Augmented Reality and Virtual Reality in Construction industry*

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Abstract– Construction expects a massive capacity in the accomplishment of states and is depended upon to create higher than ever in the next decade. Therefore, construction organizations have directed to innovative techniques such as Augmented Reality (AR) and Virtual Reality (VR) coordinated to inventive procedures to stay competitive and to extend more in the modern market, as TMG use both technologies in constructing "Noor City" which will be the first smart city in Egypt. This article offers a review of AEC use of augmented reality (AR) and virtual reality (VR). Although, a questionnaire was conducted with participation of 30 employees from 3 large construction companies to gain a wide grasp. Moreover, six scenarios were created to evaluate the true effectiveness of AR and VR: stakeholder engagement, design support, design review, construction, and management support, as well as training by displaying the level of implementation. By adding that, a 3D model is held by using REVIT program to show walkthrough concept. The present study formalizes and classifies the current use of AR and VR in the construction sector by presenting their level of implementation.

I. Introduction

The whole globe has seen enormous changes in a wide variety of aspects during the past decade. Especially construction industry had an obvious, huge conversions and improvements globally. Construction companies tend to use AR & VR as they see both innovations will lead the construction's future. Both technologies have been utilized in different essential phases through a lot of projects such as engagement of stakeholder, design review & support, support of development, Operation & management, and trainings, as in 2019 AR and VR considered through the highest ten Gartner strategic technologies trend. Through the field of construction, the utilization of VR & AR take place by adding 3D models that attracts customer's eyes, contractor & consultant to start new experience that have not been seen before (C. Parks et al., 2018).

The main objective of this study is to exploit AR and VR advantages for the AEC industries. The goals are

1. To define specific AR and VR use-cases for the AEC sectors.
2. To provide a detailed qualitative and quantitative analysis of the AR and VR usage in the AEC sectors
3. Identifying a set of the research topics required for a successful implementation of the AR and VR

These objectives help to evaluate the designing and practice the facilities construction through a model-based 3D communicating & immersive atmosphere enhance the constructability, smooth the flow, and diminish modifications on work and unproductive works could recognized before beginning of development this all to discover the aims of AR and VR in construction.

The next part describes the study's methodology. The major focus of the first section will be on VR and AR in the AEC industry. Then, the literature review will be categorized into history, procedure, types, benefits, and as well as previous studies. The approach utilized in this study will be described in Section 3 along with examples of its usage in the AEC AR and VR industries. Section 4 is a questionnaire for 30 employees from three large construction companies. In section 5, a model has been created. Results for section 6 are now accessible.

2.Research Method

To evaluate the real efficacy of VR and AR in certain tasks in construction projects, and to be focused on implementation of the research. Previous research investigations in construction industry have examined and categorized research output for AR and VR by showing the level of implementation. Moreover, a questionnaire was collected from 3 large construction organizations to gain a wide grasp of the AR and VR within the AEC sectors by utilizing sample population equation especially in residential buildings by filtering the employees into what the requirements need. By adding that, a 3D model held by using REVIT program to show the aids of VR in construction projects through using walkthrough option by proving that both innovations are expanding in utilization in construction industry, as TMG use technology in building "Noor City" which is a smart city in Egypt. Finally, both technologies have a positive impact towards owner in which he will be delivered his project as he expects and within budget and time.

* Funding was received from XXX Industry to sponsor research, travel and participating, (This is a comment at the end of the title used to acknowledge grant funding source if any. You can delete by eliminating the * at the end of the title. You can edit by moving down past the first column.)

