific headsets currently dominating the market, different types of headsets can have different effects on research results. Further research is needed to reach more participants and use the latest version of this VR headset and controllers for future research. This study also identifies a more general need to examine the functionality of

Virtual Reality technology in the construction industry and to demonstrate its capability in this sector. Because so many sectors of the construction industry can be positively impacted by using VR technology, further research is recommended into the wider adoptability of VR technologies in the industry.

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