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Exploring Augmented Reality Applications in Malaysian Construction Industry

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ABSTRACT

Despite technological advancements like Virtual Reality (VR) and Augmented Reality (AR), the construction industry has yet to capitalise on these advantages fully. AR has the potential to address construction challenges like skill shortages and time overruns. However, the adoption rate and awareness level among the workers in this sector are still low. Therefore, there is a need to explore the opportunity of AR applications in this industry. Thus, this research aims to promote strategies to encourage AR application in the Malaysian construction sector. This research objectives are to investigate the implementation benefits that can promote AR usage and to investigate the challenges that hinder AR implementation. This research targets professionals with AR experience working in the construction industry. The qualitative data collection method was used for this research through semi-structured interviews with three respondents, focusing on their experiences with AR. Thematic analysis was used to analyse the data using Atlas.ti software. The findings reveal that AR streamlines processes, improve visualisation, and enhances communication. However, challenges include technical limitations, high costs, a lack of skilled personnel, and resistance to change. AR is recognised for its potential to transform the construction industry, but its adoption is hindered by several barriers that need to be addressed for wider implementation. Due to that, the study proposes strategies, such as enhancing technical infrastructure and comprehensive training programs.

Keywords: *augmented reality, virtual reality, Malaysian construction industry.*

INTRODUCTION

The Augmented Reality (AR) software that is already applied has undergone tremendous transformation especially in the construction industry in Malaysia and comes with encouraging capability in resolving some critical issues such as lack of skilled labour, delays, and substandard work (Ahmed, 2019). Moreover, in recent decades the construction industry has spent a lot of resources in the adaptation of technology, which has seen the incorporation of numerous innovative auxiliary tools, where AR and Virtual Reality (VR) technologies are major tracking technologies that have changed the interaction of visual information in all spheres (Davila Delgado et al., 2020; Ahmed, 2019).

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Being one of the sectors that support economic development, the construction industry has an essential role in Malaysia's development, including insufficient infrastructure: housing and transportation facilities, for example (Alaloul et al., 2021). Due to the considerable drawbacks of Building Information Modelling (BIM), including low visualisation and user experience in construction sites, the integration of AR technology in construction is crucial (Noghabaei et al., 2020). AR, in combination with VR, improves visualisation and provides complete immersion for the stakeholders to reveal the defects, risks, and accidents before their emergence (Ahmed, 2019). However, issues on the benefits and perception of AR integration in construction projects in Malaysia remain underexplored, resulting in a low implementation rate. This study seeks to address the knowledge gaps on why Malaysians are still hesitant to adopt AR technology in the construction industry. By offering insights into these theoretical barriers to AR adoption, the research suggests practical strategies to promote AR application in Malaysian construction industry, bridging both theoretical understanding and practical implementation.

Other than that, the research is focused on AR applications in the construction sector of Malaysia and may not generalise to other industries and the study is limited by the availability of professionals who are willing to participate in the interviews and the number of companies that can be included in the research.

LITERATURE REVIEW

Construction Industry in Malaysia

The construction industry in Malaysia plays a crucial role in the national economy, contributing approximately 3%–6% to the GDP annually (Yap et al., 2019). However, the industry faces significant challenges, including schedule delays due to design changes, payment delays, inadequate planning, and resource shortages, as identified in a systematic review by Zidane and Andersen (2018) and supported by Yap et al. (2019). As the industry embraces the fourth industrial revolution, technological advancements are transforming construction practices, making them more complex yet more efficient. The innovations of Industry 4.0 are crucial in driving growth and development across various sectors, including construction, which is a key contributor to Malaysia's GDP (Ibrahim et al., 2021; Maskuriy et al., 2019).

Augmented Reality

Augmented Reality (AR) is an interface between the real and digital world that allows positioning, orientation, and interaction to occur in real time. This technology places digital content and data, including images, videos, and 3D objects into the physical world, thus encompassing both virtual and real spaces (Xu & Zhang, 2022; Ahmed, 2019). AR is useful in construction projects in aspects of scheduling, monitoring of progress, training of workers, safety measures, and quality control (Salinas et al., 2022).