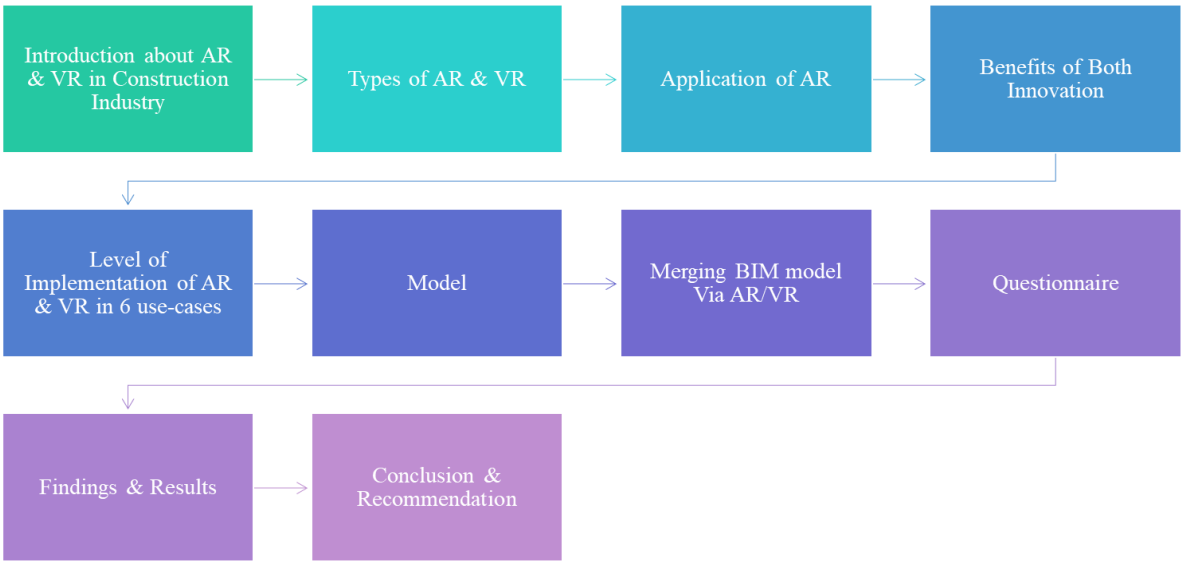


Fig. 1 shows the study's research approach.

3. *Augmented Reality in Construction*

Augmented Reality is an interactive experience of a reality world in which computer-generated perceptive information improves the items existing in the actual world. Historically, AR innovations have not been used through development sites because of arrangement & tracking issues. This technology was utilized either at homes or offices to collaborate or simulate the design stage of construction projects. However, this technology has been improved in the last decade by using it lately in construction sites for detection of defects and monitoring of progress.

3.1. Types of Augmented Reality

Augmented Reality has several types which has been utilized in construction industry each type has its way to enhance efficiency of construction projects.

1. Marker based

Marker-based AR is also called as image reorganization. The marker is perceived by the mobile camera and these markers are in the structure QR code or picture or actual object. The camera identifies the marker which is pre-characterized and afterward it triggers the PC produced data shows.

This data is displayed when a marker gets recognized by the marker distinguished by the camera, the outcome establishes the situation of both, the marker and showed content. And afterward change this present reality object position will impact the PC created content. It is utilized for the improvement of project's quality and decreasing management faults through project's constructing and the outcome is acceptable.

2. Marker-Less

In the marker-less augmented reality does not need any marker for recognition it straightforwardly places the virtual object into a real-world environment. Marker-less is also known as "dead-reckoning". This marker-less AR utilizes the camera, sensitive sensors with complex mathematics to identify the real-world atmosphere like positions of a wall, plane surface, and intersection points. With the area map, in this way AR empowers the application and spot the virtual object into a real-world climate.

3. Projection-based

Projection-based augmented reality, this projection-based AR utilized as a guide for the clients. In this, the 3D physical items on this physical object the pc generated graphical image is projected which is a realistic looking object. The projected object and the physical model have the same geometrical shape. Projection-based AR is mostly utilized in industries for providing guidance to complex structures. The benefit of projection-based AR is it gives continuous solutions.

3.1. Application of Projection-Based AR

An application is used to show one of the types of AR which is projection-based AR that utilized as a guide for the clients. Projection-Based AR has numerous advantages that benefit construction industry such as:

- *Reduces computer monitor and screen requirements, as instructions display in the task area immediately.*
- *Reduces the cognitive burden of users by following work instructions since the attention change between work instructions and the job at hand is not necessary.*
- *Include a 'no defects forward' policy in manual workflows to guarantee that the preceding step is carried out properly and confirmed.*
- *Feedback on successful process improvement, and unique digital IDs for construction cycles.*

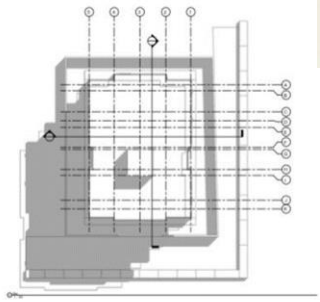


Fig.2 Projection-Based AR

4. *Superimposition-Based*

Superimposition-based augmented reality, this type progressions the real item with a virtual object by the technique of projection, the object partially-fully replaced by a virtual object. It shows the augmented view on the same Object.

