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The Augmented Reality (AR) Technology Modernized the Evolution of Construction Industry in Malaysia

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Abstract: The idea of implementation Augmented Reality (AR) is technology applicable when it helps the Architecture, Engineering, and Construction (AEC) industry in visualized their project without actually contact with many people or even need to go to physical sites visit. The globalization of the COVID-19 pandemic, as well as its economic consequences, are expected to wreak havoc on all economies around the world, plunging millions into recession and probably depression. Hence, to counter back the product in the shortest time, AR plays a big role in making it come true. The objectives of this research are to investigate the implementation of Augmented Reality (AR) the technology in the construction industry, to identify the challenges in the implementation of Augmented Reality (AR) technology in the construction industry and to identify the strategies in boosting the implementation of Augmented Reality (AR) technology. As to examine the current condition of AR adaptation technology in Malaysia, an interview session (Qualitative approach) will be held in the AR industry the and AEC industry. Here, semi-structured interviews using Google Meet act as the main tool for collecting data. Consider that higher exposure to Augmented Reality technology will benefit the AEC industries. The findings in this research expose the AEC industry to new technology and aid the industry in dealing with the new norm of the COVID-19 pandemic. It is envisaged that this would enhance their traditional enterprises and bring them in line with IR 4.0.

Keywords: Augmented Reality, AEC industry, Construction, COVID-19, I.R 4.0

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1. Introduction

Augmented Reality (AR) is a technology that allows real and live visuals to coexist with virtual information via a mobile interface (Zhou *et al.*, 2008). This technology has mostly been used in the fields of entertainment, shopping, travel, advertising, and social communication (Wang *et al.*, 2013). Because of its enhanced simplicity of use and cost, the usage of AR in the construction sector has 2 become increasingly realistic. Simultaneously, the potential for these technologies to increase efficiency and production has proven appealing to the AEC sector (Fard *et al.*, 2011). Whereas the economics of the COVID-19 outbreak may be too early to be discussed, it remains relevant due to the devastation caused by direct and indirect economic effects in each country. The economic consequences of the outbreak are commonly called "Coronanomics" (Eichengreen, 2020). As to cope with these issues, the construction industry requires greater decision making at on-site work, which demands portable and context-aware visualization on a real building site, which justifies the adoption and promise of AR as a choice tool, as opposed to virtual reality (Wang *et al.*, 2013)

2. Literature Review

The main literature review's goal is to obtain an understanding of the current research and debates pertinent to a certain topic or area of study and to deliver that information in the form of a written report. By conducting a literature study, knowledge in these cases could expand. It shows how other researchers apply the topics that have been learned in their courses to real-world challenges. Another significant advantage of conducting a literature review is to have a better grasp of how research findings are presented in the case study. According to Bademosi *et al.* (2018), the research conduct brings to the attention of construction experts the most up-to-date research trends and advancements in AR applications and helps to optimize construction processes in the sector during the pandemic. Hence, this chapter outlines the work carried out in various phases of development and shows the possible benefits of AR adoption in the AEC industry.

2.1 The Implementation of Augmented Reality in the Construction Industry

According to Chi *et al.* (2013), Augmented reality (AR) creates an environment that superimposes the information generated by the computer on the view of the user from an actual world scene. As AR technologies are growing mature and well developed, AR applications are increasingly variable and popular. The current trend for the production of AR applications that can benefit the industrial sector is AR studies and approaches. The AR technologies will be sufficiently mature to be widely applied in the industrial sector within the next 10 years with the current rates of development.

(a) Construction Phase

During the construction phase, the construction manager will oversee quality control, supervise the contractor's safety, verify contractors' work per specifications, coordinate permits, technical inspections, and testing, and monitor RFIs and submittals to ensure they are on schedule. Their attentiveness during the construction phase services is vital to keeping the project on track. Table 1 in Appendix A explains the implementation of Augmented Reality in the construction phase which is divided into construction planning, progress monitoring, construction safety, and training.

2.2 Challenges in Implementation of Augmented Reality in the Construction Industry

Augmented Reality is a relatively new technology that is not yet frequently used in the construction industry. There are a few distinct stages or divisions in the AEC industry that confront significant challenges in deploying AR technology (Delgado *et al.*, 2020).

(a) Stakeholder Engagement

The AR representations can provide customers with a greater knowledge of built assets at real scale, in an immersive setting, than photographs or films (Grudzewski *et al.*, 2018). Kim *et al.* (2009), for example, introduced an AR system to enhance cultural heritage tours by superimposing virtual items on cultural locations. Besides, Tan and Lim (2017) developed an AR virtual tour system to increase exploration experiences in locations of historical importance. According to Delgada *et al.* (2020), for stakeholders' engagement, the AR challenge has resulted in three major problems which are non-consistent and unrealistic lighting of virtual objects, drifting faults, and improper position and motion tracking virtual objects overlay at long distances.

(b) Design Support

AR can help designers identify the ramifications of their design decisions and grasp the final outcomes more effectively (Delgada *et al.*, 2020). Nee *et al.* (2012) also discussed how AR may be used to encourage collaborative design by which different users engage with a single virtual model rather than with physical mockups. Hence, Fukuda *et al.* (2019) introduced an AR method for visualizing thermal simulation data in order to facilitate retrofitting. According to Delgada *et al.*, (2020), the principal challenges of using AR to support design include the fact that changes to building information modeling (BIM) using AR systems are extremely difficult to transpose.

