Journal of Project Management Practice
Faculty of Built Environment, Universiti Malaya.
E-ISSN: 2805-4768
https://ejournal.um.edu.my/index.php/JPMP/

Mobile Augmented Reality (MAR) in Construction Cost Management: Obstacles and Strategies for Improvement

Umaira Husna Abdul Rahman [1] & Mohd Fairullazi Ayob [2*]

[1,2] Department of Quantity Surveying, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia, Jalan Gombak, 53100, Kuala Lumpur, Malaysia.

*Corresponding author: fairullazi@iium.edu.my

Submission date:
6th August 2024
***Acceptance date*:**
17th December 2024

How to cite this paper:
Abdul Rahman, U. H. & Ayob, M. F. (2024). Mobile Augmented Reality (MAR) in Construction Cost Management: Obstacles and Strategies for Improvement. Journal of Project Management Practice, 4(2), 23-36.

ABSTRACT

Mobile Augmented Reality (MAR) is a setting where digital information is viewed from a real-world perspective and is created using Augmented Reality (AR) that is integrated into a mobile application. AR is one of the emerging technologies in Construction 4.0 Strategic Plan (2021-2025) in Malaysia. Although many scholars have pointed out many benefits of MAR to the construction industry, nevertheless, the implementation of MAR practice with specific reference to cost management in the Malaysia construction industry is still at the rudimentary stage. Without MAR, professionals tend to rely on traditional technologies with limited real-time visualization, which can lead to data misunderstanding and decision-making delays. Besides, there will be a lost potential for early detection of cost overruns when MAR is not implemented in cost management. Hence, this paper is prepared to present the outcome of study on the identification of obstacles that can hinder the implementation of MAR practice, and suitable strategies for improving MAR with specific reference to the cost management practice in the construction industry. The study was designed with a qualitative research strategy that in compasses of semi-structured interview with seven (7) professionals that have established knowledge, skills, and experience in cost management. The interviewed data was analysed using content analysis and descriptive statistical analysis methods. The findings from the study have established that the financial issues such as high investment cost has been identified as a key obstacle that can hinder the MAR implementation in cost management practice. To overcome the limitations of MAR implementation, the study has identified several strategies that could be appropriate for the recommendations to improve the MAR practice in the construction industry. Providing financial support by the financial agencies is found to be the most effective strategy to enhance MAR implementation for cost management in the construction industry. Additionally, the research adds up to the body of knowledge on MAR implementation that can become significant input to enhance the cost management practice in Malaysia.

Keywords: augmented reality, construction, cost management, mobile augmented reality

1.0 INTRODUCTION

Cost management is an important stage in the life cycle of a construction project in order to execute it on time, within budget and with high quality. Nonetheless, one problem that frequently arises in construction projects is cost overrun, which is difficult to totally eradicate (Sepasgozar et al., 2022). According to Sohu et al. (2023), studied data indicated that around 55% of the projects experienced cost overruns in Malaysia. Hence, alternatives that can solve this issue have to be taken such as the implementation of emerging technology, Mobile Augmented Reality (MAR) as it is able to prevent cost overruns and assist in cost management practice (Hernandez & Brioso, 2018). Augmented Reality (AR) is a technology that allows the computer graphics and real world to overlay (Machado & Vilela, 2020). Pace et al. (2018) claim that early versions of AR implementation relied on laptop-connected visualization devices such Head Mounted Displays (HMDs). As more powerful and compact mobile devices are being introduced, using Handheld Devices (HHD) like smartphones for MAR is becoming more appealing due to its portability and accessibility (Zaher et al., 2018). Through MAR, an actual project situation is intended to be represented and translated into a 3D model that is displayed by a mobile application (Shouman et al., 2021). According to Construction Industry Development Board Malaysia (CIDB) (2020), the construction industry should utilize innovative techniques and emerging technologies to generate higher quality work as it is anticipated that project demands will become more complex and interrelated. Nonetheless, MAR is still not widely applied and recognized in the Malaysian construction industry despite the benefits that MAR technology has for cost management (Zakaria et al., 2021). According to CIDB (2020), the potential causes of low adoption of these emerging technologies such as MAR in Malaysia include people, governance, economy, and technology itself (CIDB, 2020). These four categories of causes are identified as the main resources required for MAR. Due to its low implementation in the whole construction industry itself, it results in a less implementation of MAR for the purpose of managing construction costs by those involved in cost management. To apply MAR in cost management, the current implementation, perception of the stakeholders on the technology, obstacles, and strategies to enhance its implementation must be addressed. Hence, this paper is prepared to present the outcome of study on the identification of obstacles that can hinder the implementation of MAR practice by getting into detail for each of the categories, and suitable strategies for improving MAR with specific reference to the cost management practice in the construction industry.

2.0 REVIEW OF MOBILE AUGMENTED REALITY (MAR) IMPLEMENTATION IN MALAYSIA CONSTRUCTION

Malaysia Airlines was among the first businesses in the nation to employ MAR in their 2010 advertising campaign, allowing customers to scan the sky to locate the nearest airport and receive flight discounts (Wafa & Hashim, 2016). Users can scan their mobile devices to access bargains through the implementation of AR. Nevertheless, the majority of Malaysian enterprises using AR technology are not local, rather, the technologies have been imported and recovered from first-world countries such as the United States or United Kingdom (Mohammad Azlan et al., 2022).