3.2. Benefits of Augmented Reality

- *Visualization of projects*
- *Planning and Scheduling*
- *Team Collaboration and Communication*
- *Defects and Quality Management*
- *Cost and Time Management*
- *Safety*

4. *Virtual Reality in Construction Industry*

VR is a simulated experience that can be like or completely different from the real world. This innovation has evolved significantly since the early 1990s and has begun to provide several strong alternatives to extremely challenging issues. VR techniques have the potential to enhance the efficiency and effectiveness of all stages of a project, from initial conceptual design through detailed design, planning, and preparation, to construction completion.

4.1. Types of Virtual Reality

Nowadays, there are numerous sorts of VR such as Immersive VR, Desktop VR (Non-Immersive), Fish tank VR and finally Image-based VR, but the most used in construction industry Immersive Virtual Reality and Desktop Virtual Reality so let us see in detail.

1. *Desktop VR*

Computer based VR system which is typically categorized as Desktop system. Desktop VR has emerged with AutoCAD software. Moreover, it offers the customers to have the experience of interfacing with 3D models through computer's soft wares characterized in form of images on a modern PC detailed screen.

Fig. 3 Desktop VR

2. *Immersive VR*

The fundamental distinction between immersive VR and desktop system is the screen of PC is switched with an HMD unit. Through this method users can sense as if it is a real climate. It needs locations tracking strategies, control gloves and HMD.

Fig.4 Immersive VR

4.1. Benefits of Virtual Reality

- *Improve Customer experience*
- *Perform risk assessment in buildings through the design phases*
- *Recognize Collaboration*
- *Fix problems before it occurs*
- *Improve Training and Safety*
- *Reduce On-Site Visits*

5. Use-cases of AR and VR in the AEC industries

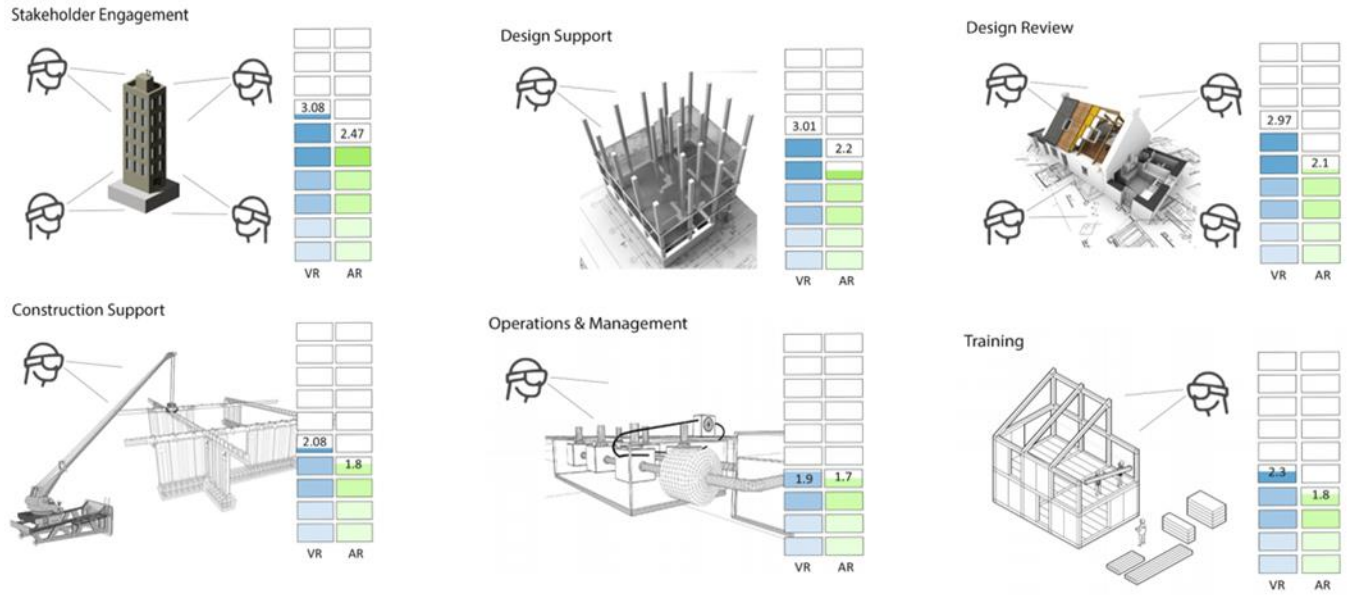


Fig. 5 Level of implementation of AR & VR in construction industry

In this section six general usages for VR & VR in Construction sector will be discussed briefly including the level of adaptation per use-case. i.e.: 1. Engagement of stakeholders, 2. Support of design, 3. Review of design, 4. Support of Construction, 5. Managing and Procedures, and 6. Exercise. However, the following figures it will be showed the level of implementation of the AR & VR in each use-cases which ***(1=not in use, 2=primary in test 3=based implementations, 4 = incompletely in use, 5 = totally implemented).***

