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IDENTIFYING THE BENEFITS AND BARRIERS OF IMPLEMENTING AR AND VR IN THE CONSTRUCTION INDUSTRY OF SINDH, PAKISTAN.

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Abstract: This research paper focuses on exploring barriers of implementing Augmented Reality and Virtual Reality (AR/VR) technologies in the construction industry, using the construction industry of Sindh, Pakistan as an example. While AR/VR technologies have the potential to provide benefits, the construction industry has been slow to adopt them. It has been found there are certain barriers that affect the implementation process of AR and VR technologies in the construction sector. To better understand this phenomenon unstructured interviews with field experts and a questionnaire survey to collect data on the potential barriers of AR/VR technologies in construction has been conducted. The results show there are also several barriers to adoption, including a lack of awareness, lack of expertise, and high implementation costs. The paper concludes that this research contributes to the growing body of knowledge on AR/VR technologies in engineering, and provides practical insights that can be used by engineering practitioners and policymakers to overcome the barriers to adoption and maximize the benefits of AR/VR technologies in construction.

Keywords: Augmented Reality (AR), Virtual Reality (VR), Barriers, construction technology.

1. Introduction

Augmented Reality (AR) and Virtual Reality (VR) are two rapidly evolving technologies that are changing the face of the construction industry. Both technologies have the potential to improve the visualization, productivity, and safety of construction projects, from design to completion. Although the concept of augmented reality (AR) as a digitally interactive experience is not new, it can be traced back to as early as 1901, when American author Frank Baum wrote about an electronic spectacle called the "character marker" that allowed for the overlap of data and reality. However, it wasn't until the 1950s and 1960s that the idea of AR was first realized through inventions such as "Sensorama" and "head-mounted display" by scientists from different fields. Today, when people discuss AR, they are typically referring to AR systems, which are made possible by the rapid development of technology. To be considered a typical AR system, it must possess three main features, as outlined by Azuma [1]. Acknowledging the rising diversity of AR applications in construction, it is noticeable that some AR applications are becoming more mature for actual projects. [2]

implemented AR for monitoring the construction progress of the Shanghai Center. [3] used AR to support quality management in a metro construction project in China. Nevertheless, most of the AR applications in the operation stage are still under lab experiments. In addition, applications such as personnel management and cost control wait for further exploration.

The use of VR in construction dates back to the 1990s when VR was primarily used for entertainment and gaming. However, it wasn't until the early 2000s that VR began to be used in the construction industry. One of the early adopters of VR in construction was the architecture firm [4], who used VR to visualize building designs and detect potential issues before construction began [5]. In 2006, Autodesk, a software company that specializes in design and engineering, developed a product called Navisworks, which allowed construction professionals to visualize building designs in VR and navigate around them in real-time. The use of AR and VR technology in construction has become more widespread in recent years, with many companies exploring the possibilities that it offers. For example, construction companies such as Mortenson have used VR technology to visualize building designs and identify potential issues before construction begins. This has helped to save time and money by reducing the need for costly rework during construction. Similarly, companies like BAM Construct UK have used AR technology to provide workers with real-time information on construction sites, such as the location of utility lines and building plan. This has helped to improve worker safety and reduce errors on construction sites. These include the ability to facilitate interactions between physical and virtual content, the capability to overlay virtual content onto the real world in real-time, and the need to be registered in three dimensions. Achieving these features requires various techniques, such as tracking, display, and interaction techniques. The utilization of such technologies enables AR to improve people's interpretation of the real world [6]. The

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COVID-19 pandemic has also accelerated the adoption of AR and VR technology in the construction industry. With many construction projects being put on hold or delayed due to social distancing requirements and other safety measures, companies have turned to AR and VR technology to continue the planning and design process remotely [7]. We still don't fully understand the factors that influence how these technologies are adopted. The basic aim is to identify the benefits and barriers of AR and VR implementation. The study play's a huge role in identifying potential factors related to AR and VR benefits and barriers in the construction industry of Pakistan.

