Drivers and Barriers of Virtual Reality in UK AEC Industry

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Abstract

Purpose – Virtual Reality (VR) offers unique features such as walking into a building's three-dimensional (3D) model during early design stages and maneuvering in the virtual environment with immersive functions. Although the potential VR is to increase the effectiveness and productivity of the project phases from initial concept design to detailed design preparation, its implementation in the United Kingdom (UK) Architectural Engineering and Construction (AEC) sector is somewhat slow compared to entertainment industry. The research focuses on ascertaining the drivers and barriers of VR in construction projects in the United Kingdom.

Design/methodology/approach – The study adopts an online survey design, Bristol Online Survey (BOS) and UK construction professionals assessed using a convenience sampling technique through a structured questionnaire. The questionnaire was analysed using Statistical Package for Social Sciences (SPSS) and both descriptive and inferential technique was used for data analysis was used to present the data.

Findings – The research findings revealed that lack of skills/expertise and cultural change were the most significant barriers to VR in UK construction industry. Improved safety, improved quality and improved productivity were found to be the main drivers of VR in as rated by the professionals in the UK construction industry.

Practical implications – The results from this study will serve as a benchmark for construction professionals interested in providing the construction industry with virtual reality technology.

Originality/value – Recently, with the increasing growth of virtual reality technology, it greatly contributes to the development of digitalisation of the UK construction industry. This study provides valuable insights to stakeholders to plan actions that mitigate the drivers and barriers of virtual reality. This study's main contribution is to group and classify various drivers and barriers into easily understood categories, in order to potentiate the drivers and reduce the barriers effectively.

Keywords Construction Industry, Drivers, Virtual Reality, Barriers, United Kingdom

Paper type Research paper

1. Introduction

The UK construction industry alone is a significant contributor to the nation's economy (Gledson and Greenwood, 2017). It is one of the first sectors to experience the impact and typically one of the last to rebound being a primary predictor of a nation's stability making it crucial to ensure UK economic stability. Farmer (2016), affirmed that competition with international companies, shortage of skilled labour, and a drastic change in construction efficiency have led to demands for improved productivity and the need for industry to implement new technologies. The construction industry today finds itself at a crossroads, organizations that address these challenges will be prepared for significant growth and reimagine their business processes. On the other hand, companies that fail to take these challenges seriously will face an uphill viability battle (Leeds, 2016).

Summaries from studies such as (Mohamed and Stewart, 2003), (Wu *et al,* 2013) and (Kelly *et al,* 2014) pointed out that problems of time constraints, uncertainty and organizational disintegration have clearly driven many small and large organizations to integrate Information and Communication Technology (ICT) into their business practices. Construction is one of the most knowledge-dependent industries, with its various forms of information consisting of detailed drawings and diagrams, cost analysis, budget reports, risk analysis maps, contract documents and schedules for preparation (Wu *et al.,* 2013; Kelly *et al,* 2014; Mohamed and Stewart, 2003). The amount of information generated and exchanged over a lifetime of the project could be significant, even for small-scale construction projects (Baskerville and Wood-Harper, 2016; Schwalbe, 2015). It is therefore important that the sharing of information can be managed as efficiently as possible to improve the productivity and quality of the projects. Engineering innovation has driven fundamental improvements in the execution of projects across industry. Virtual Reality (VR) has revolutionized practices within the Architecture, Engineering and Construction (AEC) industry among other technologies.

VR is the technology that enables the development of fully computer-generated worlds that offer the user the feeling of being totally immersed in a virtual world. It offers a way to replace the perception of the real world with an artificial 3D environment created by computers. The Virtual Reality (VR) system helps users to communicate in a simulated world with different objects (Mann *et al,* 2018). Various scholars typically give different meanings of Virtual Reality. Burdea and Coiffet (2003), described VR as an interactive, real-time simulation used to construct a realistic environment using functional computer graphics. VR is characterised as an environment created by technological developments in order to find more efficient methods for realistic applications and communication (Craig *et al,* 2009). Castronovo *et al,* (2013), defined VR as a computer-generated environment that allows its users to immerse themselves in an artificial world created by computers. Shen *et al,* (2010), found that virtual simulation produces substantial benefits from VR technology, including cost savings, time savings, and improvements in training performance and safety in fields such as healthcare, construction, and manufacturing. Sherman and Craig (2018), described VR technology as a medium composed of computer simulations that senses the behaviour and positions of the user and changes or increases the feedback to the senses of the user, creating the feeling of being present in the simulation that is mentally immersed in it.