Benefits of Augmented Reality

Streamline Processes

Smart technology such as augmented reality makes construction activity easier since it allows access to important information and project models in real time. This makes it easier to make the right decision faster while solving problems related to design and space (Ratajczak et al., 2019). Since AR addresses and avoids foreseeable risks and hindrances, it contributes positively to minimising costly mistakes and time waste, thereby improving the efficient flow of project work (Nassereddine et al., 2022). Noghabaei et al. (2020) state that AR and VR should be utilised for time and cost reduction especially in large projects, due to their impact on planning and decision-making. Pan and Isnaeni

(2024) also extend the above finding by observing that with the integration of AR and BIM, the automation is enhanced in data management and in the way, they are inspected and monitored.

Enhanced Project Visualisation

AR enables different contractors, architects, and stakeholders to superimpose certain holographic images of buildings over real construction sites, hence providing a physical representation of a certain project within its physical environment. It points to possible design faults, space clashes, and flow issues, and so eliminates the prospect of expensive changes further along in the project's life cycle (Nassereddine et al., 2022). According to Noghabaei et al (2020), visualisation through AR enhances the representation of the construction of both residential and commercial construction development. Pan and Isnaeni (2024) also explain that AR-BIM integration enhances the area of visualisation since users can view models at construction sites and make better decisions in phases of construction.

Improved Communication and Teamwork

AR helps in effective communication between project teams and guarantees that all the teams are well coordinated. Dispersed employees with AR glasses have an opportunity to see plans and specifications of the building and detailed descriptions of work progress. This helps in harmonising all the stakeholders on the same level to sort out most of the complications likely to come up within the general working process of the executing project. The improvement of communication facilitated by AR reduces confusion and shortens the time to make the proper decision (Oke & Arowoiya, 2022; Nassereddine et al., 2022). As Noghabaei et al. (2020) also point out, AR and VR tools enhance communication through organisational and clear virtual contexts in shared reality.

Table 1: Previous Study of Benefits of Augmented Reality Application

Benefits	Ratajczak et al., 2019	Noghabaei et al., 2020	Oke & Arowoiya, 2022	Nassereddine et al., 2022	Pan & Isnaeni, 2024
Streamline Processes	✓	✓		✓	✓
Enhanced Project Visualisation		✓		✓	✓
Improved communication and Teamwork		✓	✓	✓	

Challenges of Augmented Reality

Technical Complexities or Limitations

Despite the above benefits of using AR technology in construction, its application in the field has significant technical challenges and limitations. One concern is that AR devices require powering; this frequently leads to their battery drain and hence, shut down in the middle of important working processes (Chalhoub & Ayer, 2019). AR headsets are power-hungry, and the batteries of portable devices deplete rapidly when used with them most office work is disrupted (Malta et al., 2023). Although it is portable and easy to carry around, uneven hand movement is expected from handheld devices (Malta et al., 2023). Furthermore, many devices are large and sometimes heavy and thus are not very efficient, their energy intensity must be brought down so these can become more useful (Arena et al., 2022).

Integration with Existing System

Numerous construction companies rely on established software systems for project management, design, and documentation purposes. Incorporating AR technology into these pre-existing systems might encounter compatibility challenges, particularly if the AR platform necessitates specific hardware or software dependencies that aren't compatible with the current infrastructure. As supported by Arena et al. (2022), in the realm of AR applications, one of the primary challenges at the software level arises from ensuring interoperability and compatibility across various hardware platforms with differing computational capabilities.

High Initial Investment Costs

The construction industry also faces a daunting challenge to the widespread adoption of augmented reality (AR) due to the implementation costs. This is because the level of the AR system and infrastructure requires high costs. For instance, devices such as HMDs or Smart Glasses. As Delgado et al. (2020) point out, the software user interface is quite complicated, thus requiring some stakeholders to be trained to operate the software effectively. This is yet another implementation cost that the employer must bear.

Lack of Skilled Personnel

Workers in the construction sector do not have the knowledge and skills necessary to operate and adapt AR technology (Hajirasouli et al., 2022). Consequently, there will also be a lack of people who can develop these technologies (Delgado et al., 2020). Furthermore, the duration that is involved in the installation process also stresses the adoption of augmented reality (AR) technology. These constraints relate to the time taken to set up and get an AR system ready for use for different purposes (El Kassis et al., 2023).

Resistance to Change from Employees

One of the challenges of new technology seeking acceptance into an old industry that already has its standard practice is that many people do not have a clear and thorough understanding of the purpose and significance of AR and other new technologies at different stages of the life cycle of construction projects (Hajirasouli et al., 2022). Smaller construction companies find it especially hard to adopt new and risky technologies which can be very expensive for them. According to Aggarwal and Singhal (2019), this is because society is traditional and sceptical towards accepting AR in their day-to-day routines.

