Implementation of VR Technology as a BIM Design Tool

A Practical Study Through AEC Sector

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Abstract:

The world is a constant development circle of new construction and renovation of built assets. It is crucial for all parties involved to comprehend, participate, communicate, and work together during the design process of a building in order to produce a high-quality design. The building industry is gradually moving away from traditional methods and toward a highly developed digitalized form of construction. Modern tools for the industry's digital transition, like BIM and VR, are essential. Accuracy, safety, efficiency, and the whole project life cycle are all improved by BIM with VR from conceptual design to construction. The building industry is gradually moving away from traditional methods and toward a highly developed digitalized form of construction. Modern tools for the industry's digital transition, like BIM and VR, are essential. Accuracy, safety, efficiency, and the whole project life cycle are all improved by BIM with VR from conceptual design to construction.

The difficulties of communication between engineers, stakeholders and clients through AEC industry in Egypt lead to major problems that usually end up with waste time and resources, this research purpose is to prove the applicability of BIM – VR integration in current Egyptian AEC sector as an approach to reduce the communication gap and elevate construction industry in Egypt. The research examines and experiment conducted through engineering disciples and results in the promising applicability of virtual reality technology in Egypt.

Keywords

Egyptian AEC sector – Building Information Modeling – Virtual Reality – Extended Reality – Design Process – Work Collaboration – Field Implementation framework.

Introduction

The building sector is now in a very different period. Through eliminating inefficiencies and errors from the total productivity of construction projects, it is a method by which the AEC industries are changing their paradigm to accept BIM Services as the fastest instrument that can help integrate the entire industry. Additionally, with the use of BIM methodology, the level of work is increasing due to better collaboration, appropriate communication channels, and appropriate team activities. The newest and most cutting-edge technology, BIM methodology, has fundamentally altered how building projects are designed and developed. The information shared by BIM modelers enables stakeholders to build, comprehend, and visualize the BIM model with the aid of AR and VR technology.

This paper discusses the issue of difficulties in new technology adaptation and implementation in existing Egyptian system of construction, due to intense culture of Egyptian education and industry, most of the engineers and architects refuse the change of their work system, this research proves that VR-BIM technology could be implemented into the current design and field process without changing the current used systems.

Literature review

A literature review was conducted on the topic of virtual technology implementation an its utilization in AEC sector workflow enhancement and aiding, several searches (Dezen-Kempter et al., 2020), (Sidani et al., 2019), (Sampaio & Sampaio, 2018), (Johansson et al., 2014), (Liu et al., 2020)and (Alizadehsalehi et al., 2021), argues that the VR implementation in the construction industry is crucial for the success of any project through the easy simplified communication of the team members and the accuracy of right decision making.

A survey about latest developments in the utilization of extended reality in design review decision making through design process, two systematical review papers were reviewed, the first one is (Stals & Caldas, 2022), this contribution reviewed 201 papers on VR, AR or MR technologies in the architectural field and classifies them into three main categories: prototype, experiment or theoretical approach, and sub-categories defined on the sample of participants.

The conclusion from this review was that researches on the AEC sector are solving issues outside the scope of architects and are generally focusing on a specific immersive technology, also, while some researchers consider XR technology to be widely adopted (Huang, White, and Burry 2018), few studies address the adoption of these new technologies by architects or even present the current rate of implementation in the professional practice, finally, professional architects are finally not sufficiently integrated into the core of XR research architecture.

The second systematical review is (Prabhakaran, 2022), this paper used a structured methodology was used to identify 51 articles, published between the years 2010 and 2019 (inclusive) to understand the challenges faced when mainstreaming Immersive Technology (ImT) into the A & C industry. The results of this review paper can be concluded in the inefficient communication among critical stakeholders being one of the major issues faced by the A & C industry. The recent development in ImT makes it possible to use shared or distributed virtual spaces, which enables users to communicate, interact and coordinate remotely.

Methodology and Approach

This research methodology is going to be on three stages, the first approach is a theoretical methodology through which the BIM and VR implementation and integration in AEC sector is going to be reviewed, an analysis of the current Egyptian AEC field is conducted.

Then the practical approach is adopted as an experiment is conducted to evaluate the applicability of VR adaptation in the existing engineering offices in Egypt, finally a questionnaire is distributed to the participants to analyze their feedback on the experiment.