Recent studies show possible applications to indicate the drivers of VR in the AEC industry. Sacks *et al,* (2015), for example showed that VR systems are highly helpful for designers to understand the effects of projects on the safety system. Behzadi (2016), stated that with the use of virtual technology, various styles of training will illustrate improved decision taking that leads to healthier and safer decisions. Strohanova (2019), indicated virtual reality offers a specific spatial experience which leads to better decision making and better quality. Gandhi *et al,* (2016), identified providing workers with digital resources is the main factor in improving productivity. Fade (2018), stressed VR's capacity to increase efficiency in the construction sector. Miller (2020), suggested VR offers an opportunity to cut costs by taking decisions earlier in the life of the project. Also, Haggard (2017) stated that the existence of a virtual model would eliminate the need for a separate rendered model. Evading expensive renders saves money because the software provides both function and aesthetic quality. There are also clear indications from examples in other industries, such as the automotive and aerospace industries Gandhi *et al,* (2016), that research and development (R&D) investment in the AEC sectors would accelerate the adoption of digital technologies like VR.

There have been numerous research conducted to discover the drivers of VR in construction from improved information sharing and design improvements to improve communication, improved quality control and improved productivity efficiency. Findings from researches conducted have informed on its drivers for construction. Table 1 shows works by authors that covered different virtual reality drivers relevant to varying scopes of VR in construction research.

Table I. Drivers of Adopting Virtual Reality

S/No	Drivers	Authors
1.	Improved safety	Sacks *et al,* (2015); Behzadi, (2016); Hegeman (2018)
2.	Improved quality	Strohanova (2019)
3.	Improved productivity	Gandhi *et al,* (2016); Fade (2018)
4.	Cost reduction	Miller (2020); Haggard (2017)
5.	Boost research and development	Gandhi *et al,* (2016)

While VR appears to be a valuable tool in the construction industry, numerous problems exist. Table 2 summarises some of the works that have been studying VR barriers in construction. Jones (2018), reported that special training is needed to use the equipment before it can be used to extract important data. Also, Haggard (2017) suggested that the mindset of the older workers is reflected in the industry, many would prefer to maintain the methods they have used in the past as they do not want to depreciate the skill set they have gained over the years. Garrison (2019), indicated that the technology itself is costly to build, and in-house experience is not available to companies and organisations. Gebbie (2019), suggested that most of the VR systems were built for the entertainment sector; hence, their lack of engineering and construction capabilities. Furthermore, Haggard (2017) suggested that the lack of standardised applications is one of the biggest problems this technology faces.

Table II. Barriers of Adopting Virtual Reality

S/No	Barriers	Authors
1.	Lack of skills/expertise	Jones (2018)
2.	Cultural change	MacDonald (2004); Haggard (2017)
3.	Cost	Woksepp (2007); Garrison (2019)
4.	Technological immaturity	Gebbie (2019)
5.	Complexity in development of application	Haggard (2017)

The AEC industry has many possible applications for using VR technology such as supporting design reviews, supporting digital design and design, promoting the development of more effective simulations and testing of design solutions, improving education and training, improving health and safety, and improving interaction and communication among stakeholders. Whyte and Nikolić (2018), study VR's functional applications in planning, building, and controlling the constructed environment. The key cases of usage include: Product analysis support (Dunston *et al,* 2011; Aromaa and Väänänen, 2016; Berg and Vance, 2017). Boton (2018) proposed a method to help meetings of analyses of constructability using VR environments. The approach allows the export of BIM-based design models for immersive visualisation into a VR framework. Wolfartsberger (2019) presented a VR system for engineering design review, where design faults were easier to identify, and the review process was conducted faster than traditional review processes. Immersive design and drafting support (Whyte *et al,* 2000; Roach and Demirkiran, 2017); by improving communication between the design teams and health care stakeholders Lin *et al,* (2018) developed a VR approach to support the design of health care facilities.