Table 2: Previous Study of Challenges of Augmented Reality Application

Challenges	Aggarwal & Singhal, 2019	Chalhoub & Ayer, 2019	Delgado et al., 2020	Arena et al., 2022	Hajirasouli et al., 2022	Malta et al., 2023	El Kassis et al., 2023
Technical complexities or limitations		✓		✓		✓	
Integration with the existing system				✓			
High Initial Investment Costs			✓				
Lack of skilled personnel			✓		✓		✓
Resistance to change from employees	✓				✓		

Comparison Of AR Adoption in Other Country

As stated by Noghabaei et al., (2020), AR is currently widely used throughout the construction process in the United States. It is used for design visualization, project planning and on-site inspection. Similarly, the United Kingdom has a growing adoption of AR, driven by the BIM mandate that encourages the use of technology. In Japan, the focus on automation and smart technologies is to address labour shortages and improve project accuracy. The various characteristics in different countries are because of the advanced construction technology ecosystem and high investment in innovation in certain countries. Meanwhile, AR implementation in Malaysian construction industry is in its early stages. There is growing interest in using AR but limitations like lack of skilled workers, high implementation costs and resistance to change from employees have hindered the adoption.

Thus, based on previous studies, the researcher shows the benefits and challenges of AR adoption in other countries. While they might have explored AR, being in different regions can influence the results. It is why the study is a must in Malaysia where the understanding and acceptance of AR are still developing.

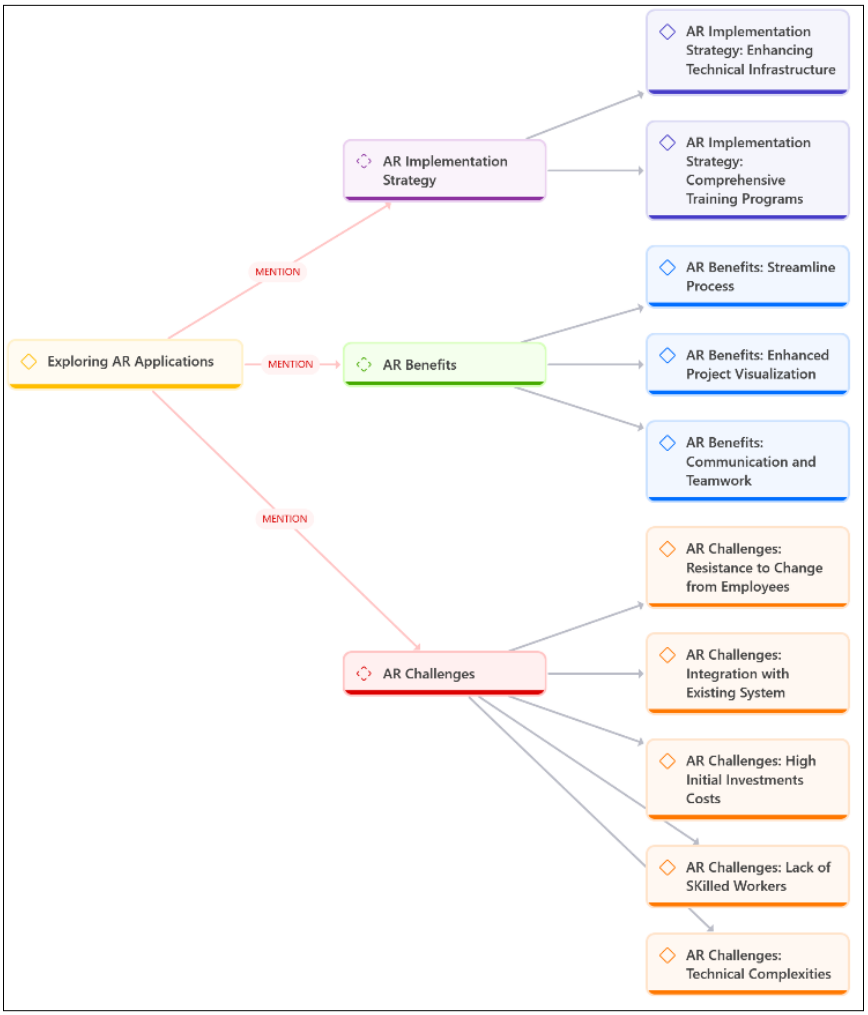

Figure 1: Conceptual Diagram

METHODOLOGY

This research used the qualitative method, and the data was collected through semi-structured interviews. Researchers try to employ a questionnaire survey, but it can limit the participant responses