(c) Design Review

The AR facilitates the transmission of design intent, allowing designs to be examined more effectively, problems to be recognized more simply, and sign-off to be completed more rapidly (Delgada *et al.*, 2020). The key problems of adopting AR for design review, similar to design support, are the difficulties of translating design modifications to BIM models and recording the experiences and talks those users had within the AR environments. It is necessary to have two-way, seamless, and automated communication between construction BIM models and AR models (Delgada *et al.*, 2020). Dris *et al.* (2019) introduced an ontology that allowed a bi-directional interface between a BIM model and a VR application, which solved some of these issues.

(d) Construction Support

Construction support is an important element of the construction process. The AEC and project manager's inventiveness throughout this period of service is critical to keeping the project on schedule. Construction support is divided into four stages which are construction planning, progress monitoring, construction safety, and training. Table 2 which indicated the challenges of Augmented Reality in construction support is attached in Appendix B. The main limitations of AR were emphasised here.

2.3 Strategies to increase the Implementation of Augmented Reality in the Construction Industry

In order to generate innovative construction goods that would fulfill consumers' preferences, enterprises must be early adopters of innovativeness and be able to accept innovative construction products or materials. Market orientation is also important in entails organizations implementing a marketing culture that prioritizes client happiness above all else. Governments (at both the national and international levels) have established and implemented numerous regulatory frameworks in most areas of the world to guarantee that the construction industry's operations are sustainable. This approach enables businesses to consider customer happiness to be the most effective method to achieve their goals. Table 3 in Appendix C shows the strategies for increasing the implementation of Augmented Reality in construction support.

3. Research Methodology

The research methodology is methods of data collecting for research purposes are identified. There are two main types of research approaches which are quantitative analysis and qualitative analysis methods. The purpose of pursuing research methodology is to provide best practices from respondents who are reacting to the field by producing guidelines, points of view, and other forms of reflection. Figure 1 in Appendix D, enlighten the flow of the research process for this study. Hence, the consequences of the pandemic have been the disruption of fieldwork conducted with local contacts, whether they survey administrative overhead or local organizations. In order to obtain all of the relevant information from the respondents for this study, the researchers chose to employ qualitative methodologies.

3.1 Research Design

The research will start by identifying the problem and issues in the construction industry. By then, an objective was created to direct good research and study. To have good evidence and proven, numerous journals from researchers have been retrieved and go through. All the data are collected from official government websites and official constituent parties' websites. An interview session (Qualitative method) will be held in the AEC sector to investigate the genuine state of AR adaptation technology in Malaysia. At least there will be interviewees from an AR developer and AEC Professional. Each respondent will be recruited from their company, who is appropriate for this research. The interview will be performed in accordance with Google Meets' quality approach.

3.2 Data Collection

(a) Primary Data

A semi-structured interview will be held. Semi-structured interviews, according to Wildermuth (2009), are more adaptable. A guided interview includes both closed-ended and open-ended questions. Furthermore, during the interview, the researcher has some autonomy to change the order of the questions to be asked and to add questions based on the context of the respondent's response. Here the interviewer asks close-ended and open-ended questions about a specific study topic and attempts to let the interview run naturally.

(b) Secondary Data

To improve the validity of data, a literature review of past journal articles and research was conducted. The published literature reviews help to provide a synthesis and analysis of past research about the issues.

3.3 Data Analysis

(a) Qualitative method: Interview Sessions

Due to limitations during this pandemic, Google Meet seems to be the best approach for realization of this research. According to Google Official Websites (2021), Google is making enterprise-grade video conferencing open to the general public. Anyone with a Google Account may host an online meeting with up to 100 attendees at one time.

(b) Snowball Sampling

According to Parker (2019), snowball sampling is a prominent form of sampling in qualitative research, with the features of networking and recommendation at its core. Researchers often begin with a limited number of initial contacts who meet the research requirements and are invited to participate in the study. The willing respondent are then requested to propose additional contacts who meet the research requirements and might possibly be willing participants, who in turn recommend more possible

participants. Based on the data gathered, researchers identified a few notable AR technology developers, the majority of whom have their headquarters offices in Malaysia. Comply with the research purposes, the respective developer and construction companies from Wilayah Persekutuan and Selangor will be involved in this process. This location was picked because it has the most construction industries and has the most robust constructions operations in comparison to other states. These three major states, including Sarawak, contributed RM18.1 billion (57.6%) of the value of building work completed in the first quarter of 2021, (DOSM,2021). Hence, the majority of listed AR developer companies are also located in these two states of Malaysia. With 349,765 workers, civil engineering had the most persons working in it (or 26.3%) (DOSM,2020). According to DOSM (2019), the construction sector accounts for 7.9 percent of Kuala Lumpur's GDP. As a result, the construction sector in Kuala Lumpur employs 67,680 people. Furthermore, the construction industry employs around 201,550 people and contributes up to 6.0 percent of Selangor's GDP. These statistics on AEC workers in Malaysia provide a chance to conduct research and reach a larger number of potential respondents. Five respondents from the AEC sector participated in the researcher's distribution of questions and conduct of the interview based on the sample participant.

4. Results and Discussion

The most important aspect of any research is data analysis. Data analysis is the process of summarizing the information gathered. It entails the analysis of data acquired by the use of analytical and logical reasoning to identify patterns, correlations, or trends. Qualitative and descriptive research methodologies have been widely used in numerous areas, including education, psychology, and social sciences (Nassaji, 2015). Good qualitative research utilizes a rigorous empirical method to answer questions about what something is like, what people think or feel about something that has happened, and why something has happened the way it has. Qualitative data is frequently in the form of words or text, but it may also contain visuals (Seers, 2011). As researchers have a stack of interview transcripts, field notes, papers, and observations they can define that analysis as a process of transformation and interpretation (Richards and Morse, 2007).