Du *et al,* (2018) presented an approach that enables the BIM data to be synchronised with VR applications in real time. The solution enables automated and simultaneous updating of a BIM model based on changes made in the VR application, e.g. change of object dimensions, change of object positions and change of object types. Make it easier to construct more practical models and test design solutions. (Mujber *et al,* 2004; Rekapalli and Martinez, 2011). Motamedi *et al,* (2017) proposed an approach to evaluating the efficacy of subway station signage on VR environments in Japan. Most notably, Ergan *et al,* (2019) used a series of biometric sensors and physiological indicators such as skin behaviour, brain activity, and heart rate to provide an indicator of the levels of stress and anxiety felt by VR users. The authors say their methodology provides architectural design firms with a structured way to get accurate customer input before finalising the design. Enhance preparation and education (Boud *et al,* 1999; Zhao and Lucas, 2015); Fogarty *et al,* (2018) explored how VR can be used to enhance student's understanding of complex spaces. Health and safety improved; Albert *et al,* (2014), introduced a VR approach for the detection of hazards at construction sites. Lovreglio *et al,* (2018) developed a VR system for evaluating the level of preparedness during earthquake building evacuations. Shi *et al,* (2019) used VR to test distinct forms of enhanced methods of learning about the actions of construction workers associated with fall risks. Dris *et al,* (2019) suggested a VR approach which would help risk detection and enhance the sharing of data between BIM models and VR applications. Finally, improving interaction and collaboration among stakeholders (Annetta *et al,* 2009; Du *et al,* 2018; Hassan *et al,* 2018); Pratama and Dossick (2019) conducted a study with AEC companies and found that the majority of businesses are using VR to create immersive walkthroughs of buildings.

Many of the studies that discuss implementation weaknesses focus primarily on technological issues such as the work of Behzadan *et al,* (2015) and Palmarini *et al,* (2018); or particular use cases such as the work of Li *et al,* (2018) on construction safety.

2. Virtual Reality Application in Construction

In general, VR provides an immense potential in the construction industry with its numerous applications and because it is able to provide a realistic and stable first person interface (Hilfert and König, 2016). VR and virtual environment technology will influence the perception of the stakeholders in construction projects and their progress in completing their projects. Fade (2018), notes that VR technologies will help increase the quality and effectiveness of comprehensive project design, scheduling and planning, and completion of a project. Increasing awareness of the design purpose, decreasing delays and increasing the project's constructability can be accomplished by observing and rehearsing the construction of the facility in an immersive and interactive 3D environment prior to construction commencement. The following sub-sections explore VR application in construction.

2.1.1 VR in Construction Safety and Training

The issue of safety at construction sites cannot be overemphasised. Creation of a virtual reality simulator for heavy mobile crane operations that can be used for user training by conducting the lifting process in the virtual environment before the actual project (Kayhanivet *et al,* 2019); creation of a system for developing training simulators for heavy construction machinery to enhance efficiency, health and quality (Vahdatikhaki *et al,* 2019); the implementation of VR and mixed reality (MR) learning and education programmes to assess the ability of VR and MR to promote the acquisition of information (Wu *et al,* 2013); the implementation of a VR safety training programme related to electrical hazards in the united states (U.S.) construction environment (Zhao and Lucas, 2015); and the use of VR systems to experiment with user social actions in dangerous conditions (Shi *et al,* 2019).

2.1.2 VR in the Construction of Houses

Virtual reality technology and applications if introduced as early as the conceptual design stage of construction projects may be useful in housing development. Creating a virtual reality system that enables architects to immerse themselves in a virtual urban design and development world (Nguyen *et al,* 2016), exploring the usage of VR technology for simulating on-site activities in architectural practises (Zaker and Coloma, 2018), and using VR for pre-sale housing to minimise project costs, quality risks, and delivery times. This system helps the user to experience un-built house design (Juan *et al,* 2018).