to a set of answers. In contrast, semi-structured interviews allow for a deeper understanding of the participants' experience and perspective. The research starts by identifying the relevant companies that met the criteria via internet search engines such as Google. Online background checking was conducted on the websites of various companies using information from the internet. Then, companies that were not involved directly in the construction industry were excluded. This led to seven companies being shortlisted, to which the invitations were sent, and four responded positively to participate in the interviews. However, one company had to be removed because it provided AR service but was not involved in the construction process directly. Employing a purposive sampling technique, respondents selected for the study must have exposure, knowledge, and experience in AR technology and working in the construction industry in Klang Valley, Malaysia. The study was meant to identify the advantages and limitations of AR technology within the construction industry in Malaysia.

Table 3: Background of Respondent

Category	Respondent		
	R1	R2	R3
Position	Engineer	BIM Coordinator	Head of Design
Company	A	B	C
Years of Experience	1.5 Years	8 Years	16 Years
Stage	Construction Phase	Construction Phase	Design Phase

Table 3 shows the background of the respondent. Even though the number of respondents is small, it is enough to achieve the research objective. According to Bekele and Ago (2022), the number of participants that is enough depends on the nature of the research, the type of question asked, and the research methodology used. These elements coupled with time and resource constraints make a small sample size appropriate for our study.

Data Analysis Method

The data analysis was done through thematic analysis, with the use of the Atlas.ti software. According to Braun and Clarke (2019), thematic analysis is flexible and useful in a variety of fields, while Vaismoradi and Snelgrove (2019) emphasise their role in structuring and interpreting collected data to address the research problem. The findings served useful purposes resulting in some recommendations and conclusions that could be useful to the industry.

FINDINGS AND DISCUSSION

Benefits of Augmented Reality Applications

Streamline Processes

Responses from R1, R2, and R3 underscore the favourable use of immersive technology, AR in this case, on the efficiency of construction activities. With AR technologies system tasks can be performed without a physical presence as appropriate project information and digital images within the context can be accessed whenever, therefore minimising manually performed actions. R1 observed that the use of AR technologies has made it easier and faster to locate problems on a construction site and resolve them, consequently improving the workflow of the project and minimising the time lost in delays. Likewise, R2 reiterated how the process has been made less tedious using augmented reality that allows the embedding of live data feeds in assisting with the management of projects. R3 claimed that AR allows for better project implementation because it mitigates the issue of encountering design issues at the latter stage, which would most likely impose delays in the construction stage.

Table 4: Respondents Answer for Streamline Processes

Respondent	Quotations
R1	"…swift identification and resolution of on-site issues…"
R2	"…optimized project management, improving coordination and overall process efficiency…"
R3	"…allowing early identification and resolution of design flaws…"

Enhanced Project Visualisation

Enhanced project visualisation is another significant benefit highlighted by R1, R2, and R3. According to R1, when AR is consistently used for inspection and validation during construction, it serves as an advanced visualisation tool that helps identify potential errors before they escalate into costly issues. R2 noted that marker-based AR improves on-site decision-making by providing instant access to detailed project models and specifications. Additionally, R3 integrates 3D software into the design process, using it to generate immersive design presentations. This allows clients to experience virtual walkthroughs of proposed designs, ensuring accuracy and aligning expectations early in the project.

Table 5: Respondent Answer for Enhanced Project Visualisation

Respondent	Quotations
R1	"…when used consistently to inspect and validate construction, AR acts as an enhanced visualisation tool to identify mistakes before they become costly to repair.…"
R2	"…providing detailed project models and specifications instantly …"
R3	"…immersive design presentations …"

Improved Communication and Teamwork

Both R1 and R3 emphasise the role of AR in improving communication and teamwork. R1 noted that AR technology enhances communication among stakeholders by providing clear visualisations of project data, which aids in discussing and resolving issues more efficiently. R3 mentioned the ease of sharing design information, explaining that teams can simply share a link for clients to view the unit design that has been created, further streamlining the communication process.

