**IDENTIFYING THE BENEFITS AND BARRIERS OF IMPLEMENTING AR AND VR IN THE CONSTRUCTION INDUSTRY OF PAKISTAN**

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**ABSTRACT**

This research paper focuses on exploring the benefits and barriers of implementing Augmented Reality and Virtual Reality (AR/VR) technologies within the construction sector, using the construction sector of Pakistan as an example. While AR/VR technologies have the potential to provide benefits such as enhanced visualization, improved design processes, increased safety, training and collaboration, the construction industry has been reluctant to adopt them. It has been found there are certain barriers that have an impact on AR and VR technologies implementation in the construction sector. To better understand this phenomenon unstructured interviews with field experts and a questionnaire survey to collect data on the potential advantages and barriers of these technologies has been conducted. The results show there are also several barriers to adoption, including lack of awareness, lack of technical expertise, and high implementation costs. The paper concludes that this study adds to the expanding information on engineering applications of AR/VR technologies, and provides practical insights that can be used by engineering practitioners and policymakers to overcome the barriers to adoption and maximize the benefits of these technologies in the AEC industry.

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

1. **INTRODUCTION**

AR and VR are two quickly developing technologies that are altering how the building sector operates. Both technologies have the potential to enhance construction projects' visualization, productivity, and safety from conception 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-1960s that the idea of AR was first realized through inventions such as "Sensorama" and "head-mounted display" by scientists and technology experts from various sectors. Currently, when people discuss AR/VR, they are typically referring to AR/VR technology systems, which are made possible by the rapid development of technology. A typical AR/VR system must possess three main features, as outlined by (1). 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 displayed in three dimensions. Achieving these features requires different methods and techniques, such as tracking, display, and interaction methods. The utilization of such technologies enables AR to improve people's interpretation of the reality (2). The COVID-19 pandemic has also accelerated the adoption of AR/VR in the AEC 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 (3). We still don't fully understand the factors that influence how these technologies are adopted. The basic aim is to find and analyze the growing benefits and barriers of AR and VR implementation. The study play's a huge role in identifying potential factors that affect the implementation of AR and VR in the AEC industry.

1. **Literature Review**

In recent years, the usage of these technologies in AEC industry has accelerated. The utilization 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/VR technologies. Researchers and construction firms continued to observe and analyze the use of these technologies in the AEC industry. 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 (4). 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 (5). 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 transform the culture of construction sector and technology sector in the years to come. (6)



**Figure 1: Number of publications in recent years**

Kulkarni et al 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 (7). 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 (8). 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 (9). However, it has been found that AR/VR implementation can be quite challenging, (10) examined the factors influencing the implementation 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, intensity of competition, internal requirements, user involvement, and organization’s own resources are the most significant factors that affect the implementation of VR in the UK construction industry. (11), (12) and (13) identified the AR/VR effects on healthcare, tourism and parks. The respondents of their study were only field experts as identified by (14). Therefore, this study aims to find the potential benefits and barriers in implementing AR/VR in construction industry, particularly in Pakistan, by taking in field experts as well as the general public with relevant experience.

1. **Research Methodology**

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

Following this, a questionnaire consisting AR and VR benefits and barriers in the construction industry of Pakistan was formulated. The questionnaire was used to gather the viewpoints of professionals working in the construction sector. The survey employed a five-point Likert scale for participants to rate the given factors, ranging 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, X1 = Strongly Disagree; X2 = Disagree; X3 = Neutral; X4 = Agree; X4 = 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 = $\frac{∑1(X\_{1}+2X\_{2}+3X\_{3}+4X\_{4}+5X\_{5})}{∑\left(X\_{1}+X\_{2}+X\_{3}+X\_{4}+X\_{5}\right)}$ (eq. 1)

**Figure 2:** Research Methodology

1. **RESULTS AND DISCUSSION**

The study conducted a thorough literature review to identify 10 potential factors that benefit AR and VR implementation, 10 factors that limit AR/VR implementation in the AEC industry. Following this, unstructured and semi-structured interviews with field experts were conducted who were having experience of more than 5 years in the AEC industry. 20 factors were identified and narrowed down to 15 factors. 8 factors were found significant while identifying the benefits and 7 factors were found significant while identifying the barriers. The following tables show the responses.

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

**Table 1:** Result of unstructured interviews for the benefits

|  |  |  |  |
| --- | --- | --- | --- |
| **S.No.**  | **AR and VR benefits** | 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 2:** Result of unstructured interviews for the barriers

A questionnaire was developed consisting of three parts. The first part gathered information about the respondents, while the second part consisted of the 10 factors that were found to be the benefits of AR/VR implementation in the construction sector of Pakistan. Third part consisted of 10 factors that were found to be the barriers of AR/VR implementation in the construction sector of Pakistan. Ranked on a Likert’s scale from 1-5 as described earlier. 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 are divided into two tables, table 3 shows ranking of AR and VR implementation benefits while table 4 shows ranking of the AR and VR implementation 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 3:** Ranking of AR and VR benefits.

The results show that the top most benefit of AR and VR implementation is "Enhanced visualization", "Enhanced Design process" and Increased safety and training. These factors were ranked according to their mean value. Similarly, when the barriers were analyzed, the top most factor was found to be "lack of awareness", the second most influential barrier was found to be "lack of technical expertise. similarly other barriers that were found were also 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.

**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. The benefits identified include enhanced visualization, enhanced design process, improved training, improved safety, improved communication, and enhanced collaboration. However, there are also 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 results suggest that while AR/VR technologies have great potential to benefit the construction industry in Pakistan, their successful adoption depends on addressing the identified barriers through a comprehensive and coordinated effort.

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