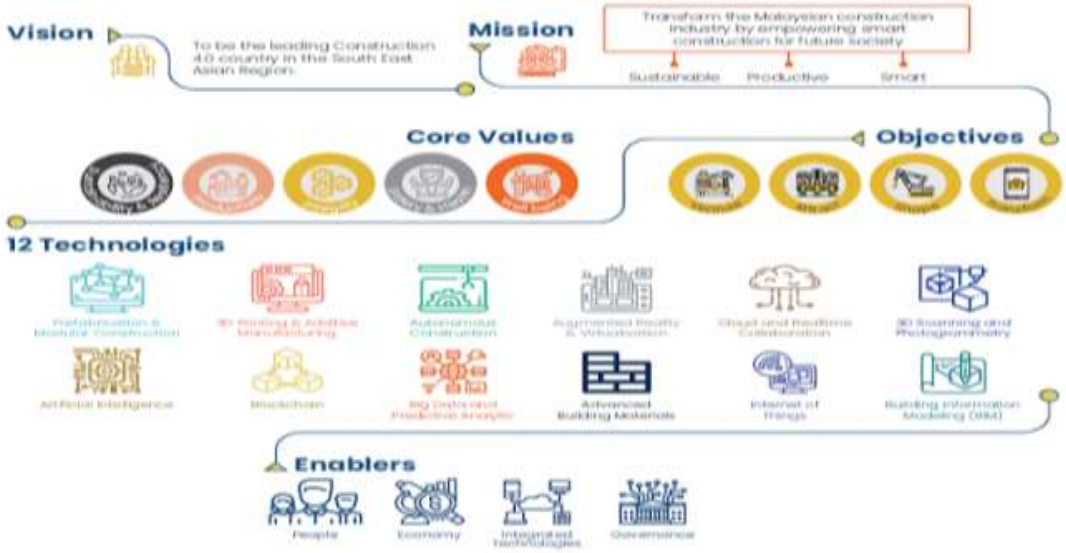

Figure 1. Strategic framework for construction 4.0 (Source: CIDB, 2020, pg. xii)

The Construction 4.0 Strategic Plan 2021–2025 in Malaysia includes AR as one of the twelve innovative technologies that would be heavily incorporated into the Malaysia construction sector as shown in Figure 1 (CIDB, 2020). Therefore, initiative was taken by MMC Gamuda KVMRT (T) Private Limited (MGKT) to utilize MAR for the infrastructure project, Klang Valley Mass Rapid Transit (KVMRT). Ballesteros (2021) notes that MMC Gamuda KVMRT (T) Private Limited (MGKT) has made a name for itself by successfully leveraging AR technology to monitor construction progress from pre-construction to post-construction, which led to the creation of the BIMAR app. Since they were aware of how costly it was to employ AR-specific devices like the Microsoft HoloLens, an internal BIMAR app which could be used on regular mobile devices was created (MMC GAMUDA, 2020). According to Kai (2023), a walkthrough of the proposed layout and the vibe of the future town can be done using tablet devices. This indicates that even by 2030, there is a high chance that MAR technology will still not be used in Malaysia for the entire construction life cycle. Currently, MAR has not been implemented widely in construction and its implementation is still restricted as there is inadequate study of AR and a lack of awareness of the technology in Malaysia (Zakaria et al., 2021; CIDB, 2020).

2.1 MAR for Cost Management

Construction cost management is crucial throughout the project life cycle. Construction cost management has an impact on every stage of the project. Planning and design at the early phase of construction will require cost management and it is closely followed by estimating, variation orders, on-site contractors and the result (Maslam, 2023). According to the CIDB's publication "Digital Cost Management - Enhancing Cost Effectiveness and Project Performance in Malaysia Construction Industry", consultants and contractors have begun to use digital solutions for cost management of construction projects (Fariq et al., 2021). MAR is one of the technologies that has the ability to assist in cost management and construction projects can benefit from MAR's assistance with planning, estimating, budgeting, and controlling which are the components that determine the efficiency of construction cost management (Senanayake et al., 2022). Previous studies have demonstrated that MAR may effectively control a project's construction costs through a variety of means, including visualization, comprehension of design, planning, information access, and error detection.

2.1.1 Visualization

AR projects virtual items as holograms overlaid on the actual world, in contrast to multimedia and Virtual Reality (VR) (Kanivets et al., 2020). Because of its visualization capabilities, MAR is frequently used to visualize construction projects at different phases and make sure that construction costs are controlled appropriately. Furthermore, real-time project visualization makes it easier to track developments (Heinzel et al., 2017; Ratajczak et al., 2019; Farghaly et al., 2023; Gounaridou et al., 2023). In addition to saving the stakeholders' travel expenses as they do not have to be physically present at the site, this can also guarantee early prevention of issues that may result in costs at the site.

2.1.2 Understanding Design

According to Senanayake et al. (2022), AR can reduce design defects, related variations, and cost overruns by improving design comprehension made possible by such technological advancements. According to a study conducted by Hajirasouli et al. (2022), it is discovered that implementing AR for design and constructability review sessions can enhance decision-making, enhance design modifications, boost the efficacy of problem-solving actions, and enhance the quality of visual presentations during the design phase of the project life cycle. On top of that, MAR can also assist the designers to better comprehend the design choices' consequences and the final output (Mohammad Azlan et al., 2022). Due to these, the project's overall cost and time can be reduced (Hajirasouli et al., 2022).

2.1.3 Cost Planning

Construction project planning will greatly improve with MAR's capacity to visualize and enhance design understanding, particularly for large-scale projects. Utilizing MAR to gain accurate information during the planning phase is indeed crucial as this phase of a construction project will highly give impact to the cost estimating and control (Bademosi & Issa, 2018). Accordingly, using a technology like MAR for efficient cost management will result in efficient cost planning for construction projects (Ahmed et al., 2017; Senanayake et al., 2022). In addition, according to Ahmed et al. (2017), AR can save cost of the construction projects during the cost planning phase of construction (Ahmed et al., 2017; Reljić et al., 2021).

2.1.4 Access to Information

MAR technology provides an experience that permits the display of virtual elements with all the necessary information and graphics in the physical world (Adebowale & Agumba, 2022). This is supported by a study that asked participants to use augmented reality (AR) to co-design concepts in the creation of an interactive interior design system. Using this technology, participants were able to contribute crucial system design information during the discussion (Shouman et al., 2021). According to Abdeen et al. (2022), MAR implementation minimize expenses and delays resulting from performance incompatibility by offering a wide variety of stakeholders prompt and easy access to information that will allow for remedial measures to be planned and executed.

2.1.5 Detect Errors

In construction, MAR can identify any errors that will or have occurred (Carlsén & Elfstrand, 2018; Li et al., 2018; Cao et al., 2023). Preventing design flaws prior to the start of construction can lower the occurrence of variation orders and related expenses (Kassis et al., 2023). Project managers can save time and money by utilizing AR technologies which can aid in project precision while lowering labour costs and expenses related to construction rework and errors (Ahmed et al., 2017). In addition, AR's monitoring capabilities make it easy to identify any mistakes or deviations in a facility during building monitoring operations (Pace et al., 2018).