Figure 1: Methodology of the research, Source: Author

1. Theoretical literature review
1.1. BIM implementation in AEC sector

One of the most promising recent advancements in the architecture, engineering, and construction (AEC) sector is building information modelling (BIM). A precise digital model of a building is created using BIM technology. The planning, design, construction, and operation of the facility can all be done using this model, also referred to as a building information model. It aids in the identification of any potential design, construction, or operating concerns by enabling architects, engineers, and builders to visualize what is to be built in a virtual setting.(Azhar, 2011)

BIM has been around for nearly two decades but has recently become more mainstream in the professional consciousness. The adoption of BIM technology has been slower than expected in India due to some inherent challenges. Here are some significant hurdles that BIM adoption in the Indian construction industry faces:

A. Lack of Expertise

Lack of universal competence is the major obstacle blocking the building industry from adopting BIM. BIM trials result from a lack of internal competence. Because running costs have increased, projects are less effective and lose money. This gives the impression that technology adoption is difficult.

B. Lack of Awareness

The lack of knowledge about BIM technology is the second biggest obstacle. The application of BIM and its potential advantages are not widely known. This translates into a lack of managerial sponsorship or support, both of which are necessary for any strategic endeavor to succeed.

C. Cost-effectiveness for small projects

By drastically lowering operating and inventory costs, BIM has more than shown its worth in large-scale projects. For smaller undertakings, this cannot always be said.

D. Resistance to change.

BIM is being used for building projects by an increasing percentage of organizations who specialize in the industry. However, the construction company's operations must alter as a result of the BIM implementation. More accountability for flawless execution comes with better preparation. Companies that are concerned about the cultural impact prefer to operate conventionally rather than spending money on BIM-driven workforce recruitment or training of the current personnel.

E. Lack of cooperation between stakeholders

The integration of the workflows of all the concerned stakeholders is the key benefit of BIM technology. It is challenging to complete work, whether it is BIM-led or not, because of conflicts that result from stakeholder noncooperation.

1.2.   Virtual Reality implementation in AEC sector

Through enhanced design visualization and improved communication among key participants in the construction industry, virtual reality (VR) technology helps everyone understand the project. Associating with greater collaborative information is always facilitated by this procedure and knowledge of these many forms of data.

VR, or virtual reality, is a technology that allows users to interact with and experience digital environments. In other words, virtual reality can be defined as a computer-generated environment in which scenes and objects seem to be real. With these images of reality in mind, users will tend to feel more immersed.

1.3.   VR – BIM integration and advantages

The modern technique of the VR-BIM process is of great use and great importance. The core reason for this is to have a deep analysis of problems and also discuss alternative solutions too. Interacting with the BIM model, in order to visualize the geometry of the elements and to consult the parametric data, is an improvement in the development of a collaborative project.

Benefits of VR- BIM integration could be summarized as follows:

- Detecting errors at the beginning of the construction project
- Optimizing costs and schedules
- Improving collaboration
- Increase the quality of delivery.
- Avoiding rework costs
- Make the project more accessible for your clients.

2. Practical Experimental Methodology

The practical experiment was conducted during a 3-week training by KAITECH office, the training scouted 25 participant of Architecture, Civil and MEP educational background, the training was to learn Unity game engine from scratch and its utilization in the creation of interactable applications that was exhibited during Metaverse conference held in Trumph Hotel in Cairo.

Experiment Participants

The participants of the experiment age vary between 20 and 30 years, with field professional experience of average 3-5 years, the professional background aimed to vary between architects, civil engineers, MEP engineers, Engineering Informatics specialists, BIM Architects, and visualization architects.

The participants educational background covered most of Egypt from Helwan university, Tanta University, Benha university, Ain shams University and Suez Canal university, to ensure the validity of the results.

Application Aims and Development

The applications should have the concept of simplifying specialists' information to the clients and stakeholders through the development of interactable immersive VR applications, the participants were divided into 4 groups with different themes as follows:

Table 1: Experiment Application Product, Source: Author

Application Concept	Application Development
Heritage representation Application	

Architecture Design Review Application	
Faculty Management	
Project Tracking Application	

The software used through the experiment was Sketch Up, 3Dmax, Revit for 3D modeling, Unity3D Version 2018 and 2019 for VR application development and Visual studio for coding of applications.

The applications were exhibited to potential investors from Orascom Developments, Ministry of Tourism and several international private construction offices, and the feedback from the attendees was promising and successful.

Figure 2: Metaverse Conference in Cairo 2021, Source: KAITECH office

3. Analytical Methodology and Questionnaires

The knowledge and applicability of Virtual reality is undermined in the Egyptian engineering field, this questionnaire aims for the applicability evaluation of integrating virtual reality technology in design and decision-making process, the questions will evaluate the experience of selected engineers that participated in a training experience using Unity game engine and oculus VR headset to produce interactable applications.