2. Literature Review

In recent years, the usage of AR and VR technology in the construction sector has accelerated. The use of technology could completely alter how construction projects are planned, created, built, and maintained. To visualize, simulate, and analyses different aspects of a building project both before and after completion, the construction industry uses AR and VR technologies. Researchers and construction firms continued to investigate the use of AR and VR technology in construction in the years that followed. In order to aid construction workers in visualizing and simulating construction processes, researchers from the University of Texas at Austin created an augmented reality tool in 2012 [8]. The tool allowed employees to examine how construction components fit together and see possible faults by superimposing digital information onto the actual surroundings using a mobile device. Today, the construction sector makes substantial use of AR and VR technologies. For instance, to discover design flaws and replicate the construction process, construction companies employ VR technology to produce virtual tours of their projects [9]. A recent study conducted shows the number of reviewed papers on AR and VR in construction industry around the globe. The graph shows significant gain in the studies conducted on AR and VR in construction industry around the world. It can be analyzed that AR and VR has great contributions to change the culture of construction industry and automated sector in the years to come. [10]

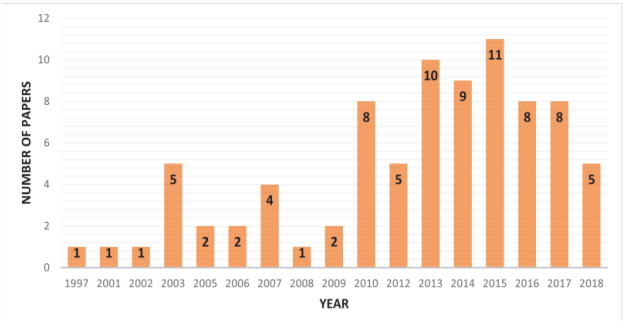

Figure 1: Number of publications in recent years

[11] identified AR and VR technology provides a three-dimensional (3D) visualization of construction projects and allow stakeholders to walk through the building before it is built. This helps identify potential design issues and reduce rework, saving time and money [11]. AR and VR provides a safe environment for workers to practice hazardous tasks without the risk of injury. This technology can simulate various construction hazards such as falls, electrocution, and heavy equipment accidents, improving workers' safety and reducing the rate of accidents on construction site [12]. AR and VR technology can be used to analyze construction sites and assess the feasibility of a project. This technology can be used to simulate the environment of the construction site, including weather conditions and terrain, and can help identify potential challenges before construction begins [13]. However, it has been found that AR/VR implementation can be quite challenging, [14] examined the factors influencing the adoption of VR in the public sector of top UK construction firms. To identify these factors, they conducted research and organized them into different categories. The authors then distributed questionnaires to 33 leading UK construction companies to collect data. The findings reveal that senior management support, technology advocates within the company, degree of business competition, internal requirements, user involvement, and organizational resources are the most significant factors that affect the adoption of VR in the UK construction industry. [4], [15] and [16] identified the AR/VR effects on healthcare, tourism and parks. The respondents of their study were only field experts as identified by [17]. By extensive literature review, it was found that from 2012 to 2018, a wide number of publications outline the tools used for AR and VR. In 2018, 14 publications were submitted that discussed the use of unity 3D a game engine used as an AR and VR tool. Similarly, other publications also discussed various tools used for AR and VR.

Software	Year Range	# (%) of Publications
Unity 3D (Game Engine)	2012–2018	14 (30.4%)
Autodesk 3ds Max	2009–2017	8 (17.4%)
Autodesk Revit	2011–2017	7 (15.2%)
Torque 3D (Game Engine)	2009–2016	4 (8.7%)
Autodesk MAYA (Game Engine)	2011–2015	4 (8.7%)
Trimble Sketchup and 3D Warehouse	2013–2017	3 (6.5%)
Microsoft XNA Game Studio (Game Engine)	2011–2013	3 (6.5%)
3DVIA Virtools (Game Engine)	2012	2 (4.3%)
Not listed	-	10 (21.7%)

Table 1: Software that are used in AR and VR that are discussed in publications till 2018

Therefore, this study aims to identify the benefits and barriers in implementing AR and VR in construction industry particularly in Pakistan by taking in field experts as well as the general public with relevant experience.

3. Methodology

To identify the factors that benefits and limits AR and VR implementation in construction industry of Pakistan, a formulated methodology was incorporated, figure 2 illustrates the methodology followed in this research paper.