2.2 Review of Obstacles Hindering MAR Implementation for Construction Cost Management

In Malaysia, the adoption rate of MAR remains low despite its potential benefits for construction cost management (Zakaria et al., 2021; Mohammad Azlan et al., 2022). People, governance, economy, and technology itself are the categories of the obstacles of MAR implementation listed by CIDB (2020). These categories fall under the resources that must be obtained to use MAR. Due to the inability of acquiring these resources, it has become the obstacles that hinders the MAR implementation.

2.2.1 People

The lack of awareness about MAR technology makes it difficult to draw in highly qualified workers and a workforce who are ready for the future (CIDB, 2020). A few studies have noted that there are low numbers of professionals who are enthusiastic to study MAR technology due to a lack of understanding about MAR and AR in general (Piroozfar et al., 2018; Cao et al., 2023; Pan & Isnaeni, 2024). According to a study by Lin (2021), lack of understanding emerging technologies such as MAR will hinder our ability to advance in the building sector. Hence, there is a lack of professionals who have sufficient knowledge in MAR technology to apply it for construction cost management purposes.

2.2.2 Governance as well as Internal and External Pressure

It will be challenging to expand the use of MAR technology in the absence of clear regulations for systems or equipment supporting IR4.0 technologies and procedures (CIDB, 2020). In fact, the construction parties will not execute the MAR broadly and extensively due to the absence of pressure or directions from the governance (Zakaria et al., 2021). Given that MAR implementation include unique work methods which can only be handled by experts, the adoption process could be accelerated by the creation of a standard or guideline (Zakaria et al., 2021). Previous studies did indicate the government regulations influence the rate of adoption of MAR (Mugumya et al., 2019; Sidani et al., 2021; Wang et al., 2023).

2.2.3 Economy and Financial

According to several studies, the cost of adopting AR technology is a widely faced obstacle (Chai et al., 2019; Delgado et al., 2020; Zakaria et al., 2021; Mohammad Azlan et al., 2022; Wang et al., 2023). CIDB (2020) noted in the strategy plan for construction 4.0 that the high cost of implementing and investing in AR technology is impeding the deployment of technology. Any business that intended to use AR technology in the past had to make a large financial investment. Our economy is not steady and is still catching up to rise, therefore it will be challenging to apply these technologies right away (Mohammad Azlan et al., 2022). Furthermore, the higher upfront expenses of purchasing AR technology and updating infrastructure to support it have limited the adoption of AR. Many of the respondents believed that changing from the current procedure to a new one would result in expenses when deploying new technologies. Their main concern when introducing new technology is its higher cost. The cost can include purchasing the required software and hardware in addition to having the license renewed (Zakaria et al., 2021). In addition, it is expensive to continue using AR technology (CIDB, 2020).

2.2.4 Technology

A few other researchers pointed out that the complexity of AR is impeding its adoption in the construction industry (Masood & Egger 2019; Shouman et al., 2021; Oke & Arowoiya, 2022). There is no denying that increased technological complexity will make MAR adoption more challenging. Furthermore, most senior staff members and higher management had difficulty adjusting to new technologies. Furthermore, powerful authorities oppose the growth of innovative technologies in the building sector, preferring to stick to outmoded practices and be secure. This makes the use of AR technology itself challenging (Mohammad Azlan et al., 2021).

2.3 Review of Strategies to Enhance MAR Implementation for Cost Management

Due to these obstacles listed, strategies have been planned to enhance MAR implementation for construction cost management. Researchers have mentioned a few strategies that can address these obstacles which can be categorized according to the resources categories which are people, governance, financial and technology.

2.3.1 People

To create a workforce that is recognized by the industry, a new type of upskilling and reskilling program that includes education for anticipated new competencies is needed (Roslan et al., 2021). This can be used to produce MAR technology experts. According to a study by Zakaria et al. (2021), learning and training programs should be made available to boost MAR knowledge and generate the technology professionals in Malaysia. Researchers widely have also emphasized how crucial training is to enhance the implementation of this technology (Carlsén & Elfstrand; 2018; Ahmed, 2019; Rajaratnam et al., 2021).

2.3.2 Governance

In the Construction 4.0 Strategic Plan 2021–2025, CIDB (2020) states that the government can use specific technologies such as MAR to enhance government policy interventions. Senanayake et al. (2022) claimed that the government should create regulations to guarantee the standardization of AR implementation in the construction sector, likewise, supporting this. The government will take action to promote AR's use in the construction industry because it is recognized as a new technology in our nation and is included in the Construction 4.0 Strategic Plan (2021–2025).

2.3.3 Financial

Despite technical advancements, the Malaysian construction industry still does not routinely adopt new technologies due to a number of issues, one of which is cost (Syed Zakaria & Singh, 2021). Numerous academics have discovered that there are problems with MAR technology investments. According to research by Nassereddine et al. (2022), lack of financial resources is an obstacle that is hindering the implementation as well. It is crucial to attract investors and attention needs to be paid to developing capital budgeting and investment assessment studies for AR in the building sector during this process (Rajaratnam et al., 2021).

2.3.4 Technology

Mohammad Azlan et al. (2022) state that researchers believe AR technology can be improved in the Malaysian industry if everyone is fully aware and exposed to the idea of these technologies. Everyone who possesses knowledge on MAR, regardless of social standing will be able to adapt to this technology. According to Chai et al. (2019), if industry participants possess a strong understanding of AR, they ought to be able to maintain or even boost their competitiveness in both domestic and global markets. The most effective way to address technological problems like technology complexity will be to increase knowledge in MAR.