4.1 Thematic Analysis

The data analysis process is best depicted as a spiral by traveling in analytic rings leading to a more centered circle (Creswell & Poth, 2018). Throughout this key step of the research process, the researcher will gather analytical inferences from the data represented as codes and then themes. Despite the fact that the phases of data analysis are stated in a linear order, interpretation does not have to wait until the completion of the process. In reality, the researcher's interpretation should occur throughout the first three phases compiling, disassembling, and reassembling (Matowe, 2019). Researchers will frequently create a thematic map as part of this level of analysis, which is a visual depiction of themes, codes, and their interactions (Daley, 2004). This graphic depiction adds another dimension to the study by allowing the researcher to locate the themes in the wider context of the phenomenon's bigger environment (Kuckartz, 2014).

4.2 Section A: Background of Respondents

Table 4: Background of Respondents

Respondent	Position	Sector	Company	Years of Experience
R1	CEO	AR Developer	A	4
R2	Project Manager	AR Developer	B	3
R3	Head of BIM	AEC Professional	C	12

R4	Project Manager	AEC Professional	D	25
R5	Associate Architect	AEC Professional	E	9
R6	Architect	AEC Professional	F	8
R7	Sale Engineer	AEC Professional	H	7

According to Table 4, all respondents will be represented by the letter R. While discussing, the letters A, B, C, D, E, F and G will be used to represent the company. Each company is represented by its own management or people concern. As a result of massive, only company A and B is an AR Developer, while the others (C, D, E, F, G) are in the AEC industry. As stated, all respondents were from Kuala Lumpur and Selangor. They were all authorized companies under the Malaysian Construction Industry Development Board (CIDB) and the Malaysian Institute of Architects (PAM). The background of seven respondents from the interview is shown in Table 5 in Appendix E. Their job experience, educational qualifications, and job responsibilities will be included here.

4.3 Section B: Implementations of Augmented Reality (AR) Technology in the Construction Industry

Table 6 will present the results of the interviews performed about the implementation of Augmented Reality (AR) Technology. According to a survey of seven respondents, just two have utilised AR in their company. The remaining five respondents are aware of how Augmented Reality is implemented and used. The purpose of this part is to collect respondents' ideas and perspectives on Augmented reality technology in the construction process.

Table 6: Implementation of Augmented Reality (AR) Technology in Their Company

Category	Respondent						
	R1	R2	R3	R4	R5	R6	R7
Implementation	✔	✔	✔				
Source	✔	✔	✔				
Effect	✔	✔	✔				
Circumstance	✔	✔	✔				

Based on Table 6, only three respondents had experience in implementing Augmented Reality in their business. Even though R1 was in charge of developing the AR and VR application, their company (Company A) had no prior experience using their product in the construction sector. R1 stated that it is not practical for the construction industry to use AR due to the expensive cost. Furthermore, the construction industry already has BIM, which will ultimately enable AEC to focus their duty. R1 recommended Revit and Autodesk as applications for persons working in the construction industry. The pricing was substantially lower but the end outcomes remained the same, assisting AEC in visualizing the project at an early stage. R1 explains that as an AR developer, they obtain their technology from Microsoft and Google. He stated here that there are now just a few companies that have managed to develop an AR VR ecosystem. For your knowledge, all of these sources are from the United States.

Next is R2 from Company B. As a developer he makes an AR and VR apps. He is in charge of all programming in their company. As a result, he is well-versed in the limitations of each technology. In terms of implementation, their company has no prior involvement with the construction industry, but they have worked with other industries. According to what researchers have discovered, there are currently a plethora of AR frameworks available, such as AR Core and AR Kit. When he updated the framework in order to understand each app's limitations, he discovered that the construction sector is

well-suited to integrating AR technology into their processes. The essential point is that they may experiment with marker tracking and marker striking technologies.

Moving on to R3. As a former employer in Company B, R2 has already implemented Augmented Reality (AR) in their project. They experiment with a few AR applications from the international market following standard, they decided to incorporate Dalux, AR VR for Autodesk, and Scale. As a result, he could say these three applications mentions before provide the finest services in comparison to others. AR, in their opinion, has a bright future in our nation. According to R2, he hopes Malaysians begin to perceive AR as more than simply a flashy software. If our government supported future budgets adequately, more companies would strive to use AR. In regards of R3, he believes that there is already a positive trend in our country to improve AR technology. He also believes that contractors would embrace AR since it will help their employees. It may be a long process, but it is increasingly becoming the new standard for contractors.

Even though R4, R5, R6 and R7 have never used AR technology in their works, they are all aware of it and have some knowledge of it. Respondents R4, R5, R6 and R7, believe that AR will be effectively used in our construction industry in the next 5 to 10 years. All of this is because CIDB encouraged AEC to adopt new technologies while executing their responsibilities. Table 7 in Appendix F shows the responses of seven respondents on the implementation of Augmented Reality (AR) Technology in the Construction Industry. They provide a brief assessment of how the use of AR will update the AEC sector in general.

4.4 Section C: Challenges in Implementations of Augmented Reality (AR) Technology in Construction Industry

To verify the difficulties and challenges of implementing AR technology in the construction sector and dealing with a variety of circumstances. The researcher would like to investigate the challenges that respondents have while implementing AR technology in the construction industry with six respondents in this section. Based on an interview with six respondents, researchers identified the challenges that must be overcome when implementing AR technology. Even though four companies (D, E, F, G) have yet to implement this technology, they have shared a brief explanation as the reason. Every respondent has a valid justification for doing so. The findings from the interviews concerning the challenges of Augmented Reality (AR) Technology will be shown in Table 8.