5.1. Stakeholder Engagement

A more accurate representation of a developed asset may be provided to potential clients via AR and VR, leading to more relevant or informed comments. AR and VR representations can offer customers with a greater knowledge of constructed assets than images or movies Today, it is very simple to create an AR mobile app that visualizes a virtual model of a developed asset on top of a table or a VR walk-through of a built asset using only a mobile phone and mobile VR headset.

5.2. Design Support

Augmented reality and Virtual reality can help designers better comprehend the consequences of their design decisions.

5.3. Design Review

AR and VR make it easier to communicate design intent, assess designs in a more efficient manner, identify flaws more easily, and sign off projects more quickly.

5.4. Construction Support

Four Categories of AR and VR application in construction assistance may be distinguished:

1. Construction Planning

In this sector, the major goal of AR and VR is to predict future difficulties and enhance allocation of resources when it comes to building simulations. Where VR focuses on generating immersive construction simulations, while AR focuses on visualizing virtual objects that will be created immediately on-site.

2. Progress monitoring

AR has the potential to significantly increase the capacity to identify quickly and clearly what has been created and what is missing. To ensure on-time delivery, it's vital to discover schedule delays early in the process. Using virtual reality, it is possible to monitor development remotely, which is very useful for risky areas.

3. Construction Safety

AR and VR may be used to improve construction safety, which is one of the most obvious uses for these technologies, as it is possible to create safer working environments by utilizing AR and VR for the purposes of danger detection and safety inspection.

4. Operative Support

In this regard, augmented reality (AR) is the appropriate technology, since it helps workers complete a task in the most efficient manner possible. Using AR and VR, construction workers will be able to access more contextual information, while equipment will be controlled remotely.

5.5. Operations and management

As a means of providing relevant information to site employees who operate and maintain buildings, AR has enormous potential to enhance building operations and management. Remote operation of the facility in an immersive environment is possible using virtual reality (VR). By adding that, VR may be utilized to give more exact hazard scenarios and post-action evaluations, such as a fire emergency simulation and evaluation, as well as an earthquake evacuation assessment.

5.6. Training

Instead of learning critical data from a naturalistic body of knowledge, VR may give realistic situations in which users gain knowledge and abilities by completing simulations of actual tasks. Training expenses may be reduced by replicating the usage of expensive equipment and risky settings, lowering travel costs, and enhancing health and safety with AR/VR technology.

6. Merging BIM with AR/VR

Building information modeling (BIM) is one of the most promising recent developments in the architecture, engineering, and construction (AEC) industry. With BIM technology, an accurate virtual model of a building is digitally constructed. This model can be used for planning, design, construction, and operation of the facility. The premise of BIM goes back to 1975 when Charles M. Eastman, an American professor, distributed his portrayal of a working model in the AIA Journal. BIM helps designers and architects to communicate better design among the members of the team and the customer via VR/AR which lead to smoother construction and faster completion.

Fig. 6 BIM via AR/VR

7. Questionnaire

During this research, a visit to the most popular 3 construction companies Memar Al-morshady, Hassan Alam and Orascom have been made for a questionnaire. However, this visit's main objective is for approving the research's scope. The questionnaire was divided mainly in 2 groups in each company, because the number of employees were large for making specified group for the questionnaire. Moreover, from each 2 groups some based specifications have been made to select as according to the General Respondent Information, BIM Knowledge & Experience and finally AR/VR Knowledge in the AEC industry. Therefore, after applying these

specifications on the respondents, there are only 30 were took into consideration to make this questionnaire statistics.