2.1.3 VR for Site Layout Planning

Ning *et al,* (2011), reported that construction site layout planning was viewed by experts and scientists as a crucial phase in construction planning and is regarded to be a decision-making process that involves identifying problems and opportunities, designing alternatives, and selecting and updating the best alternative. An efficient and structured approach to designing an integrated site development plan makes optimal use of the available workspace, resulting in cost and time savings during construction, fostering a safe working atmosphere and ensuring non-destructive access to and from the site (Hammad *et al,* 2017; RazaviAlavi and AbouRizk, 2017). Use of a VR technology on the construction site for site layout preparation, construction site logistics planning assessment and collision detection (Muhammad *et al,* 2019), and using VR and augmented reality (AR) as a development method for site design, construction layout support, and logistics rationalisation to improve efficiency and reduce operating costs (Ciuffini *et al,* 2016).

2.2 Types of VR Technology

Virtual reality technology can be classified into two major categories: (1) non-immersive VR and (2) Immersive VR. The best technology to adopt is Desktop-based VR due to the low cost and training associated with VR. That argument is based on the fact that this VR category only requires a gaming laptop / PC and runs with a mouse and a keyboard on a desktop computer. The system uses a basic computer monitor as the interface to handle virtual activities (Chen *et al,* 2007). Desktop-based VR displays a virtual 3D environment on a desktop screen without any accompanying tracking equipment. It relies on the spatial and perceptive abilities of the users to experience what is happening around them. Using the mouse and keyboards can do some of the functions. Since the technology relies mainly on the use of monitors, keyboards, and mouse, compared to other technologies, it is considered to be relatively cheap (Wang *et al,* 2018).

The immersive VR system on the contrary requires the use of an HMD or goggles or mobile devices such as tactile glove controls so the user sees only details in the virtual world to ensure maximum immersion. The user's image is projected on a TV or monitor to engage in the virtual walk-through process via a laptop / personal computer (PC) and a projector for the entire construction team (Ozcan-Deniz, 2019). Inside a spatially immersive display (SID), the user stands as a secondary form of immersive VR. Although there are various degrees of immersion, the aim is to create a spatial immersion with graphics that allows the user to experience the virtual world as real (Thabet *et al,* 2002). A common example of SID is the CAVE Automatic Virtual Environment (CAVE), which generates an immersive virtual environment around the user to incorporate capability in real time (Waly & Thabet, 2003). Cruz-Neira *et al,* (1993) emphasises the CAVE's user interface, which uses 4-6 wide, cube-shaped projection screens to be fully interactive. That is because the user enters the CAVE (virtual world) and through a projection device, stereo images are projected onto the cube walls so that the user is fully absorbed and restricted to seeing the displayed images in the virtual environment only.

3. Methodology

The research methodology involves the technique used to attain the research aim and objectives. The research reviews current VR technology literature, its concept, barriers and drivers, as well as the UK AEC sector. The review guides the development of the adopted research instrument. Several studies have explored issues influencing the adoption of VR such as Fernandes *et al,* (2006), Laurell *et al,* (2019), Paulo *et al,* (2018), and also tom *et al,* (2017). A quantitative research method was employed for data collection and analysis through a structured questionnaire. The questions includes a 5-point response scale of the Likert type with ratings as follows: 1 = not at all, 2 = occasionally, 3 = neutral, 4 = frequent and 5 = very frequent. A response scale of the 5-point Likert type is recommended for use (Saunders *et al,* 2015).

The non-probability sampling technique was adopted in this study, which was used to select respondents. The use of non-probability sampling is opined by (Cohen *et al,*2013) that it is used when selecting a sample for a particular purpose or need. The research used a technique of convenience sampling to collect data from construction workers. Convenience sampling is a technique of non-probability sampling that facilitates the selection of construction professionals with close proximity to the researcher (Kumar, 2019). Due to its ability to collect data within a limited time frame, convenience sampling was adopted. The research also makes use of convenience sampling due to its ability to pick respondents who meet relevant requirements (Etikan *et al,* 2016).

The criteria in this study are respondents that are actively involved with construction project (project managers, architects, engineers, quantity surveyors, and building surveyors) that also have an understanding about the virtual reality. A total of fifty (50) construction professionals were selected using online survey Bristol Online Survey (BOS), to obtain expert opinions based on their level of accessibility to the researcher. However, as shown in Table 3 out of the selected professionals only twenty-four (24) were properly completed and returned representing 48 per cent which is higher than the normal 30 per cent of questionnaire survey for construction research as stipulated by (Akintoye, 2000).