Table 8: Responses About the Challenges in Implementation of Augmented Reality (AR) Technology in Construction Industry

Challenges	Respondent						
	R1	R2	R3	R4	R5	R6	R7
General	✔	✔	✔	✔	✔	✔	✔
Stakeholder Engagement	✔	✔	✔	✔	✔	✔	✔
Design Support & Review	✔	✔	✔	✔	✔	✔	✔
Construction	✔	✔	✔	✔	✔	✔	✔

In relation to Table 8, the following were the primary issues that must be overcome while implementing AR Technology. According to the data gathered, R1 believes that there would be few issues if AR is used in the construction industry in 2021, as we are still a developing country, not a first-world country with advanced technology and numerous experts. Furthermore, AR is still in the process of being evaluated and is not yet stable. R2 mentioned that quality is their major issue throughout development. AR has a tough time maintaining their good texture of projection. They are working hard to improve this section. The graphic is also important. The performance of the result invention is also

important in determining whether it will lag or not. In addition, the budget is a barrier. Because visualization is vital in AEC, R2 said that the graphic did play a significant part here.

According to R3, the biggest problem with using AR and VR throughout the design stage is when they have a continuous presentation. R3 and the team are constantly updating the project plan (floor/elevation/section) for top management and clients. As a result, they must immediately update the new data in their cloud computing system. It is quite time consuming, since one job might take two to three months or more to finish. Researcher can say here, time constrain also the issue they need to face. R4 stated that as a small company, they were unable to implement such revolutionary technologies as AR. R5 highlighted that it must be practically difficult if we need to coordinate the usage of AR technology in a short period of time. Even our economy, as she stated, was not stable. We must deal with difficulties such as the worst fluctuation.

According to R6, the challenge of implementing new technology such as AR is not on the shoulders of AEC professionals, but on the shoulders of the highest authority, or as we say, the government. Architects need physically submit bids and other papers to their office, which is not suited for the current circumstances, but the authorities make this difficult. Both parties should take a step forward. It will not function well if only one party moves by themselves. R7 mentioned that one of the issues with AR is a shortage of talent and skills. Because the existing AEC is not truly exposed to AR. They didn't have this type of technology back then. As a result, they must study on their own through classes and YouTube. Table 9 in Appendix G justify the explanation from respondents.

4.5 Section D: Strategies in Increasing the Implementation of Augmented Reality (AR) in Construction Industry AR

Researchers conducted interviews with seven respondents in this part to assist them in determining the most legitimate and appropriate strategies for integrating AR technology in the construction sector. Based on interviews with seven employees from Companies A, B, C, D, E, F and G. Every respondent has an intriguing and valuable suggestion for increasing the adoption of new technology in the present construction industry. Table 10 displays the findings from the interviews regarding the strategies for increasing the implementation of Augmented Reality (AR) Technology.

Table 10: Strategies in Increasing the Implementation of Augmented Reality (AR) in Construction Industry

Strategies	Respondent						
	R1	R2	R3	R4	R5	R6	R7
General		✔	✔	✔	✔	✔	
Governance	✔	✔	✔	✔	✔	✔	✔
Company/Worker	✔	✔	✔	✔	✔	✔	✔
Mass media & Society		✔				✔	

All respondents (R1, R2, R3, R4, R5, R6 and R7) in Table 10 have elaborated on how each party should play their role in order to implement Augmented Reality Technology in the Malaysian construction industry. The primary purpose for every government to implement new reforms is to stabilize its economy.

R1 stated that Malaysia has a lot of software talent. The problem is that we don't have the capacity to manufacture hardware. Without the proper hardware, even the best software is rendered ineffective. According to R1 “good software without good hardware is pointless.” Aside from that, R1 disagrees with the assertion that social media plays an important role in promoting AR technology. This is due to the fact that not all citizens are required to apply in their daily lives. Only specialized professions need to be exposed to this type of technology, and all of these professionals already have their own sources of references, not mass media.

According to R2, one of the best strategies for increasing the implementation of AR technology is for the government to give subsidies or plans for industries to try to adopt AR. It might be either direct (as in monetary payments) or indirect (such as tax breaks). Subsidies are often offered to alleviate some form of burden, and they are frequently seen to be in the best interests of the general public, given to promote a social good or an economic policy. Since the main drawback is that AR may be quite expensive. The government must also educate our industry, since they are still unaware of the long-term benefits of AR.

R3 came up with a suggestion to get additional ideas. R3 stated that large authorities such as JKR and CIDB should encourage the adoption of new technologies. As previously stated, they have marketed the usage of BIM as outrageous. Until recently, every company has followed the rules. Not only that, however the company must play a part in ensuring that all employees are in accordance with the current industry.

As a Project Manager who manages the activities of an organization involving clients, R4 has her own opinion to increase the implementation of AR technology in construction industry. Regarding R4, the construction industry must go through a technological enforcement. The construction sector should limit the number of foreign workers on construction sites. We need to replace it with new technologies, such as Augmented Reality. Not only that, but the government should provide adequate funding for the implementation of all of these technologies. Here are some strategies offered by an Associate Architect, R5, who works with individuals at all levels of the building sector. R5 believes that all excellent things must begin at the beginning. Since a result, she believes it would be beneficial if the construction sector held a class or sharing session with university students, particularly those with an AEC background, as it would be more relevant. This sharing session might help both parties.

Based on R6, the government should revise their plan and strive to make it compulsory for all contractors to be AR ready in the future. Not only should that company provide proper training to its employees. Furthermore, the company and the student can work together to mentor one another. R7, like the other respondents, believes that the company should provide training to prepare employees for the current industry. Not just that company should be open to change. Company H, has a one-time investment to deal with their problem in the survey stages. Table 11 in Appendix H clarify the strategies suggest by seven respondents. Hence, most of the key player for a new change is either the government or their own organization/company.