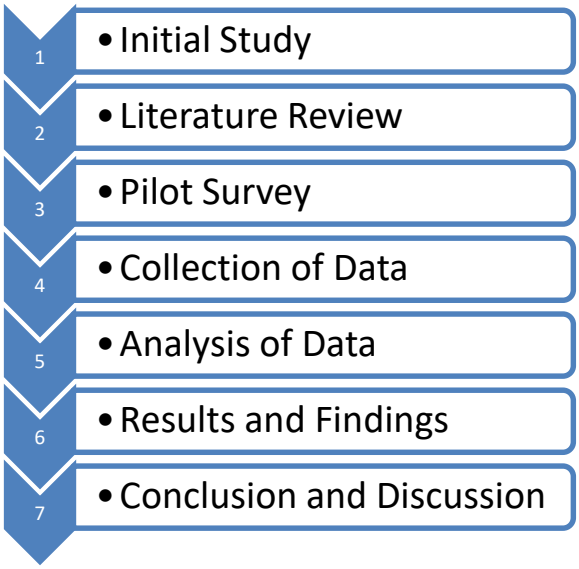

Figure 2: Research Methodology

In the initial stages of this research different conference proceedings, books, articles and scientific databases were reviewed. This information was carefully reviewed to find the influential factors of AR and VR benefits and barriers. After mapping these factors, unstructured interviews were conducted with experts from the construction sector to verify the reviewed the information. More than 40 papers were reviewed to find the most influential factors.

Following this, a questionnaire consisting AR and VR barriers in the construction industry of Pakistan was formulated. The questionnaire was used to gather the perspectives of practitioners in the construction industry. They were asked to rate the factors on a five-point Likert scale, which ranged from strongly disagree to strongly agree. SPSS version 24 was used for data analysis to identify the most significant factors. A total of 120 questionnaires were distributed, out of which 110 were considered valid for analysis. Respondents used, X_1 = Strongly Disagree; X_2 = Disagree; X_3 = Neutral; X_4 = Agree; X_4 = Strongly Agree scale to provide feedback for each listed reason in the questionnaire. The significance level was evaluated using the Average Index (AI) method, which was calculated based on the frequency calculated using the statistical software SPSS. The AI value was calculated using the following formula, as adopted from:

$$AI = \frac{\sum 1(X_1+2X_2+3X_3+4X_4+5X_5)}{\sum(X_1+X_2+X_3+X_4+X_5)} \quad \text{(eq. 1)}$$

4. Results and Discussion

The study conducted a thorough literature review to identify factors that benefits and limits AR and VR implementation in the construction industry of Pakistan. Following this, unstructured and semi-structured interviews were conducted with construction industry experts who had work experience of more than 5 years. These factors were identified and narrowed down to factors that are most influential in the construction sector. The following tables show the responses.

S.NO	AR and VR benefits	YES	NO
1	Enhanced Design Process	11	02
2	Increased Safety	13	00
3	Improved Training	12	01
4	Improved Communication	10	03
5	Customer Satisfaction	08	05
6	Enhanced Project Management	07	06
7	Improved Collaboration	10	03
8	Improved Quality Control	10	03
9	Increased Efficiency	09	04
10	Enhanced Design Process	07	06

Table:2 Response of unstructured interviews for AR and VR Benefits

S.No.	**AR and VR barriers**	YES	NO
1	Lack of Awareness	11	02
2	Technical Expertise	09	04
3	Increased Cost	09	04
4	Availability of Hardware and Software	08	05
5	Limited Adoption	10	03
6	Limited Compatibility	08	05
7	Resistance To Change	08	05
8	Data Security	05	08
9	Lack of Standards and Guidelines	02	11
10	Errors and inaccuracies	07	06

Table 3: Result of unstructured interviews for AR and VR barriers

A questionnaire was developed consisting of three parts. The first part gathered information about the respondents, while the second part consisted of the factors that were found to be the benefits and barriers of AR and VR implementation in the construction industry of Pakistan. Ranked on a Likert's scale from 1-5, where 1 indicated "Strongly Disagree" and 5 indicated "Strongly Agree. A total of 120 questionnaires were distributed to industry experts, of which 110 were considered valid for analysis. The responses were analyzed using SPSS. The obtained results show ranking of AR and VR implementation benefits and barriers.