Table III. Analysis of questionnaires distribution

Respondents	Questionnaire
Number distributed	50
Number properly completed	24
Percentage response	48%

Using IBM SPSS Statistics 23 to calculate the frequencies, data was analysed both descriptively and inferentially. Additionally, the Mean Score was calculated using MS Excel. This metric was used in research on construction management, in which Bishop and Herron, (2015) articulated it as:

$$\overline{X} = \frac{\sum X_i}{n}$$

Whereby: X denotes the Mean Score

$\sum X_i$ is the sum of the number of responses and score awarded a variable (V_i; for $5 \geq V_i \geq 1$); and

n denotes the total number of responses

The obtained Mean Score was used as a basis for evaluating where each factor analyzed falls towards the 5-point scale used (Holt, 2014). In addition, MS Excel was used to measure the Relative Significance Index (RSI), which will serve as a basis for the rating of VR drivers and barriers in the UK construction industry. The suitability of using RI on frequency is obtained from the works of (Holt, 2014) and (Joshi *et al,* 2015) in which they express RI as follows:

$$RI = \frac{1n_1 + 2n_2 + ... An_A}{AN} \quad (0 \leq RSI \leq 1)$$

Where:

$n_1, n_2, ... , n_A$ = number of respondents scoring response stem integers 1 to Amax (5), respectively.

A = largest integer on the response item (5 for this research)
N= total number of respondents

In addition, the proportion of respondents rating above or below the mean value is determined. Such an approach helps to draw inferences from scoring profiles for each factor studied (Holt, 2014; Joshi *et al*, 2015; Bishop and Herron, 2015; and Harpe, 2015).

4. Discussion of Results

The demographics of the respondents are depicted in Table 4, which includes professional backgrounds, years of experience, and area of specialization. Although 50 questionnaires were administered online, only **24** questionnaires were retrieved which corresponds to 48 percent. All 24 questionnaires retrieved had complete data suitable for analysis. The results of the retrieved questionnaires are subsequently presented.

Table IV. Respondents Demographics

Category	Classification	Frequency	Percentage
Professional backgrounds	Project managers	7	29.2%
	Architects	6	25%
	Engineers	2	8.3%
	Quantity surveyors	6	25%
	Building surveyors	3	12.5%
Total		**24**	**100%**
Firm years of experience	0-5 years	1	4.2%
	6-10 years	4	16.7%
	11-20 years	4	16.7%
	21-50 years	7	29.2%
	50 years and above	8	33.2%
Total		**24**	**100%**
Area of specialization	Infrastructure projects	3	12.5%
	Education	3	12.5%
	Residential	4	16.7%
	Commercial	4	16.7%
	Public sectors	3	12.5%
	All types of projects	7	29.2%
Total		**24**	**100%**

The results of the respondents professional backgrounds reveals that 29.2% were project managers, 25% architects, 8.3% engineers, 25% quantity surveyors, and building surveyors and 12.5% participated respectively. The results reveals the years of experience of the respondent's firms as follows; 4.2% had experience between 0-5 years, 16.7% had experience between 6-10 years, 16.7% had experience between 11-20 years, 29.2% had experience between 21-50 years, and 33.3% had over 50 years' experience. This indicates that most of the respondents' organizations have more than 50 years of working experience. The result reveals that 12.5% of the respondents specialized in infrastructure, education and public sectors projects, whilst 16.7% each were within residential and commercial projects, and 29.2% covered all types. However, this shows that the majority of respondents specialized in all types of projects.

4.1 Level of VR Awareness

Results show that while 25 percent of respondents claim to possess 'high level' of VR awareness, 50 percent of respondents claim to possess 'average' level of VR awareness. Also, 25 percent of respondents claim to possess 'low' level of VR awareness. Therefore, it can be inferred from the study that professionals within the UK AEC have some level of VR awareness.