4.6 Discussions

According to the data collecting and analysis procedure, the researcher could claim that every Research objective mentioned in the Literature review, including the implementation, challenges, and strategies for increasing Augmented Reality, was in line. Every respondent reinforced the preceding researcher's opinion by collecting additional journals. Table 12 shows the relation between Literature Review and data from respondents.

Table 12: Relation of Literature Review and Respondents

Category	Literature Review	Respondent
Implementation	Delgada *et al.*, (2020): - AR could see virtual items on construction sites	R1: "I could say that AR is also beneficial in another aspect since workers are not required to visit construction sites." (AR help in visualizing construction site without actually go there).
Challenge	Delgada *et al.*, (2020): - lack of interaction with existing certification standards.	R6: "The problem is not that we have a person who refuses to adapt, but that the authority itself refuses to shift from its existing place." (Highest authority and government don't play their roles and stuck in traditional ways).

Strategy	Manning *et al.*, (2012) - Government is a well-known factor that has a substantial impact on sustainability standards.	R4: "To ensure fairness, the government must standardize the technique of executing processes in the construction industry." (Government should give play their role in enhancing the implementation of new technologies).

5. Conclusion

This is the final chapter of the research. This chapter discusses the overall results and recommendations of the researcher's study. Furthermore, this chapter will evaluate whether the research's objectives which are related to Augmented Reality technology and the construction industry succeed or not. It is essential to analyze if all of the objectives have been fulfilled or otherwise. The study's findings are also expressed based on data collected from six respondents who respectively from six different companies. All of the respondents were keen to share their knowledge and experience with the researcher. This chapter also discusses all of the limitations and constraints encountered by the researcher while doing this investigation. In a nutshell, further study initiatives from researchers are also discussed in order to improve future research. Generally, the objectives indicated in the findings were met by this research. The following requirements were achieved:

1. To investigate the implementations of Augmented Reality (AR) technology in the construction industry.
2. To identify the challenges in the implementation of Augmented Reality (AR) technology in the construction industry.
3. To identify the strategies for increasing the implementation of Augmented Reality (AR) technology in the construction industry.

5.1 Research Objective 1: To investigate the implementations of Augmented Reality (AR) technology in the construction industry

As the interview session progressed, the overwhelming of respondent responses were quite linked to what the researcher indicated in the Literature Review. During a researcher's interview with a respondent regarding the implementation of AR technology, the interview questions were divided into four sections, which were implementation, source, effect, and circumstance.

According to the Literature Review, Augmented Reality is already being used in Malaysia's construction industry. Even after the researcher conducted an interview with the target respondent, it was discovered that there are construction companies that have already implemented AR. However, the rate of adoption remains modest. Respondents agreed with the assertion that AR aided the AEC in convincing them to do their task. According to Behzadi (2016), it is undeniable that augmented technology has the potential to significantly enhance the productivity of aspirational architects and field engineers.

The key impediment or circumstance here is that the majority of people in the AEC industry have no clue about AR technology and have never been educated about it. Even the majority of AR developers and companies have yet to have a partnership with the construction sector. Can also say that in Malaysia, everything is still in BETA mode and unstable. Regarding certain companies that use AR technology, the majority of them are not locally based; the technologies are often brought and recovered by first-world countries such as the United States.

5.2 Research Objective 2: To identify the challenges in the implementation of Augmented Reality (AR) technology in the construction industry

The second focus of this research is to identify the challenges in the implementation of Augmented Reality Technology in the construction industry. Even though only three of the respondents had prior experience with Augmented Reality technology, the vast number of respondent responses were directly

related to what the researcher suggested in the Literature Review. However, the remainder of the left representatives have never used this technology before, and they have attached explanations for their actions by sticking with old and inferior technology for the time being. The interview questions for a researcher's interview with a respondent about the challenges in the implementation of AR technology were divided into four segments, which were general challenges, stakeholder engagement, design stages and construction support.

Generally, the money is a barrier to using Augmented Reality Technology. Previously, the expenditure for using AR technology in any industry was extravagant. Because our economy is not solid and is still catching up to rise, it will be tough to implement these technologies on the spot. Following that, one of the challenges divisions has been sought for is stakeholder engagement. The majority of top management and senior workers found it difficult to adapt to new technologies. Not only that, but even high-level authorities are opposed to advancing new technologies in the construction industry because they prefer to play it safe and stick to old practices. According to Delgada *et al.* (2020), one of the major challenges in implementing AR technology in the construction sector is a lack of engagement with existing certification standards.

Furthermore, there are a few challenges that must be overcome during the design stages. Every detail is important in the construction industry. As a result, the AR Developer mentions that there is a need to improve the projection of AR objects and modify with appropriate technology. It is because they are aware that every scale in construction activity must be genuine in order to avoid errors. When it comes to Construction Support, the issues were difficult to notice because we already had a few technologies that had the same output as AR technology in seeing things that were much more reasonable. As a result, Nee *et al.* (2012) have already mentioned how AR might be used to foster collaborative design by having several users interact with a single virtual model rather than physical mock-ups.

5.3 Research Objective 3: To identify the strategies for increasing the implementation of Augmented Reality (AR) technology in the construction industry

The final objective of this study is to identify strategies for increasing the adoption of Augmented Reality Technology in the construction industry. Despite the fact that only three of the respondents have prior involvement with Augmented Reality technology, every one of them had a splendid idea for how to make this a reality. All of the suggestions made by respondents are relevant to the Literature Review. The question of strategies has been divided into four categories, which are as regards general strategies, governance strategies, company role, and mass media roles.