Factors	Mean	S.D	Rank
Enhanced Visualization	2.22	.923	**1st**
Enhanced Design Process	2.10	.875	**2nd**
Increased Safety	2.08	.859	**3rd**
Increased Training	1.92	.918	**4th**
Improved Communication	1.76	.910	**5th**
Enhanced Project Management	1.75	1.024	**6th**
Improved Quality Control	1.69	1.035	**7th**
Improved Collaboration	1.65	1.066	**8th**

Table 4: Ranking of AR and VR benefits.

The results for the benefits of AR and VR implementation in the construction sector of Pakistan show that the top most benefit of AR and VR implementation is "Enhanced visualization", the second most influential benefit was found to be "Enhanced design process". similarly other benefits that were found were also ranked according to their mean values as analyzed through SPSS.

The results for the barriers of AR and VR implementation in the construction sector of Pakistan show that the top most barriers of AR and VR implementation is "lack of awareness", the second most influential barrier was found to be "lack of technical expertise. similarly other barriers that were found were also ranked according to their mean values as analyzed through SPSS.

Factors	Mean	S.D	Rank
Lack of Awareness	2.32	1.165	**1st**
Technical Expertise	2.23	1.152	**2nd**
Resistance to Change	2.18	1.125	**3rd**
Increased Cost	2.15	1.213	**4th**
Limited Adoption	2.12	1.147	**5th**
Availability of Hardware & Software	2.05	1.258	**6th**
Limited Compatibility	2.0	1.224	**7th**

Table 4: Ranking of AR and VR barriers.

Furthermore, the study has revealed several benefits associated with the implementation of AR and VR technologies in the construction industry. Enhanced visualization emerged as a significant advantage, enabling stakeholders to gain a three-dimensional perspective of construction projects. This aligns with the findings of [11] who emphasized the role of AR and VR in providing 3D visualization for project assessment and error detection.

Another benefit, enhanced design process, is in line with the work of [3] who showcased the use of AR to support quality management in construction projects. The increased safety resulting from simulation-based training resonates with the insights of [11]. further underscoring the potential of AR and VR to mitigate risks on construction sites.

The findings on collaboration and training resonate with [11] and [18] who highlighted the potential of AR and VR to foster collaborative communication among stakeholders and provide efficient training for construction professionals.

Similarly, the barriers identified, such as lack of awareness, lack of expertise, and high implementation costs, echo the concerns highlighted in previous research by [19]. These studies have stressed the importance of addressing these challenges to facilitate the wider adoption of AR and VR technologies in the construction industry.

5. Conclusion

Based on the literature review, unstructured interviews, and questionnaire survey conducted in this study, it can be concluded that augmented reality and virtual reality technologies offer several potential benefits to the construction industry in Pakistan. However, there are several barriers to the adoption of these technologies, such as lack of awareness, lack of technical expertise, increased cost, limited adoption, limited compatibility, and resistance to change. Overall, the findings of this study suggest that successful adoption depends on addressing the identified barriers through a comprehensive and coordinated effort.

5. Future Recommendations

Although this study identified a number of benefits and barriers to the adoption of AR and VR in the Pakistani construction sector, more research is still required in this area. Future research can, for instance, concentrate on examining the particular skills and abilities needed for engineers and construction workers to effectively embrace and use AR and VR technology. Investigating the possible effects of AR and VR technology on project schedules, finances, and overall project outcomes may also be helpful.

Conducting comparison studies between the application of AR and VR technology and conventional construction techniques in order to pinpoint the precise benefits and limitations of each strategy could be another area of future research. This might provide us a more nuanced view of the advantages and disadvantages of using AR and VR in Pakistan's building sector.

The implementation of AR and VR technologies in Pakistan's construction sector has the potential to considerably improve project outcomes and strengthen collaboration among project stakeholders, according to the study's overall conclusions. To fully realize this technology's promise and remove the current adoption hurdles, additional study is necessary.

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