3.0 METHODOLOGY

As Malaysia is still new in applying MAR in the construction industry, there are less professionals in the construction industry who have implemented MAR implementation and this led to the lack of MAR's experts (Zakaria et al., 2021; Mohammad Azlan et al., 2022). Therefore, this study used a qualitative research method to address these limitations. Semi-structured interview is applied in this study where it allows the respondents to express their opinions about how MAR is currently used in Malaysian construction cost management. Besides, if a new or exciting line of inquiry emerges during the interview, the researcher can follow up with additional questions (Mannan, 2020). This will boost the amount of data obtained from the interview session while also allowing for the collection of more detailed information. Furthermore, semi-structured interviews

enable them to stay on top of their study while also providing the flexibility and adaptability to ask their interviewee any questions they may have (Mannan, 2020; Ruslin et al., 2022). As a result, a semi-structured interview was chosen as the data collection approach, as there are few practitioners of MAR technology in the construction industry who are involved in cost management. Semi-structured interviews will assist the researcher in gathering in-depth data exclusively from those involved in cost management for the MAR application in construction cost management.

The respondents are chosen based on the set of criteria listed such as the respondents must possess at least the knowledge, experience and expertise in MAR and cost management to ensure the data obtained from the interview is reliable and valid. The questions for the interviews consist of both open-ended and closed-ended questions. Open-ended questions seek for more detailed information from the interviewee in their response while closed-ended questions ask the interviewee to score the questions using a Likert scale to obtain their level of agreement on the questions. These closed-ended questions are designed to gather comprehensive information about the current issues surrounding the MAR implementation for cost management, its advantages in the industry and the industry players' acceptance of the technology. Snowball sampling has been applied to collect the data for this research. The respondents were identified by the researcher through various social media platforms such as LinkedIn, Facebook, WhatsApp, and Telegram. Keywords such as "cost management," "construction management," "quantity surveying" and “cost engineer” were used to search for possible respondents from these platforms. Personalized connection requests and messages were then issued to ask people to take part in the study. The respondents chosen are those who have been involved in the construction cost management practice and those who met the set of criteria as listed below.

i. The respondent possesses a degree or certificate in the built environment field such as quantity surveying, architecture, engineering, project management, town planning, landscape architecture, facility management and any related courses.
ii. The respondent must have at least one or two years of experience working in the built environment field.
iii. The respondent possesses at least the necessary knowledge and/or has any experience and/or expertise in MAR and cost management.
iv. The respondent is willing to participate and support this study.

The data collected from the respondents were analysed using content analysis and descriptive statistical analysis. For open-ended questions, content analysis will be used to analyse the data while descriptive analysis was used to analyse the data obtained from close-ended questions. As for content analysis, an essay-style detailed explanation was done for open-ended questions. According to Miles et al. (2014), descriptive analysis reduces complex datasets and provide concise, interpretable insights which are required for exploratory or preliminary studies. Hence, it is suitable to be applied to this research as MAR is still at the exploratory stage for cost management. Descriptive statistical analysis included for this research are mean ranking analysis and standard deviation which are used to analyse questions using Likert scale. The mean ranking analysis was done to figure out which item responses can be classified as highly significant and should be included in the answer set of the corresponding questions (Ahmad & Ayob, 2023). Items with mean scores greater than 3.75 are considered highly significant (Ayob & Abdul Rashid, 2020). Meanwhile, standard deviation was calculated to determine the level of consensus attained among the respondents (Ayob & Abdul Rashid, 2020). Table 1 shows the standard deviation values which serve as the evaluation standards for determining the degree of agreement reached by the respondents (Ayob & Abdul Rashid, 2020).

Table 1. Standard deviation and level of consensus (Ayob & Abdul Rashid, 2020)

Standard deviation (SD)	**Level of consensus achieved.**
$0 \leq X < 1$	High level of consensus
$1 \leq X < 1.5$	Reasonable/ fair level of consensus
$1.5 \leq X < 2$	Low level of consensus
$2 \leq X$	No consensus

4.0 RESULTS

4.1 Demographic Background

This section shows the background information of the interviewees that met the set of criteria listed and participated in the semi-structured interview. Table 2 represents the respondents' background which include their years of experience in cost management, involvement in projects using MAR and the type of project used MAR. Meanwhile, Table 3 shows the necessary information of the respondents' organizations. These are part of the questions in Section A of the questionnaire.

4.1.1 Background of Respondents

Table 2. Background of Respondents.

Respondent	Experience in cost management	Involvement in project using MAR	Type of project
1	More than 10 years	Yes	Buildings
2	Between 1 to 5 years	Yes	Buildings
3	Between 5 to 10 years	No	-
4	Less than 1 year	No	-
5	More than 10 years	No	-
6	Between 5 to 10 years	No	-
7	Between 1 to 5 years	No	-

Respondents' backgrounds demonstrate a wide variety of cost management experience. Some have more than ten years of experience, while others have less than a year. This variation offers a thorough understanding of how cost management knowledge affects MAR uptake and efficacy. In addition, the fact that only two respondents had direct experience with MAR projects where both of which are building-related type of project indicates that MAR may not be widely used or understood in the sector. The majority of respondents who did not participate in MAR point to possible adoption or accessibility gaps, underscoring the necessity of investigating obstacles like ignorance or change aversion.

4.1.2 Background of Respondents' Organizations

Table 3. Background of Respondents' Organizations

Respondent	Type of organizations	MAR implementation	Type of project
1	Developer	To a certain extent	Buildings
2	Consultant	To a certain extent	Buildings
3	Project Management Consultant	To a certain extent	Infrastructure
4	Contractor	To a certain extent	Fabrication
5	Urban Rail Developer	To a certain extent	Infrastructure
6	Contractor	Not at all	-
7	Consultant	Not at all	-

According to data collected, the respondents involved came from a variety of organizational kinds and it is said that the MAR implementation is described as partial or having a limited extent. This illustrates different

adoption levels which are probably impacted by company priorities or resources. The emphasis on construction projects highlights MAR's sector-specific significance and raises the possibility that it could be useful in cost control for these kinds of projects. The inadequate adoption, however, suggests difficulties such as lack of funding, technological difficulties or insufficient knowledge. These results imply that resolving these organizational issues and broadening MAR's application beyond construction projects are essential to its efficacy and wider adoption.

4.2 Obstacles Hindering MAR Implementation for Construction Cost Management

The data collected for the obstacles that are hindering the MAR implementation for cost management are shown in table 4. The interviewees had to rate their level of agreement for each of the obstacles to know how these obstacles are applied to them who are the current players in the industry associated with cost management.