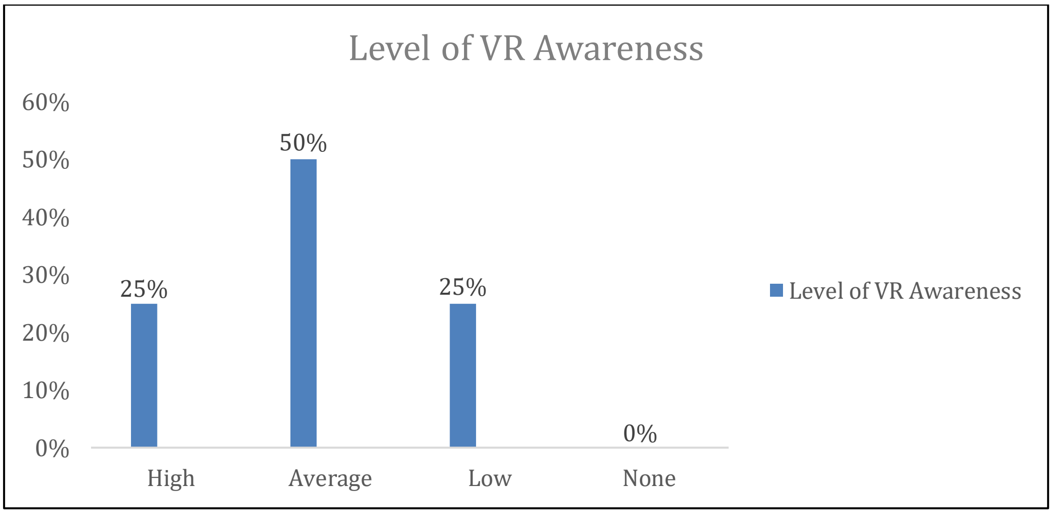

Figure 1. Level of VR Awareness

4.2 Understanding the Concept of Virtual Reality (VR)

Figure 2 shows a general understanding of the concept of VR, with 62.5% of respondents suggesting an understanding of virtual reality as a 3D CAD visualization, 29.2% indicating an understanding of the concept of VR as a simulation, and 8.3% stating an understanding of the concept as the combination of technology and individuals. Furthermore, based on these results, it can be deduced that professionals within the UK AEC understand VR to be more of 3D CAD simulation within UK construction firms as against any other application of VR.

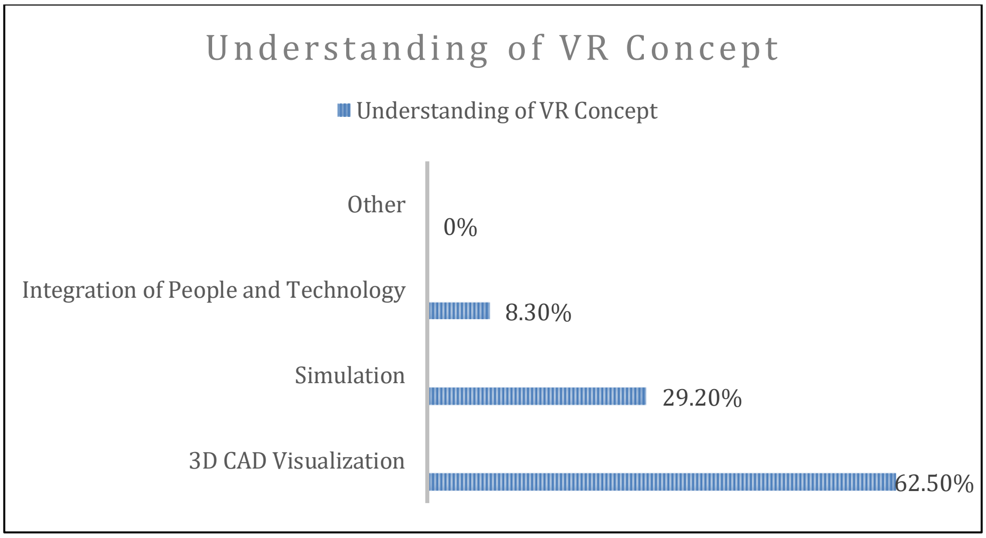

Figure 2. Understanding of VR Concept

4.3 Number of Years to Exploit VR Fully

Figure 3 shows that 75% of respondents reported that they are under 5 years, 20.8% between 5 and 10 years, 5% between 11 and 21 years, and 4.2% over 20 years. Hence it can be inferred that VR is fully exploited by the majority of respondents within less than 5 years.