According to Manning *et al.* (2012), as backed by the Literature Review, government support is critical in growing the implementation of Augmented Reality in the construction industry. It is due to the fact that the government is a well-known factor that has a significant influence on sustainability standards. Furthermore, it is critical for organisations to improve the technical skills of their employees.

The company might work with a number of professional and trade organizations to guarantee that BIM and AR are accepted by all communities in the construction business, particularly SMEs (Zakaria *et al.*, 2021).

Researchers believe that AR technology can be improved in our industry if everyone is thoroughly educated and introduced to the concept of these technologies. All parties must perform their respective roles. Starting with the educational level. If we provide every level of people with a clear understanding of the benefits of this technology, perhaps one day everyone will be able to adapt to it.

5.4 Research Limitations

According to Pearson (2018), every study has limitations. Study limitations may develop as a result of study design or technique constraints. Regardless of the impact, everyone in the study report should clearly state any limitations. Here are some of the constraints that the researcher encountered while doing the research:

i. Limited access to Literature
Researchers might remark that it was challenging to identify particular strategies for implementing AR technology in the construction industry for this research. Respondents, fortunately, have explained all of the issues raised. Interviews with representatives from the AR and AEC sectors provided answers to the researcher's research objectives and research questions.

ii. Data collection process
Unlike prior years, during this year's semester, we were able to conduct in-person interviews with participants for the first time, thanks to internet platforms like Google Meet. All data and information could still be gathered smoothly because all respondents collaborated so generously. Even better, the researcher may immediately record the whole interview session from the laptop. Every element of the data may be clearly obtained because the recorded video is accessible and flexible for researchers to analyses.

In conclusion, the objectives of this investigation were achieved. This study is anticipated to deliver helpful and beneficial information to all stakeholders, particularly AR developers and the AEC industry. This research also aims to improve the construction industry by introducing new technologies and moving away from a safe zone. Everyone, even in these sectors, requires stepping stones to success in life. To guarantee the success of Augmented Reality deployment, all stakeholders must collaborate.

The suggestion for this additional study enables for future research to be conducted depending on the findings of the current study. This study also leaves room for future researchers to make improvements based on previous research. The recommendation has been divided into three category which are industry field, new knowledge, and for further research. The first objective is to investigate the level of satisfaction in the AEC industry with the implementation of Augmented Reality. Next, to identify the flexibility of Augmented Reality implemented in other industry and the last one is to identify level of maintenance required to sustain the good performance of Augmented Reality in a construction company.

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Appendix A

Table 1: The Implementation of Augmented Reality in Construction Phase

Author	Phase	Functions
Delgada *et al.* (2020) Mutis and Ambekar, (2020) Chu *et al.*, 018)	Construction Planning	AR focuses on visualising virtual objects that will be built immediately on-site. AR could see virtual items on construction sites. AR might be utilised to enhance information retrieval from BIM models
Delgada *et al.* (2020) Zhou *et al.* (2017)	Progress Monitoring	AR could considerably increase its capacity to rapidly, clearly identify what was constructed and what is missing. Introduced an AR technique to aid in the examination of segment displacement during tunnelling construction
Li *et al.* (2018) Moore and Gheisari (2019) Park and Kim (2013)	Construction Safety	An evaluation of the AR construction safety applications in which three key areas of application were identified, namely danger detection, safety and education, safety inspection and safety instruction. AR assists employees in reducing risk and carrying out activities safer. ARs allows employees to better identify, risk recognition and communication between the construction manager and the employees in real time.
Delgada *et al.* (2020) Sekizuka *et al.* (2017) Pereira *et al.* (2019)	Training	AR technology can save training expenses by replicating the usage of expensive equipment, modelling risky locations, lowering travel expenses, and enhancing health and safety. Introduced an augmented reality system for training and evaluating hydraulic excavator operators. Introduced an Augmented Reality system to improve fall risks training

Appendix B

Table 2: The Challenges of Augmented Reality in Construction Support

Author	Stages	Challenges
Delgada *et al.* (2020)	Construction Planning	The key limitations of AR for construction planning are a lack of compatibility between BIM systems and AR models, and the difficulty of automatically updating BIM models and building schedules from the AR system
Delgada *et al.* (2020)	Progress Monitoring	For AR-enabled progress monitoring there are many technical challenges still to be overcome, including:

		- an automatic 3D rebuilt component revision of dot clouds and not only polygon mesh creation. - the reliable marker-less object recognition; and - an automatic comparison and update of as-built and planned models.
Moore and Gheisari (2019)	Construction Safety	The usefulness of AR for construction safety is limited by a lack of customized hardware, compatibility among systems, uncomfortable gadgets, and a lack of standardised assessment
Delgada *et al.* (2020)	Training	The key problems of adopting AR for training are: - lack of expertise to create AR material, - lack of systematised evaluation methods, and - lack of interaction with existing certification standards.

Appendix C

Table 3: The Strategies in Increasing the Implementation Augmented Reality

Author	Strategic Goals	Enabler	Purposes
Zakaria Z. (2013)	Increase knowledge about current technology	Government	To meet the Government's objective, an Industry Delivery Team will be developed to help all Government Departments in developing their own BIM and AR adoption strategy. The Government Construction Board is kept up to date on the progress of these strategies.
	Increase Technical Skills	Organization Employees	Collaborates with a variety of professional and trade organizations to ensure that BIM and AR are adopted by all communities within the construction sector, particularly SMEs.
Damanpour 2010) Cheng, Chang and Li (2013) Kock *et al.* (2011) Goode, Dahl and Moreau (2013)	Increase Product Innovativeness	Government and Organization	Product innovativeness is regarded to be an internal attribute, and a distinguishable occurrence that results in organizational global competitiveness As a result, more innovative products need greater business resources as well as a unique methodology to be effective. Product innovativeness refers to a company's ability to produce new goods with the use of technology in order to outperform competitors.