Table 6: Respondents Answer for Improved Communication and Teamwork

Respondent	Quotations
R1	"…providing clear visualisations of project data, which helps in discussing and resolving issues efficiently…"
R3	"…We can just give the link for them to view the unit design that we have created…"

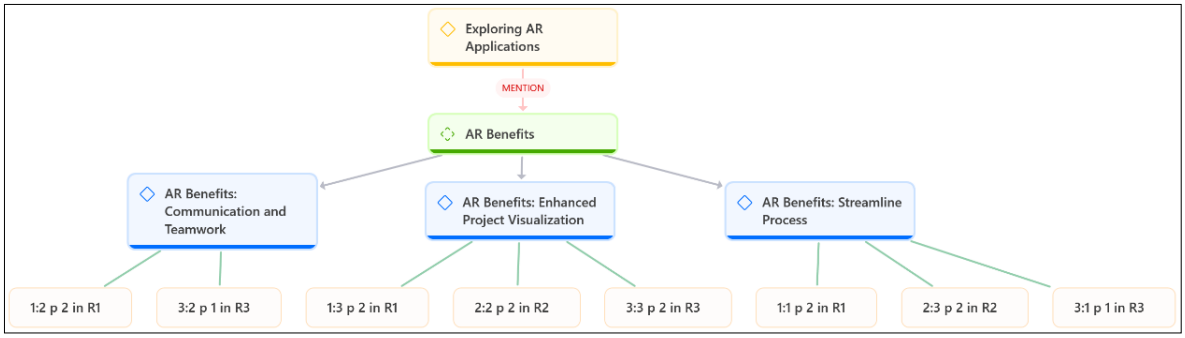

Figure 2: AR Benefits

Challenges of Augmented Reality Applications

Technical Complexities or Limitations

Respondents R2 and R3 highlight the technological challenges and limitations associated with AR technology. R2 pointed out that integrating AR into traditional construction workflows can be difficult due to the sophisticated technical requirements and the need for specialised software and hardware. R3 added that these technical complexities can hinder AR's seamless deployment, particularly in large-scale projects where precision and reliability are critical.

Table 8: Respondent Answer for Technical Complexities or Limitations

Respondent	Quotations
R2	"…sophisticated technical requirements and the need for specialised software and hardware …"
R3	"…the challenges are time, not every project has enough duration to use AR…"

Integration with Existing System

Respondents R1 and R2 mainly discuss the challenges involved in implementing Augmented Reality technology in construction with the legacy infrastructure. AR integration has become necessary for many companies, and the process has been made difficult due to already developed processes and systems in place at most organizations. In R1, compatibility and integration with other systems, as well as data management processes were identified as important factors that must be considered to reduce interruptions while implementing the system. R2 also pointed out that increasing the stability, speed, and conversion constancy further according to the customer expectations is crucial. Moreover, R2 also noted that future work should focus on the creation of apps that rely on the Android culture to reach as many users as possible and to be easily integrated.

Table 9: Respondent Answer for Integration with Existing System

Respondent	Quotations
R1	"…compatibility with existing software and data management procedures is critical for minimising interruptions during adoption …"
R2	"…improve conversions more stable, faster, and consistent with customer type requirements, and develop an app for Android..."

High Initial Investment Costs

R1 emphasised the significant initial investment required for AR implementation, which includes the costs of purchasing AR hardware, developing custom applications, and training personnel. For smaller construction companies, these financial commitments can be a considerable barrier to adopting AR technology. R1 pointed out that the cost of subscribing to AR services is high, and developing proprietary AR applications demands substantial time as well as research and development expenses. These financial hurdles can slow down or even prevent smaller companies from embracing AR technology in their workflows.

Table 10: Respondent Answer for High Initial Investment Costs

Respondent	Quotations
R1	"…the cost of subscribing to AR services is high, and developing proprietary AR applications requires significant time and research and development costs …"

Lack of Skilled Personnel

The concern related to the shortage of skilled workers is shared by the respondents R1, R2, and R3. Stating that special attention should be paid to cooperation with the teams of AR app development

highlighted by R1. For increased effectiveness of AR applications, it is crucial to integrate people with construction backgrounds into the development of the applications. R2 pointed out that part of the process of working with the R&D team is that it could advance discussions and solutions around those skills gaps that are seen as necessary in advancing AR. R3 also noted that issues such as time projects and the shortage of skilled staff restrict the application of AR technology, it is applied only in some cases. According to R2 and R3, the absence of skilled personnel may also cause a delay in the implementation process and a decline in the quality of AR applications.