Table 1:" Detailed explanation of target regions"

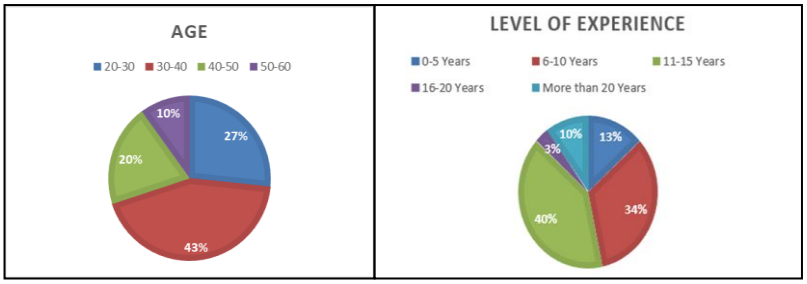
Fig. 7 Question 1

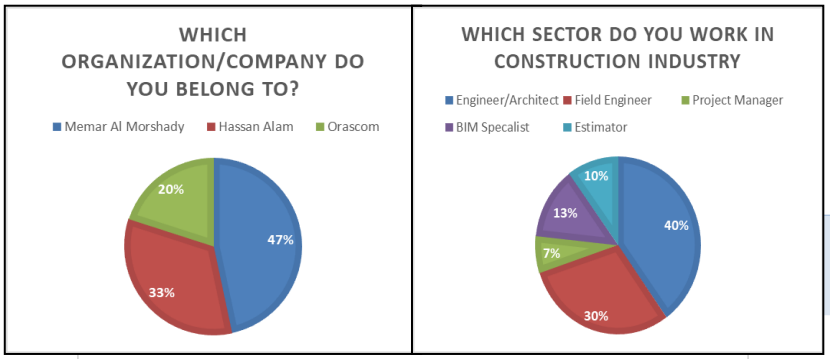
Fig. 8 Question 2&3

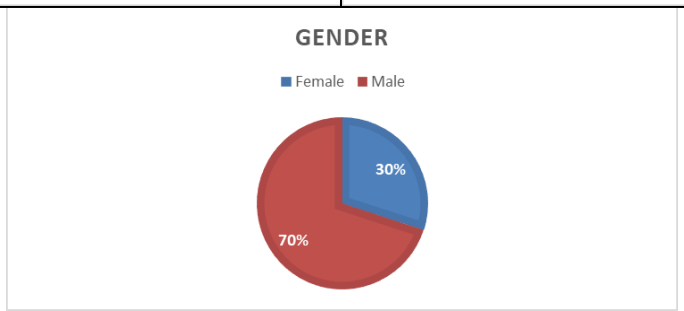
Fig. 9 Question 4&5

7.1. General Respondent Information

70% of all respondents were male and 30% were female. Respondents were between the ages of 25 and 60 and a total average of 34 years. About 70% of respondents were under the age of 40. Participants additionally questioned concerning their role in the AEC industry. Professional capability is an additional crucial sign of participants' knowledge. Most of the respondents with knowledge in Augmented Reality/Virtual Reality innovations were relatively young.







7.2. AR/VR Experience and Knowledge

This section examines the application of innovation in the AEC sector of AR/VR. Respondents' knowledge and use of AR/VR increased significantly. This growth demonstrates that AEC professionals are familiar with the use of AR/VR.

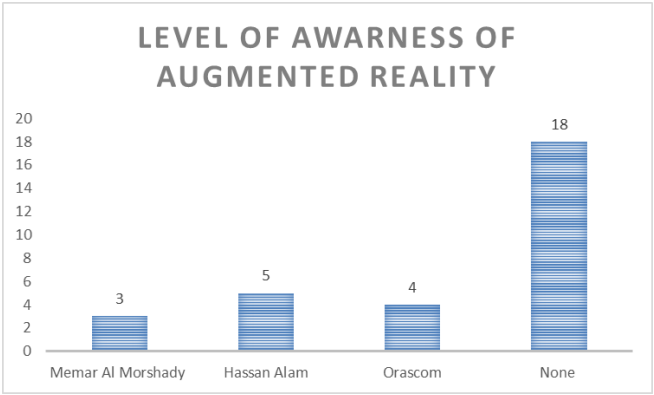


Fig. 10 Question 6

Results in figure 13 showed that only 12 out of the 30 participants which means 40% aware of AR 3 participants from Memar Al morshady, 5 participants from Hassan Allam and 4 participants from Orascom. Finally, 18 out of the 30 participants which means 60% of the participants do not aware of Augmented Reality.