Table 4. Obstacles that hinders MAR implementation for cost management.

Rank	Obstacles	Mean	Standard Deviation
1	High investment cost for MAR	4.71	0.49
2	High cost to change method to MAR	4.57	0.54
	High expenses (apps, license, maintenance)	4.57	0.54
3	Lack of support from the Governance	4.43	0.54
	Unable to adjust to new technology	4.43	0.54
4	Ignorance in MAR	4.43	0.79
5	Absence of precise MAR's guideline	4.14	0.69
6	Absence of MAR experts	4.00	1.00
7	Complex operation	3.43	0.79
8	Higher risks	3.29	0.95

As for the Section B of the questions, the interviewees are required to state their degree of agreement on all the obstacles that are hindering the MAR implementation for cost management of construction projects in Malaysia. Table 4 shows the outcome of the data collected from the interviewees including the mean and standard deviation scores. It has been found out that financial issues are chosen as the most dominant obstacles as the mean score exceed 3.75 score. The financial issues are high investment cost (mean 4.71), high cost to change the traditional method to MAR and high expenses of items related to MAR such as apps, license and maintenance (mean 4.57). Out of these top three ranked obstacles, the high investment cost ranked as number one with the highest mean score and lowest standard deviation (0.49) that has been identified as the key obstacle for the MAR implementation for cost management in the construction industry. Besides, most of the obstacles which are lack of support from the Governance, unable to adjust to new technology, ignorance in MAR, absence of precise MAR's guideline and absence of MAR experts achieved mean score more than 3.75. However, the calculated mean score for complex operation and higher risks were less than 3.75. This is because R1, R3, R5 and R6 were neutral on this obstacle. In addition, R4 disagreed on complex operation as the obstacle of MAR implementation and indicated that the operation of MAR is not complex and can be operated if there is knowledge. Meanwhile, most of the interviewees are neutral in agreeing that higher risks are the obstacle and some disagreed that the MAR technology has higher risks. Furthermore, the standard deviation score for all the obstacles except for absence of MAR experts are less than 1.00 which shows that the interviewees have high level of consensus on the degree of agreement for these obstacles. As for absence of MAR experts, it achieved a score of 1.00 which proved that it has achieved a reasonable level of consensus among the interviewees.

From an open-ended question, interviewee 3 said that most businesses rely on the policies of their clients, which presents another challenge. Only when the client requests the technology or method like MAR technology will money be spent. For instance, no business will invest the money to buy the software and send employees for training if the client does not want the work program in Primavera P6 format. The business will continue to create work programs using the conventional style of Microsoft Project software. It has to do with MAR technology. The business will take the initiative to implement MAR for the projects if the client requests that MAR technology be employed.

4.3 Strategies to Enhance MAR Implementation for Construction Cost Management

Table 5 shows the strategies that can be implemented in Malaysia to enhance the implementation of MAR for construction cost management. This part also requires the interviewees to rate their level of agreement for these strategies which are to provide financial support, educate on MAR, provide training, and establish proper guidelines for MAR technology.

Table 5. Strategies to enhance MAR implementation for cost management.

Rank	Strategies	Mean	Standard Deviation
1	Give financial support (Government supporting future budgets)	4.71	0.49
2	Educate on MAR technology	4.57	0.54
3	Provide training to produce experts in MAR	4.29	0.49
4	Establish proper guidelines and standard regulations	4.29	0.76

Section C of the questionnaire required the interviewees to rate their degree of agreement on the strategies that can be applied to enhance the MAR implementation for cost management of construction projects in Malaysia. All the strategies listed in this section achieved the mean score more than 3.75. This shows that all of the strategies are highly significant to the enhancement of MAR implementation for cost management. Giving financial support to use MAR is the most significant strategy chosen by the interviewees (mean 4.71) with the lowest standard deviation (0.49) that has been identified as the key strategy recommended by the respondents for the study. Furthermore, the standard deviation for all of the strategies calculated were less than 1.00 which indicate that high level of consensus has been achieved for all of the strategies. Giving financial support and providing training to produce experts in MAR shared the highest standard deviation score of 0.49 which indicate that these strategies have the highest level of consensus among the interviewees. Additionally, interviewee 3 emphasized in the open ended question that the government or customer should incorporate MAR technology use by contractors or businesses into their regulations. Companies or contractors working on the project will be forced to utilize MAR technology once it is incorporated into the policies.

5.0 DISCUSSIONS

5.1 Obstacles Hindering MAR Implementation for Cost Management

The interviewees have agreed that high investment cost for MAR as the main obstacles of its implementation for cost management. This is aligned with some of the past research studies that stated the technology itself requires high costs to be invested to acquire it (Zakaria et al., 2021; Pan & Isnaeni, 2024). Due to this, the companies become reluctant to spend on MAR technology with high costs and persist on using the traditional method. Besides, high cost to change the traditional method to MAR and the expenses related to MAR also recorded as relatively high mean score and level of consensus from the standard deviation score among the interviewees. In relation to this, MAR technology requires some costs to be allocated to buy appropriate mobile devices and for its expenses such as the apps, license, and maintenance. This is agreed as past literatures stated that the cost of upgrading, maintaining, and other related expenses is included in the high cost of switching to MAR technology (Chai et al., 2019; Adebowale & Agumba, 2022). Next in rank is the lack of support from the Governance which can be seen as there is no financial support, policy, framework, and partnership with stakeholders. This is also noted in the Construction 4.0 Strategic Plan (2021–2025), where the government's support in a few areas were emphasized (CIDB, 2020). The inability to adjust with MAR also shares the same rank as the previous obstacles as it is partly due to their lack of understanding about it (Mohammad Azlan et al., 2022). Without the knowledge and understanding, it influences the ignorance in

MAR technology to increase as agreed by most of the interviewees.