Table 11: Respondent Answer for Lack of Skilled Personnel

Respondent	Quotations
R1	"…collaboration with AR app development teams is crucial. It is essential to involve individuals with construction experience in the AR app development…"
R2	"…meet Datamesh company R&D team, to discuss the development…"
R3	"…the challenges of project duration and lack of competent people to use the technology make the usage of this technology low and only get to be used on certain projects…"

Resistance to Change from Employees

R1 identifies employee resistance to change as a significant challenge. Construction workers who are accustomed to traditional methods may be reluctant to adopt new technologies like AR. R1 explained that the adoption of AR on construction sites is challenging because many in the industry are traditional-minded and prefer established methods. Overcoming this resistance requires comprehensive change management strategies, including education and training initiatives. R1 also emphasised the importance of demonstrating the tangible benefits of AR technology to gain acceptance among employees and encourage broader adoption across construction teams.

Table 12: Respondent Answer for Resistance to Change from Employees

Respondent	Quotations
R1	"…adoption of AR on construction sites is challenging as many in the industry are traditional-minded and prefer established methods …"

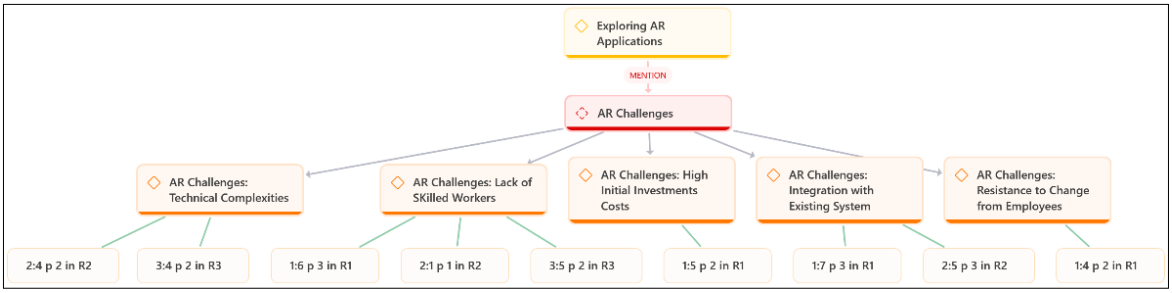

Figure 3: AR Challenges

Strategy to Increase AR Implementation Rate

Enhancing Technical Infrastructure

This comprises leveraging better AR hardware including better layered devices and creating bespoke apps that meet certain project specifications. To reduce the risk of disruptions of business as usual as well as seamless interchange of data between the proposed construction management system and existing ones is also important. Also, reliable network connectivity is critical for real-time performance, and its reliability is imperative for AR applications on-site. These are the investments that are required to make absolute use of AR regarding the enhancement of project productivity and decision-making processes (Sacks et al., 2020). In this way, the integration of AR tools with existing platforms can be used by construction companies to improve companies productivity and project results

(Davila Delgado et al., 2020). Action must be taken by the key stakeholders in the construction industry to support the development and implementation of AR.

Comprehensive Training Programs

This is important given the fact that it must ensure the staff has enough knowledge and skill in the use of AR technology. A program on AR devices and applications should entail the following technical aspects regarding construction involving information relating to the equipment that is used in construction and information regarding the application of the application construction. In addition, there is a need for professional development to upgrade oneself with the current trend in technology as well as sharpen AR skills. It reminds the personnel about the availability of the new AR features and the new ways they can be applied (Wang et al., 2019).