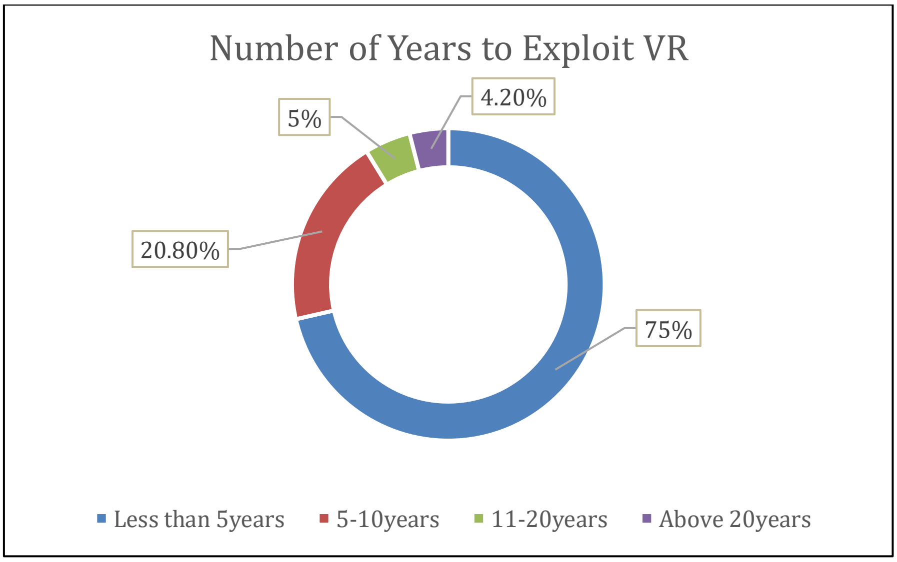

Figure 3. Number of Years to Exploit VR

4.4 Drivers to VR Adoption

Table 5 depicts the results of the benefits of VR adoption. While 'improved safety' ranked 1st (with a Mean Value of 4.88; RI of 0.98), 'improved quality' ranked 2nd (with a Mean Value of 4.29; RI of 0.86). Also, while 'improved productivity' ranked 3rd (with a Mean Value of 4.04; RI of 0.81), 'cost reduction' ranked 4th (with a Mean Value of

3.75; RI of 0.75). 'boost research and development' ranked 5th (with a Mean Value of 3.63; RI of 0.73).

Table V. Drivers to VR Adoption

Drivers to VR adoption	**Frequency of responses**					**Total**	**Scores below median**	**Scores above median**	**Mean Score**	**RI**	**Rank**
	5 SA	**4 A**	**3 N**	**2 D**	**1 SD**						
Improved safety	21	3	0	0	0	24	0	24	4.88	0.98	1st
Improved quality	11	5	7	0	1	24	1	16	4.29	0.86	2nd
Improved productivity	11	9	4	0	0	24	0	20	4.04	0.81	3rd
Cost reduction	6	9	6	3	0	24	3	15	3.75	0.75	4th
Boost research and development	5	8	9	1	1	24	2	13	3.63	0.73	5th

Legend: 5- Strongly Agree, 4- Agree, 3- Neutral (Neither Agree or Disagree), 2- Disagree, 1- Strongly Disagree

Results of scores above the median also show that the opinion of all the respondents are on the agreement level that improved safety is a driver of VR adoption. Similarly, results also show that over half of the respondents are on the agreement level that all other factors are benefits of VR adoption.

Additionally, results of the Mean Score show that on the average, the opinion of the respondents on improved safety being a driver of VR adoption tends towards 'strongly agree'. Also, results show that on the average, the opinion of the respondents on following factors to being benefits to VR adoption tends towards 'agree': improved quality; improved productivity; cost reduction; boost research and development.

4.5 Barriers to VR Adoption

Table 6 depicts the results of the barriers of VR adoption. 'lack of skills/expertise' and also 'cultural change' both ranked 1st (with each having a Mean Value of 4.54; RI of 0.91). Also while 'cost' ranked 2nd (with a Mean Value of 4.04; RI of 0.81) 'technological immaturity' ranked 3rd (with a Mean Value of 3.71; RI of 0.74). 'complexity in development of application' ranked 4th (with a Mean Value of 3.58; RI of 0.72).