This is followed by the absence of precise MAR's guidelines for cost management. The interviewees mostly agreed on this obstacle, and it is aligned with the literature which mentioned that guidelines shall be provided by government authorities to major stakeholders for the adoption of new technologies (Mugumya et al., 2019). These guidelines are important to contribute to the enhancement of the MAR implementation. Next, the absence of MAR experts also contributes highly to the implementation of MAR as experts are needed to operate MAR technology efficiently. Nevertheless, despite the fact that there is availability of the tools, devices, data, and software to apply MAR, there are not many MAR experts because of a lack of knowledge and interest in Malaysia (Ahmed, 2019; Zakaria et al., 2021; Kassis et al., 2023). Furthermore, the complex operation of MAR is next in rank. Most of the interviewees agreed on this obstacle as the technology itself is quite complex at the first place. In fact, the system will become more complex with the addition of lack of expertise, the need for additional funding and reluctance to using the technology (Shouman et al., 2021). However, as time passed by, researchers have stated that the operation of MAR is getting easier which is why there are some interviewees such as R4 who also stated that MAR technology can be utilized easily nowadays. This is supported by CIDB (2023) which stated that AR is one of the easy tools to be used in construction. Reljić et al. (2021) also mentioned that as opposed to other systems that use standard audio or video communication, MAR offers simpler ways to operate the technology. Lastly, higher risks are the least agreed obstacles by the interviewees. Nonetheless, it is undeniable that finding strategies for effectively integrating emerging technologies like MAR always necessitates taking significant risks and effort in order to ensure project success (Wang et al., 2023).

5.2 Strategies to Enhance MAR Implementation for Cost Management

Giving financial support for the construction players to apply MAR in cost management is crucial as financial issues have been identified as the main obstacles for MAR implementation to be applied in cost management. The government can be part of the sources of funding that provide financial assistance to enhance MAR implementation for cost management. According to Oke & Arowoiya (2021), the government should be prepared to offer subsidies in order to facilitate the increasing adoption of these advanced technologies in the construction sector. Next, the interviewees agreed on providing education on MAR technology as this can increase the knowledge regarding MAR technology for cost management. Professionals involved in cost management should get education and training to encourage the use of developing technologies like MAR according to the Construction 4.0 Strategic Plan (2021–2025) (CIDB, 2020).

Third in rank is to provide training to produce more experts in MAR technology as most of the interviewees agreed that this strategy is highly significant to MAR implementation enhancement. According to Rajaratnam et al. (2021), raising awareness and offering training will aid in addressing the problems associated with a lack of MAR experts and a lack of understanding of MAR technology. Lastly, establishing proper guidelines and standard regulations for MAR to be applied in cost management has a high mean and consensus among the interviewees. According to Mohammad Azlan et al. (2022), guidelines are crucial to improve MAR implementation as it will allow the experts in the field to have appropriate regulations to refer to while utilizing MAR technology in the building sector, guidelines are crucial to improve its implementation.

5.3 Limitations

Some limitations were discovered while doing this investigation. As a result, it is critical to recognize these limitations and interpret the results in light of them. Firstly, there are a few experts in the built environment industry who have knowledge, experience or skill in MAR for construction cost management. This study discovered a very small number of eligible interviewees. As a result, the outcome may differ if more eligible interviewees are available. Secondly, the research was undertaken in a short timeframe, resulting in a small number of interviewees. Furthermore, the obstacles are confined to only four (4) main categories for MAR due to time constraints in study. As a result, the outcome may not reflect in-depth findings. Besides, when analyzing the study, it is crucial to consider that the results are mostly applicable to mid-sized construction enterprises in developed regions with relatively established technological infrastructure. The findings may not be immediately applicable to small businesses or those operating in areas with limited access to technologies. As a result, while the study implies that MAR may improve cost management efficiency in specific circumstances, future research is needed to determine its application in other regions.

6.0 CONCLUSION

This paper has presented the obstacles that can hinder the MAR implementation in cost management of construction projects, and suitable strategies that can be appropriately for recommendation to improve the MAR practice. The study has identified eight (8) obstacles that have hindered the MAR implementation where the high investment cost has been identified as the key obstacle. The study has identified four (4) strategies where the respondents have reached consensus that providing financial support as the key strategy to overcome the obstacles of MAR implementation for cost management practice. Apart from identifying the obstacles and strategies, this research contributes to the insight's knowledge about MAR implementation in construction cost management which will indirectly boost the awareness about MAR technology for cost management. Limited research currently available on the implementation of MAR for cost management, hence it is appropriate for recommendation a second phase of study to be carried out on the effectiveness of MAR application for cost control that could add up to the body of knowledge in the cost management practice in the construction industry.

ACKNOWLEDGEMENTS

This paper presents part of the findings of an unpublished dissertation submitted by the first author under the supervision of the second author:

Umaira Husna Binti Abdul Rahman 2015020 (2024). Mobile Augmented Reality (MAR) Application for Construction Cost Management in Malaysia. [Unpublished Degree's Dissertation], International Islamic University Malaysia.

7.0 REFERENCES

Abdeen, F. N., Gunatilaka, R. N., Sepasgozar, S. M., & Edwards, D. J. (2022). The Usability of a Novel Mobile Augmented Reality Application for Excavation Process Considering Safety and Productivity in Construction, Construction Innovation, 24(4):892–911.

Adebowale, O. J. & Agumba, J. N. (2022). Applications of Augmented Reality for Construction Productivity Improvement: A Systematic Review, Smart and Sustainable Built Environment, 13(3):479-495.

Ahmad, A. J. & Ayob, M. F. (2023). Flood Mitigation Management Practice: A Comparison Between Stormwater Management Road Tunnel (SMART) and Sponge City Methods, Journal of Management Practice, 3(2):1-17.

Ahmed, S. (2019). A Review on Using Opportunities of Augmented Reality and Virtual Reality in Construction Project Management. https://www.researchgate.net/publication/330218685_A_Review_on_Using_Opportunities_of_Augmented_Reality_and_Virtual_Reality_in_Construction_Project_Management

Ahmed, S., Hossain, M. M. & Hoque, M. I. (2017). A Brief Discussion on Augmented Reality and Virtual Reality in Construction Industry, Journal of System and Management Sciences, 7(3):1-33.

Ayob, M. F. & Abdul Rashid, K. (2020). Investigation on Quality of Cost Data Input in Life Cycle Cost (LCC) Analysis in Malaysia, Journal of Architecture, Planning and Construction Management (JAPCM), 5(2):1-9.