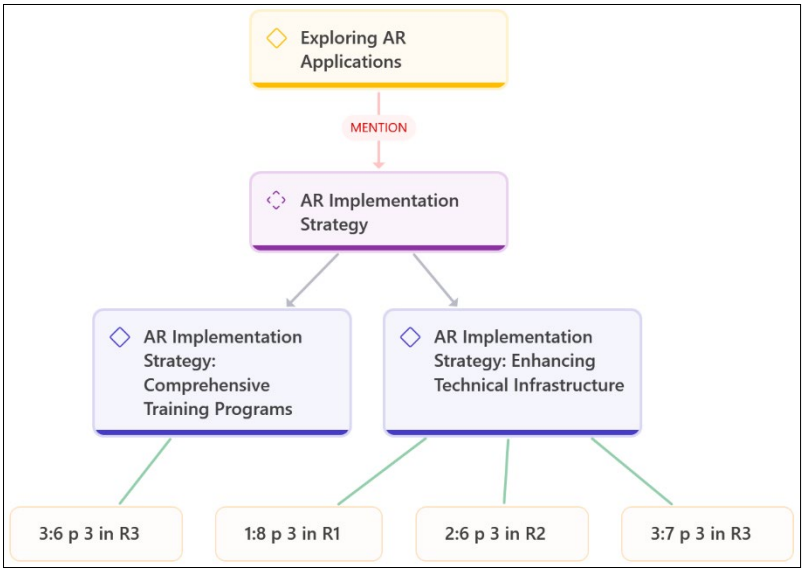

Figure 4: Strategy to Implement AR

DISCUSSION

The findings of this study indicate AR implementation can help to address the industry challenges as stated by Zidane and Andersen (2018), such as schedule delays due to design changes. By adopting AR, the design stage will be more thorough and complete. The benefits such as streamlining the construction process are key findings agreed upon by every respondent mentioned in the literature review. Nassereddine et al. (2022) pointed out that preliminary ideas presented by AR are very important in helping to see the possible design errors and hence avoid expensive problems. Despite its benefits, the challenges with initial investment costs and technical complexities are not something companies can put aside. Delgado et al. (2020) support that the problem with high-cost software is complicated and needs further cost to be invested to properly be employed.

Pan and Isnaeni (2024) talk about the use of AR-BIM integration to examine virtual models on-site supporting the findings that AR can enhance project visualization. As the layman on the construction site may not understand the drawing properly, it can be tackled with an AR model. However, the benefits are hindered by challenges such as a lack of skilled workers and resistance to change. Hajirasouli et al. (2022) state that workers do not have the knowledge and skill to properly adopt AR technology. Other than that, the construction industry has its traditional practices and cannot be easily changed. The adoption of AR technology can influence the training program for new workers. This is

because the companies would need workers who can operate the AR technology to adapt to future innovations.

CONCLUSION

In conclusion, the integration of AR in the construction industry, as evidenced by the experiences of R1, R2, and R3, reveals a significant potential to revolutionise the way projects are visualised, managed, and communicated. The use of AR demonstrates the technology's ability to enhance both client and team engagement, streamline project workflows and, foster more effective stakeholder communication. However, the research also brings out several key issues of concern that must be resolved for an effective AR to be realised in this industry. There are technical problems that may hamper adoption, system compatibility factors and high initial investment are other factors that need attention. In addition, the lack of trained personnel as well as the problems with resistance to change in management emphasise the importance of delivering proper education and training. These findings not only align with existing literature but also provide practical insights into the current state of AR adoption in Malaysia's construction industry. By addressing these challenges, there is a clear opportunity to harness AR's benefits more effectively, leading to greater operational efficiency and more innovative construction practices. The strategies to implement AR also have been identified and divided into two main actions: enhancing the technical structure and comprehensive training programs. The strategies will be crucial in guiding future implementations and research in this area. This research recommendation for future research is to expand the sample size and diversity, the study should target a larger sample size and a more diverse sample of respondents. Incorporating diversity in the study will contribute to more information on AR implementation in the construction industry from different professional backgrounds. Next, the study should focus on how different user interfaces and training methods will affect the effective usage of AR by stakeholders in construction companies. The thorough research in various contexts will help to increase the understanding of AR technology in the construction industry in Malaysia.

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AUTHORS' CONTRIBUTION

Muhammad Izzat Said carried out the research and wrote and revised the article. Both Muhammad Izzat Said and Mohd Shahir Mohamad Yusof conceptualised the central research idea and designed the research. Mohd Shahir Mohamad Yusof supervised the research progress and took the lead in writing the manuscript and submitting the article. Wan Zuriea Wan Ismail's review and Hikmah Kamarudin's contributed to the interpretation of the results and revised the article. All authors offered insightful criticism and contributed to the development of the study, analysis, and writing of the manuscript.

CONFLICT OF INTEREST DECLARATION

The article is the original work of the authors and co-authors. The article has never been published before and isn't being considered for publishing anywhere else. This study/manuscript has not been submitted for publication or published elsewhere, either in full or in part. We testify to the fact that all Authors have contributed significantly to the work, validity, and legitimacy of the data and its interpretation for submission to Jurnal Intelek.

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