General Section	Section Name	Gathered Data	Objectives
Background and Experience	General Information	Age, Gender, and professional experience	Determine how respondents in different parties envision the future of AR/VR
	BIM Knowledge and experience	BIM experience and used BIM tools	Evaluate how respondents with different BIM knowledge envision the future of AR/VR
AR/VR evaluation	Vision for the future of AR/VR	Opportunities of AR/VR in the AEC industry	Represents the industry future on AR/VR

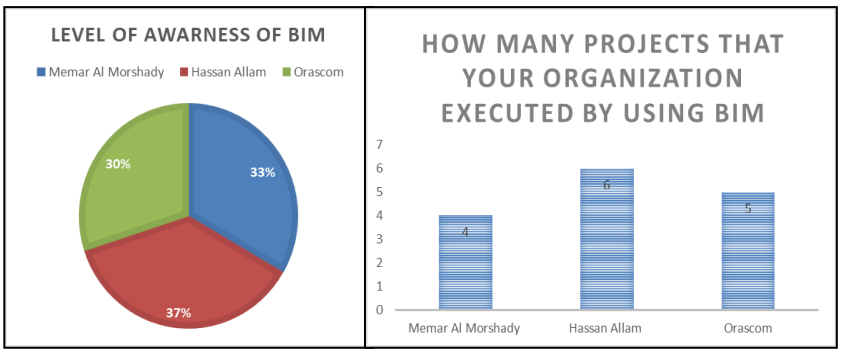
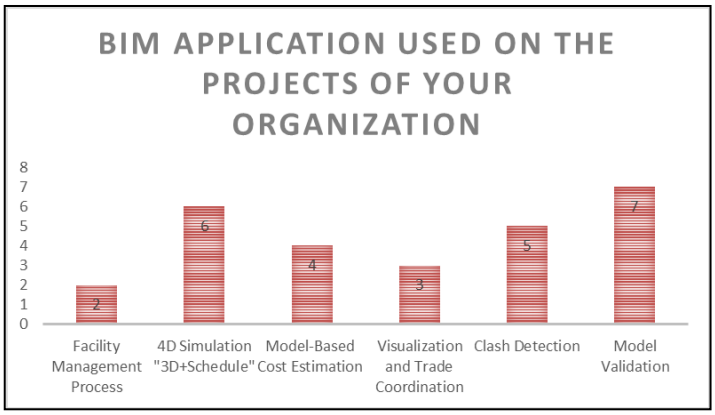


Fig. 11 Question 7

Results in figure 14 showed that only 20 out of the 30 participants which means 66.67% aware of AR 5 participants from Memar Al morshady, 8 participants from Hassan Allam and 7 participants from Orascom. However, 10 out of the 30 participants which means 33.33% of the participants do not aware of Virtual Reality.



7.3. BIM Knowledge and Experience

There were some questions related to BIM to assess the respondents' knowledge of BIM. The first question is about the level of BIM use. Over 75% of respondents said at least once a month they would use BIM tools. More than 32% of engineers use BIM each month. The high utilization of BIM amongst engineers shows the significance of this innovation in the industry.

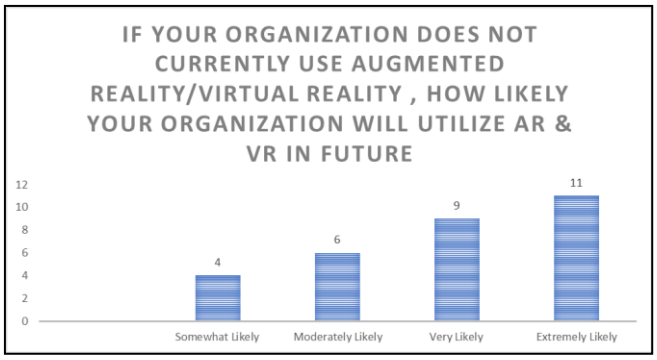
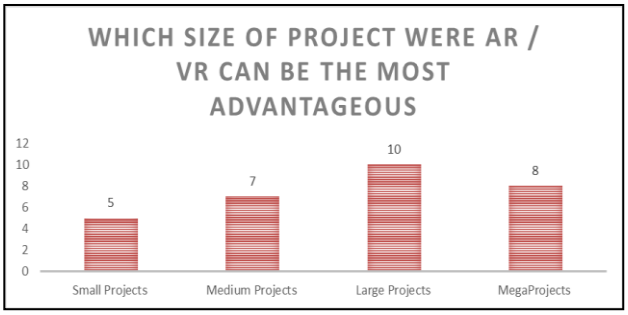


Fig. 12 Question 8



The last question in this part was the respondents were asked about the applications of BIM they used. Many BIM solutions were available in the industry; however, the application of BIM tools was greatly reduced. Yet, the shortage of BIM in these sections requires additional space for potential uses of Augmented Reality/Virtual Reality innovation.