Bademosi, F., Blinn, N., & Issa, R. R. A. (2018). Use of Augmented Reality Technology to Enhance Comprehension of Construction Assemblies, Journal of Information Technology in Construction, 24(4):58–79.

Bahaudin, A. Y., Elias, E. M., Dahalan, H. & Jamaluddin, R. (2012). Construction Cost Control: A Review of Practices in Malaysia, The 3rd. International Conference on Technology and Operation Management (ICTOM 2012), Bandung, Indonesia, pp 1-10.

Ballesteros, J. (2021). MMC Gamuda KVMRT (T) Private Limited Secures Win at Malaysia Technology Excellence Awards. Singapore Business Review. https://sbr.com.sg/co-written-partner/more-news/mmc-gamuda-kvmrt-t-sdn-bhd-secures-win-malaysia-technology-excellence-a

Cao, J., Lam, K. Y., Lee, L. H., Liu, X., Hui, P. & Su, X. (2023). Mobile Augmented Reality: User Interfaces, Frameworks, and Intelligence, ACM Computing Surveys, 55(9):1-36.

Carlsén, A. & Elfstrand, O. (2018). Augmented Construction: Developing a framework for Implementing Building Information Modeling through Augmented Reality at Construction Sites. https://www.diva-portal.org/smash/get/diva2:1215627/FULLTEXT01.pdf

Chai, C. S., Lau, S. E. N., Eeydzah, A., Loo, S. C., Gheisari, M. & Mohamed AbdelRaouf, A. (2019). Integration of Augmented Reality in Building Information Modelling: Applicability and Practicality, WIT Transactions on the Built Environment, 192(3):281-290.

Chi, H., Kang, S.-C., & Wang, X. (2013). Research trends and opportunities of augmented reality applications in architecture, engineering, and construction. Automation in Construction. Construction Industry Development Board (CIDB). (2023). Taking Construction to The Next Level with AR/VR. https://www.cidb.gov.my/eng/taking-construction-to-the-next-level-with-ar-vr/

Construction Industry Development Board (CIDB). (2020). Construction Industry 4.0 Strategic Plan (2021-2025). https://www.cream.my/data/cms/files/Construction%204_0%20Strategic%20Plan%202021-2025(1).pdf

Construction Industry Development Board (CIDB). (2020). ICW, International Construction Week 2020(ICW 2020): Embracing Construction Revolution. https://www.cidb.gov.my/international-construction-week-2020-icw-2020-embracing-construction-revolution/

Delgado, J. M. D., Oyedele, L., Beach, T. & Demian, P. (2020). Augmented and Virtual Reality in Construction: Drivers and Limitations for Industry Adoption. Journal of Construction Engineering and Management, 146(7). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001844

Farghaly, K., Amin, K., Mills, G., & Wilson, D. (2023). Enhancing Interactions in Augmented Reality for Construction Sites: Introducing the Archi Ontology, In Proceedings e report, pp 848–855 (2023).

Fariq, N., Fatina, J. & Tan, S. (2021). Construction Industry Development Board (CIDB), Digital Cost Management: Enhancing Cost Effectiveness and Project Performance in Malaysia Construction Industry. https://smart.cidb.gov.my/article/digital-cost-management-enhancing-cost-effectiveness-and-project-perfomance-in-malaysia-construction-industry-392

Gounaridou, A., Pantraki, E., Dimitriadis, V., Tsakiris, A., Ioannidis, D., & Tzovaras, D. (2023). Semi-Automated Visual Quality Control Inspection During Construction or Renovation of Railways Using Deep Learning Techniques and Augmented Reality Visualization, In Proceedings e report, pp 865–876 (2023).

Hajirasouli, A., Banihashemi, S., Drogemuller, R., Fazeli, A., & Mohandes, S. R. (2022). Augmented Reality in Design and Construction: Thematic Analysis and Conceptual Frameworks, Construction Innovation, 22(3):412–443.

Heinzel, A., Azhar, S. & Nadeem, A. (2017). Uses of Augmented Reality Technology During Construction Phase, Conference: 9th International Conference of Construction in the Twenty-first Century (CITC9), Dubai, United Arab Emirates, pp. 1-8.

Hernandez, C. C. & Brioso, X. (2018). Lean, BIM and Augmented Reality Applied in the Design and Construction Phase: A Literature Review, International Journal of Innovation, Management and Technology, 9(1):60–63.

Kai, J. (2023). GET, Envisioning the Future Through Augmented Reality. https://gamuda-get.com/gamudacove_ar/

Kanivets, O. V., Kanivets, I., Kononets, N. V., Gorda, T., & Shmeltser, E. O. (2020). Development of Mobile Applications of Augmented Reality for Projects with Projection Drawings, Proceedings of the 2nd International Workshop on Augmented Reality in Education, pp 262-273.

Kassis, R. E., Ayer, S. K. & Asmar, M. E. (2023). Augmented Reality Applications for Synchronized Communication in Construction: A Review of Challenges and Opportunities. https://www.mdpi.com/2076-3417/13/13/7614

Li, X., Yi, W., Chi, H. L., Wang, X., & Chan, A. P. (2018). A Critical Review of Virtual and Augmented Reality (VR/AR) Applications in Construction Safety, Automation in Construction, 86:150–162. https://doi.org/10.1016/j.autcon.2017.11.003

Lin, J. P. (2021). Augmented Reality Use in Construction - A Case Study of the Industry.https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi? article=1525&context=cmsp

Machado, R. L., & Vilela, C. (2020). Conceptual Framework for Integrating BIM and Augmented Reality in Construction Management. Journal of Civil Engineering and Management, 26(1):83–94.

Mannan, S. (2020). Best Practices of Semi-Structured Interview Method. https://www.researchgate.net/publication/341232398_Best_practices_of_Semi-structured_interview_method

Maslam, W. (2023). Project Manager, Construction Cost Management: Managing Construction Costs. https://www.projectmanager.com/blog/construction-cost-management

Masood, T., & Egger, J. (2019). Augmented Reality in Support of Industry 4.0—Implementation Challenges and Success Factors, Robotics and Computer-integrated Manufacturing, 58:181–195. https://doi.org/10.1016/j.rcim.2019.02.003

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). Qualitative Data Analysis: A Methods Sourcebook.