Cucculelli and Ermini (2012)			Another component of product innovativeness is the degree of newness of the product in comparison to previous items manufactured by the business. New products are seen as being indicating the highest level of product innovation.
Manning *et al.* (2012) Shi *et al.* (2013)	Government Support	Government Organization	Government is a well-known factor that has a substantial impact on sustainability standards. The government, its agencies, and construction companies share the duty for construction sustainability.
Chou and Yang (2011) Hajipour and Ghanavati (2011)	Market Orientation	Organization	Market orientation has been as a set of behaviors and procedures, aim their efforts toward obtaining customer happiness through continual requirements fulfilment. It reflects organizational culture that establishes a firm's capacity to notice and adapt swiftly to fluctuations in consumer demand, so putting customer pleasure at the heart of corporate operation

Appendix D

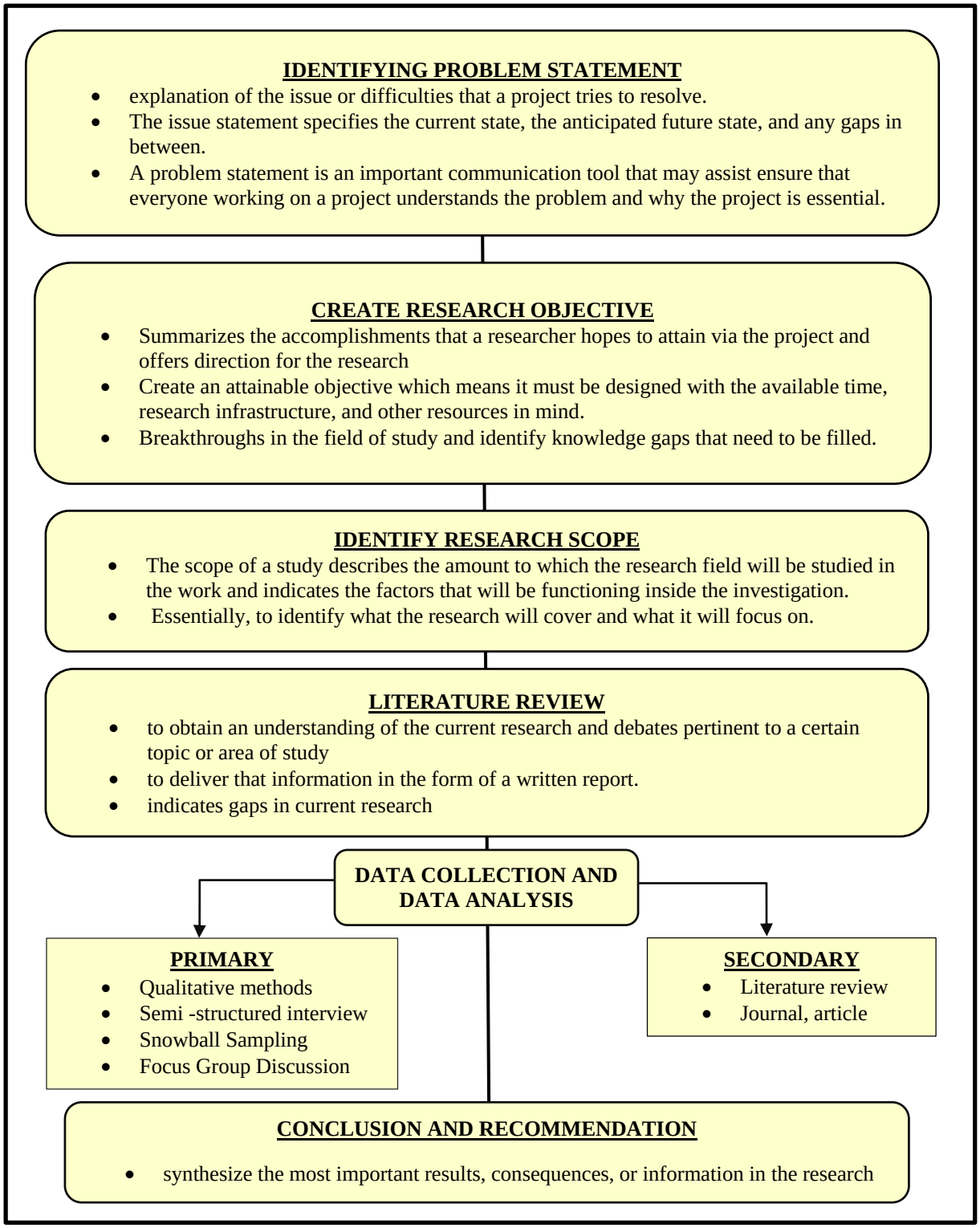

Figure 1: Research Process

Appendix E

Table 5: Background of Respondents

Respondent	Background
R1	R1 is the CEO of AR Company. R1 is in charge of generating entirely new digital environments that individuals may view through a smartphone. Company A specialises in the development of commercial solutions with AR/VR technologies.
R2	R2 majored in Cognitive Science at university and now works as a project manager for company B, an AR company. Company B has been involved in over 50 projects including AR, VR, mobile, and web. They feel that creative and innovative qualities are crucial in various industries.
R3	R3 has worked in the AEC sector for 12 years after graduating. In charge of the development of project information models, which include 3D visualizations of data, drawings, and schedules related to a project's design and planning process. R3 also have the privilege of working in construction company at UAE.
R4	R4 has previously worked with a variety of organizations, including G7. PETRONAS has awarded the company a license to provide oil and gas-related goods and services. Company D has provided a wide range of services and trade for the Oil and Gas sectors, as well as the Marine, Energy, and General Industry. R4 spent 25 years in the AEC sector before deciding to establish his own business.
R5	As an Associates Architect, R5 represents the AEC industry as a whole. Associates Architects usually have more responsibilities than other staff architects. R5 is in charge of project management and reporting work progress to the lead architect. Company E has professionals and technical workers to manage projects of various sizes and scopes.
R6	R6 is in charge of new construction, as well as renovations and redevelopments. R6 formerly worked at a well-known architectural firm before opting to join Company F. Company F seeks to develop an unusual yet basic architectural language that is relevant to social and cultural surroundings.
R7	R7 works as a sales engineer for Company H. He has seven years of experience in the AEC industry, especially in civil and structural engineering. Company H is primarily involved in civil and structural engineering, hydraulic engineering, land filling engineering, and transmission line construction. Company H's work scope includes both within and outside of Malaysia. PLUS, TMB, and Landfill Operator are some of their primary clients.

Appendix F

Table 7: Responses About the Implementation of Augmented Reality (AR) Technology in Construction Industry

Respondent	Response
R1	“When it comes to the construction industry, they already utilize BIM systems and AutoCAD 3D as part of their practice. So, there is no reason to invest in something that would yield the same results.”
R2	“In some situations, we need to know precisely what the user or clients is looking for; this is referred to as "marker-based or marker tracking AR." In other cases, we only need to show 3D augmented reality models, which we can do without using a marker, hence the term "marker less or marker striking AR."
R3	“Accuracy is crucial in the construction process, and as consultants, we feel that the best way to offer ideas is through AR/VR. As a result, even if the construction is wrecked by a pandemic, we can still convey the project's scale to clients”.
R4	“Perhaps that one day, all new technologies will be adopted in construction industry in order to make task easier”

R5	"As AR becomes more engaging, I believe it will be extensively used in our industry. It demonstrates new dimensions and constructs something distinct from what we're seeing now."