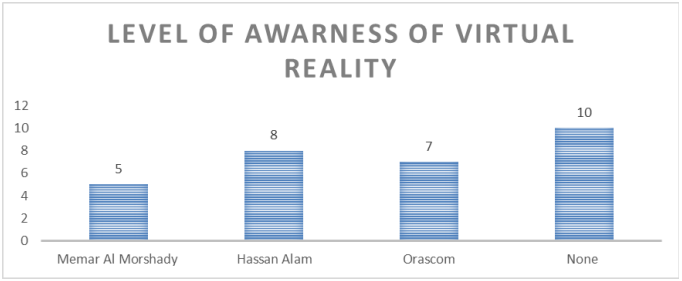


Fig. 13 Question 9

7.4. Future AR/VR visions

This section has been developed to monitor AR/VR chances in the AEC sector. Participants requested to expect how likely Augmented Reality / Virtual Reality will be utilized for all or most projects. Over 70% of all participants selected "Very Likely" or "Extremely Likely", showing a major growth in acceptance of AR / VR innovation.

Fig. 14 Question 10

In this sector, I asked for the optimum size of project where AR / VR can be the most advantageous. Larger projects were the most responsive, and large and megaprojects showed that they were able to take full advantage of AR / VR technology compared to small and medium-sized projects.

Fig. 15 Question 11

Although, I have asked which region AR/VR will enhance more in the projects if the organization applies AR/VR on projects, as showed in figure 34, 53.3% of the participants expects that visualization & productivity will be the more enhanced part in the construction procedure.

Fig. 16 Question 12

Last question in this section, what do you expect if BIM integrate with AR/VR based on the results it was found that 73% of the participants expect the integration of BIM with AR/VR will be useful while 27% expected it will not be useful.

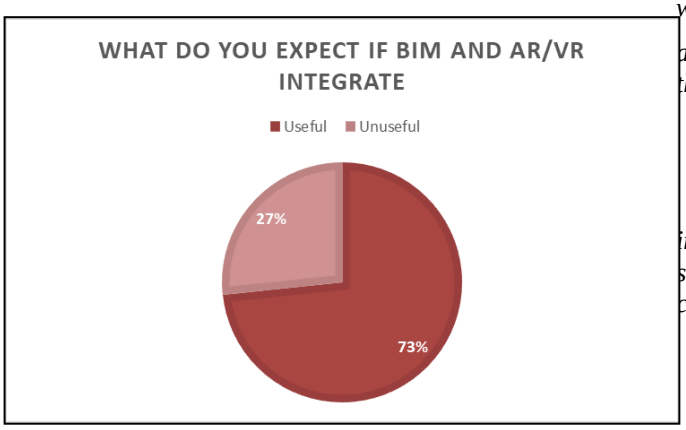


Fig. 17 Question 13

7.5. Survey Findings and Results

Survey responses are evaluated as follows:

1. *Comprehend the ongoing state and expansion of AR/VR in AEC industry*

3D View Day

3D Night View

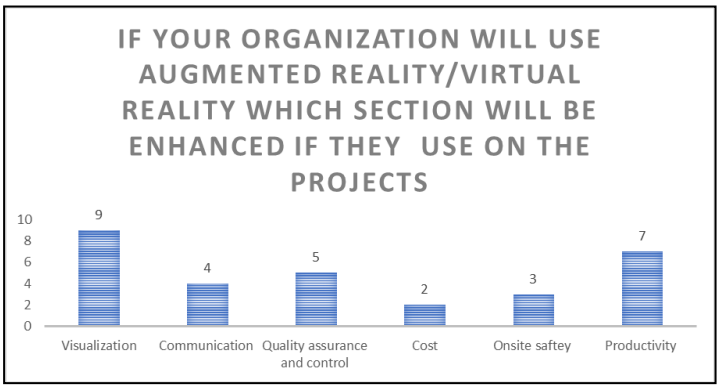
2. *Comprehended BIM knowledge and experience*
3. *Comprehend the applications which is most used in BIM.*
4. *Opportunities are identified of AR/VR development in enhancing visualization and productivity, and*
5. *Opportunities of merging BIM with AR/VR*

8. Model

Through this research a model has been developed by using Revit program to show the advantages of the visualization technology, as it will be shown through applying walk-path concept. It is a 4-story residential building with an area about 215 m^2 *.As we mentioned before, walking-through concept allows to meet all customer requirements.*

8.1. 3D walkthrough Rendering

3D Walkthrough and 3D Architectural Rendering are innovative ways to display your project, and these are successful strategies. Architectural 3D Access to the customer's structure allows to capture the overall structure



and mood, the interior design, and the format. The second, for instance builds 3D Flythrough Animation, allowing the whole excursion and a high flyover with some remarkably improved visualizations or re-enactments of motion.