MMC GAMUDA. (2020). Developing and Implementing AR for Construction Validation. https://mmcgamudamrt.com.my/developing-and-implementing-ar-for-construction-validation/

Mohammad Azlan, N. A. H., Omar, R. & Mohamed, S. (2022). The Augmented Reality (AR) Technology Modernized the Evolution of Construction Industry in Malaysia, Research in Management of Technology and Business, 3(1):627-647.

Mugumya, K. L., Wong, J. Y., Chan, A. & Yip, C. C. (2019). The Role of Linked Building Data (LBD) in Aligning Augmented Reality (AR) with Sustainable Construction, International Journal of Innovative Technology and Exploring Engineering, 8(64):366-372.

Nassereddine, H., Hanna, A. S., Veeramani, D., & Lotfallah, W. (2022). Augmented Reality in the Construction Industry: Use-Cases, Benefits, Obstacles, and Future Trends, Frontiers in Built Environment, 8. https://doi.org/10.3389/fbuil.2022.730094

Oke, A. E. & Arowoiya, V. A. (2022). Critical Barriers to Augmented Reality Technology Adoption in Developing Countries: A Case Study of Nigeria, Journal of Engineering, Design and Technology, 20(5):1320-1333.

Pace, F. D, Manuri, F. & Sanna, A. (2018). Augmented Reality in Industry 4.0, American Journal of Computer Science and Information Technology, 6:1-17. https://doi.org/10.21767/23493917.100017

Pan, N. H. & Isnaeni, N. N. (2024). Integration of Augmented Reality and Building Information Modeling for Enhanced Construction Inspection—A Case Study, Buildings, 14(3):1-21.

Piroozfar, P., Bosesley, S., Essa, A., Farr, E. R. P., & Jin, R. (2018). The Application of Augmented Reality (AR) in the Architectural Engineering and Construction (AEC) Industry, The Tenth International Conference on Construction in the 21st Century (CITC-10), Colombo, Sri Lanka, pp 1-8.

Public Works Department (2019). National Construction Policy 2030. https://www.kkr.gov.my/sites/default/files/2022-10/Dasar-Pembinaan-Negara-NCP2030.pdf

Rajaratnam, D., Weerasinghe, D. M. L. P., Abeynayake, M., Perera, B. A. K. S., & Ochoa, J. J. (2021). Potential Use of Augmented Reality in Pre-Contract Design Communication in Construction Projects, Intelligent Buildings International, 14(6):1–18.

Ratajczak, J., Riedl, M. & Matt, D. T. (2019). BIM-based and AR Application Combined with Location Based Management System for the Improvement of the Construction Performance, Buildings, 9(5):1-17.

Reljić, V., Milenković, V., Dudić, S., Šulc, J. & Bajči, B. (2021). Augmented Reality Applications inIndustry 4.0 Environment, Applied Sciences, 11(12):1-17.

Roslan, A. F., Baslan, N., Safura, N., Ghani, M. K., Jusoh, R. M., Abd. Hamid, Z., Syed Aluwi, S. N., Sundaraj, G., Aminuddin, E., Abidin, N. I., Lau., S. E. N. & Hong, H. T. S. (2021). Construction 4.0 to Transform the Malaysian Construction Industry, The Ingenieur. http://bem.org.my/documents/20181/268613/5.1.pdf/ea3269cb-ec2e-4d89-884a-33e24d2faa2a

Ruslin, Mahsuri, S., Abdul Rasak, M. S., Alhabsyi, F & Syam, H. (2022). Semi-structured Interview a Methodological Reflection on the Development of a Qualitative Research Instrument in Educational Studies. Journal of Research & Method in Education, Vol. 12, Issue 1, pp. 22-29. https://doi.org/10.9790/7388-1201052229

Senanayake, S., Gunawardana, P. a. M., Perera, B., & Rajaratnam, D. (2022). Examining the Potential Use of Augmented Reality in Construction Cost Management Tools and Techniques, Journal of Engineering, Design and Technology. https://doi.org/10.1108/jedt-10-2022-0512

Sepasgozar, S. M. E., Costin, A. M., Karimi, R., Shirowzhan, S., Abbasian, E., & Li, J. (2022). BIM and Digital Tools for State-of-the-Art Construction Cost Management, Buildings, 12(4):1-28.

Sidani, A., Dinis, F. M., Duarte, J., Sanhudo, L., Calvetti, D., Baptista, J. S., Martins, J. P., & Soeiro, A. (2021). Recent Tools and Techniques of BIM-Based Augmented Reality: A Systematic Review, Journal of Building Engineering, 42(1):1-22.

Shouman, B., Othman, A.A.E. and Marzouk, M. (2021). Enhancing Users Involvement in Architectural Design Using Mobile Augmented Reality, Engineering, Construction and Architectural Management, 29(6):2514-2534.

Sohu (2023). The Application of AR Mobile Augmented Reality Technology in Smart Construction Sites Are Changing the Way Traditional Construction is Done. https://www.sohu.com/a/711566900_121257929

Syed Zakaria, S. A. & Singh, A. K. M. (2021). Impacts of Covid-19 Outbreak on Civil Engineering Activities in The Malaysian Construction Industry: A Review, Journal of Engineering, 33(3):478-485.

Wafa, S. N. & Hasim, E. (2016). Adoption of Mobile Augmented Reality Advertisements by Brands in Malaysia, In Procedia - Social and Behavioural Sciences 219, pp 762-768 (2016).

Wang, K., Guo, F., Zhou, R., & Qian, L. (2023). Implementation of Augmented Reality in BIM-enabled Construction Projects: A Bibliometric Literature Review and A Case Study from China. Construction Innovation, 26:441-457. https://doi.org/10.1108/ci-08-2022-0196

Zaher, M. M., Marzouk, M. M. & Greenwood, D. (2018). Mobile Augmented Reality Applications for Construction Projects, Construction Innovation, 18(2):152-166.

Zakaria, Z., Omardin, M., Rahman, R., & Haron, A. (2021). Barriers to Augmented Reality Application in Construction: An Exploratory Study in Malaysia, In PENERBIT UNIVERSITI MALAYSIA PAHANG eBooks, pp 77-102 (2021).