R6	"Believes that augmented reality technology will continue to advance. It is due to the fact that emerging technologies exceed expectations. Meta is now borderless. In addition, the world continues to outperform in many sectors. There is a good likelihood that more architects will employ augmented reality to visualize their designs."
R7	"Augmented reality will be the future. However, not all contractors will employ AR in their implementation. Only for the heavy hitters. The problem here is to persuade the subcontractor to utilize AR. As a result, we require government assistance. As we now have IBS scores that people must obtain, let us do the same with AR."

Appendix G

Table 9: Responses About the Challenges in Implementation of Augmented Reality (AR) Technology in Construction Industry

Respondent	Response
R1	"AR is still in Beta Mode (experimental stage), particularly in the Malaysian industry. The most of AR technology is mainly used on social media platforms such as Instagram, Facebook, and Snapchat. However, smartphones have also used this technology to create expressive emoticons, and some movie productions have used point clouds (an AR division) in emerging characters."
R2	"It may be tough to project AR in the new world. We must guarantee that we are on the correct side of the scale. Even though AR is a complex application, if an issue arises, we try to recover to the basics by returning to the AR Table, where we utilize marker tracking."
R3	"We need to invite our top management to attend the discussion in order to explain the current situation and to keep them up to date on new technologies. Previously, our director struggled with drawing, but AR and VR have greatly improved their knowledge."
R4	"We do not have the funds to implement such cutting-edge technologies. Most of the current applications we use in our organization are ones that are common in the construction sector, such as Microsoft Project, Excel, and AutoCAD. Perhaps when there are more fresh graduates from universities, they will be able to share and execute all of these new technologies with top executives in the organization."
R5	"AR seems to be interesting to adapt by an architect as you share all of the good benefits from it, but in this short period it appears to be a little challenging. Our country has recently been hit by the deadliest epidemic in history, and we need time to heal. Even in our market, there is a lot of uncertainty. Our company is also struggling with this problem because the cost of construction materials is always shifting."
R6	"The problem is not that we have a person who refuses to adapt, but that the authority itself refuses to shift from its existing place."
R7	"There are issues that occur because existing AEC professionals have not been exposed to Augmented Reality. We need to get back on track with our own initiative."

Appendix H

Table 11: Responses About the Strategies in Increasing the Implementation of Augmented Reality (AR) in Construction Industry

Respondent	Response
R1	"To keep up with globalization and modern tech, every industry in Malaysia should be prepared to accept software innovations. They must start implementing AR technologies in order to purchase trends."
R2	"As we can see, we can develop a positive perception of AR technology in our citizens. As an example, consider MySejahtera. Every generation now knows how to scan a QR code before entering a store. This mindset has been difficult to discover during the last five years. However, it appears that everyone is now familiar with it and can adjust to it. The scenario is same with AR Technology. As an AR developer, I am pleased that at least some people are aware of this technology. Allow folks to try new things and get new experiences. Then, in real life, this technology will be extremely familiar."
R3	"Our company works with each employee to shape and polish their skill set. We also ask the employees to be more productive. Even for top management and senior colleagues, we assist them in classes that are suitable for their level. At the very least, they'll be aware of the existing situation."
R4	"To ensure fairness, we must standardize the technique of executing processes in the construction industry."
R5	"An event or class should be held on a regular basis between AEC students and AEC professionals to keep both sides up to date on industry developments."
R6	"Back at my previous company, we tried doing a mentoring programme with Architecture students and Senior Architects. Every architect student group has a senior architect. This benefits both of them in the long run. Students learn new things, and seniors are exposed to cutting-edge technology."
R7	"In general, we need to invest in equipment based on the extent of our task, such as a drone and GPS to cope with issues on survey stage. We don't need to use sub-contractor anymore."