Fig. 18 3D Day &Night View

8.2. 3D Walkthrough Signification

- *Cost Savings*
- *More advanced than 2D plans*
- *Offers quick adjustments*
- *Time Savings*

8.3. Create and Edit a Walkthrough Animation

1. You first specify the path you want the camera to track, and then

2. you modify the goal and location for the video you desire.

3. I clicked on the View tab to establish a camera route for the tour.

4. To set the route, click on points in the display.

5. To change the height of your camera as points, use the Offset option on the Options bar.

6. Click Finish Walkthrough to specify the route.

Fig. 19 Walkthrough Outside View

Fig. 20 Walkthrough Inside View

9. Conclusion & Recommendation

One of the world's biggest sectors is the industry of construction. From the beginning the history of building business is undergoing enormous transformations. Among the modifications made in different construction industry difficulties, AR and VR technologies are delivering unexpected alterations and progress. The study used a literature to provide conclusions which are both academic and industry leading. The main results as set by the study's goals are: (i) indicating the general level of adoption in industry and in the peruse case, (ii) defining the usages for which AR and VR may be used, and (iii) identifying a set of the research topics required for a successful implementation of the AR and VR.

Therefore, a global shift towards technology has taken place, as technology has made building sites more efficient and safer for work. They also improved communication, enhanced production, and worked on other complex projects. For example, robots and simulated intelligence are deployed on the ground to monitor operational development and give practical real-world information to enhance field efficiency. Construction companies using and implementing technology are paid for greater returns by improving efficiency and collaboration and achieving costs and time projects.

Recommendation

The nature of AEC industry is complex, as it is known as to be from the leading industries. So, I recommend utilizing both innovations Augmented Reality and Virtual Reality, as significant impact will rely on construction projects as It was mentioned before

- *It enhances data about real-time projects,*
- *errors are detected,*
- *enhances team collaboration, and*
- *finally improving construction safety standard.*

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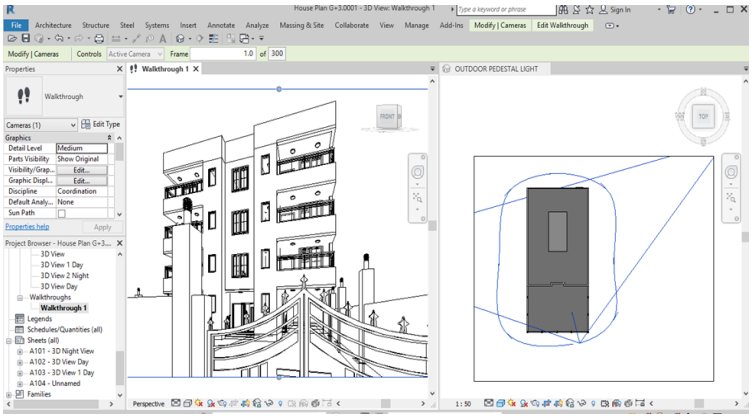

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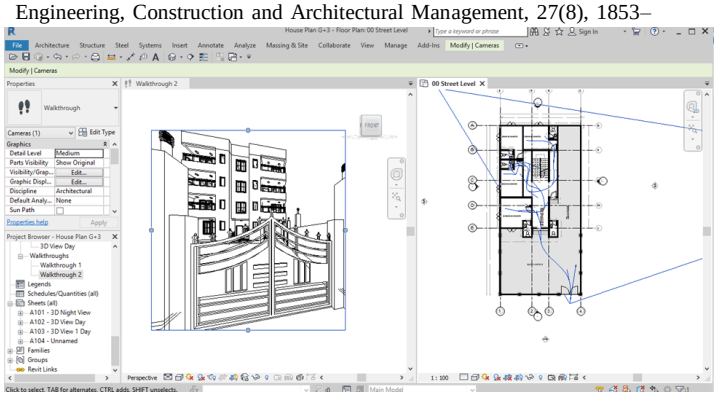

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