***Table* VI.** Barriers to VR Adoption

Barriers to VR Adoption	Frequency of responses					Total	Scores below median	Scores above median	Mean Score	RI	Rank
	5 SA	4 A	3 N	2 D	1 SD						
Lack of skills/expertise	14	9	1	0	0	24	0	23	4.54	0.91	1st
Cultural change	14	9	1	0	0	24	0	23	4.54	0.91	1st
Cost	9	9	5	0	1	24	1	18	4.04	0.81	3rd
Technological immaturity	6	6	11	1	0	24	1	12	3.71	0.74	4th
Complexity in development of application	5	7	9	3	0	24	3	12	3.58	0.72	5th

Results of scores above the median also show that the opinion of over 95 percent of the respondents are on the agreement level that 'lack of skills/expertise' and also 'cultural change' are barriers of VR adoption. Also, while 75 percent of the respondents are on the agreement level that cost is a barrier of VR adoption, 50 percent of the respondents are on the agreement level that both technological immaturity as well as complexity in development of application are barriers of VR adoption.

Additionally, results of the Mean Score show that on the average, the opinion of the respondents on lack of skills/expertise being a barrier of VR adoption tends towards 'strongly agree'. Also, results show that on the average, the opinion of the respondents on all other factors studied being barriers of VR adoption tends towards 'agree'.

5. Findings

Overall, there is some degree of VR awareness among professionals within the UK AEC. This finding contradicts that stated by Kovach (2018) VR is greatly hampered by lack of knowledge, as many see the primary application for VR technology as gaming and entertainment rather than in a professional setting. The virtual reality concept is generally understood within UK construction firms as 3D CAD simulation. This is similar to that stated by Hilfert and König (2016), describing VR as a functional immersive real-time simulation used to build a realistic computer graphics world, and Fade (2018) emphasized VR's potential to improve efficiency in the construction industry. The majority of professionals in the UK construction industry will be making maximum use of VR within less than 5 years. This supports the findings of Fade (2018), VR is likely to soon become the standard by which all construction projects are built, so the adoption of the technology is needed to overcome some obstacles and become common practice in construction, as it is still in its early stages and is only set to improve.

In addition, UK construction industry professionals strongly agree that improved safety is a driver of VR adoption. This supports the findings Sacks *et al,* (2015) that VR technologies are extremely advantageous to designers in appreciating the effects of projects on the safety programme. This also supports the findings of Behzadi (2016) that various forms of training will demonstrate improved decision-making through the use of virtual technology contributing to better and healthier choices.

Also, professionals within UK construction firms agree with lack of skill / expertise as a barrier to adoption of VR. This supports findings Jones (2018), that special training is required to use the device before it can be used to collect valuable data. Cultural change is a barrier to the adoption of VR, which is agreed by UK construction professionals. This supports Haggard (2017) findings that the mindset of the older workers is reflected in the industry, many would want to maintain the techniques they used in the past as they don't want to depreciate the skill set they gained over the years.

6. Conclusion and recommendations

This study has explored the barriers and drivers of VR in the UK construction industry. It revealed that 'lack of skills/expertise (mean score 4.54)', 'challenges in system integration (mean score 4.54)', were the most significant barriers to VR in construction. The barriers were categorized into five, namely: lack of skills/expertise, cultural change, cost, technological immaturity and complexity in development of application. Of these categories, lack of skills/expertise and complexity in development of application are the most and least barriers to VR in construction respectively. On the other side, 'improved safety (mean score 4.88)', 'improved quality (mean score 4.29)', and 'improved productivity (mean score 4.04)' were found to be the main drivers of VR in UK construction industry. The study also assessed the level of VR awareness among UK AEC professionals. The findings revealed an average level of VR awareness (50%) and that majority of those that are aware of VR possess little understanding of its techniques. The results discussed in this study may not be generalizable to the UK construction industry because the sample was not critical.

However, the study is significant as it draws attention to the level of VR awareness, understanding concept of VR technology, barriers and drivers of VR in the UK construction industry. Since there is average level of VR awareness, the study suggests consistent increased awareness among UK AEC professionals and clients through diverse form. Government and professional institutes should embark on robust campaigns, awareness raising programmes and training of AEC professionals and clients on the VR's benefit to the construction industry, clients and the country. Further research on VR adoption is recommended. More so, simplified VR training techniques and adoption framework are other areas for future research work.

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