Table 2: Points evaluated through questionnaire, Source: Author

Knowledge	Did you hear about virtual reality application in Egypt before the training?
	Did you hear about game engines application in Egypt before the training?
Design and work before Virtual reality experience	There are difficulties in design decision and clash detection through traditional 3D software
	Using traditional 3D software doesn't allow the needed immersions for the design to be successful
	There is an area of development in the traditional 3D software (Revit \ 3DMax \ etc..)
	There are communication difficulties in the design with clients using traditional 3D software
Evaluating spatial experience using Virtual Reality	The color of the material is easy to recognize
	The color of material is realistic and vivid
	The texture of the material is easy to recognize
	The texture of the material is realistic
	The size of a specific element (e.g., window/door) easy to recognize
	The environment is natural enough to conduct a design review
	It is easy to review the suitability of the height of the area
	The space (area/volume) of the building is satisfactory
Evaluating Satisfaction with Quality of Visual Presentation	The design and review task using Virtual Reality was physically demanding
	The design and review task using Virtual Reality was mentally demanding
	Using the system improved design review performance
	Using the system for design review increased productivity
	The system is useful in design review
	Using the system enhanced the effectiveness in design review
	Learning to perform the design review in the system was easy

	Interacting with the system did not require a lot of mental effort
	It would be easy to become skillful at using the system for design review
	It is satisfaction to use VR in design review
	It can be assumed that using VR will increase the process of the construction industry
Applicability of Virtual reality in Egyptian AEC sector	Learning software used to create virtual reality is easy and manageable
	There is a need for a VR specialist in every BIM office in Egypt
	The integration of VR in Egyptian AEC sector is applicable through simple trainings
	The current engineering education builds the foundation for easy learning of VR
	Design decision and clash detection through virtual reality are simpler and more efficient
	Virtual reality allows the needed immersions for the design to be successful
	Communication is easier for the design with clients using Virtual reality

the questionnaire was distributed to the participants of the experiment to evaluate several points that vary from their professional background, design, and work before virtual reality experience, evaluating spatial experience using virtual reality, evaluating satisfaction with quality of visual presentation and the applicability of virtual reality in Egyptian ACE sector.

Results

The experiment aim was to prove the applicability of VR-BIM integration in existing Egyptian AEC sector, the participants were asked first about their knowledge of VR application in Egyptian AEC sector and about 60% of them answered that this field suffered from poor implementation and training conduction, the questionnaire design aimed to analyze the participants experience before using VR and after, the results of practical evaluation are concluded in the following points:

First: Design and work before Virtual reality experience

The design experience of the participants before using VR-BIM technology suffered from a gap in communication with 60% of them agreeing that there could be an area of development within current usage of traditional 3D software.
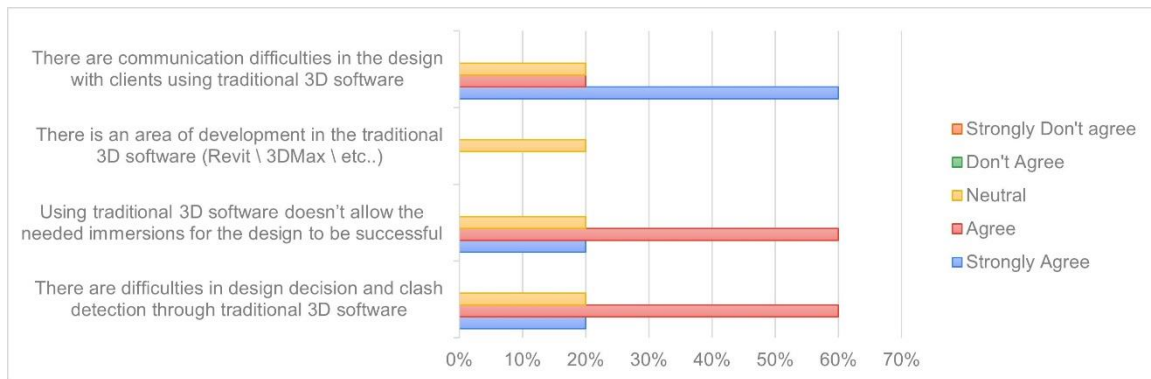

Figure 3: Design and work before Virtual reality experience chart, Source: Author

Second: Evaluating spatial experience using Virtual Reality

The experience of using virtual reality resulted in positive feedback as an average of 80% of the participants evaluated the experience to be successful and the virtual environment to be recognizable and realistic enough to perform design review.
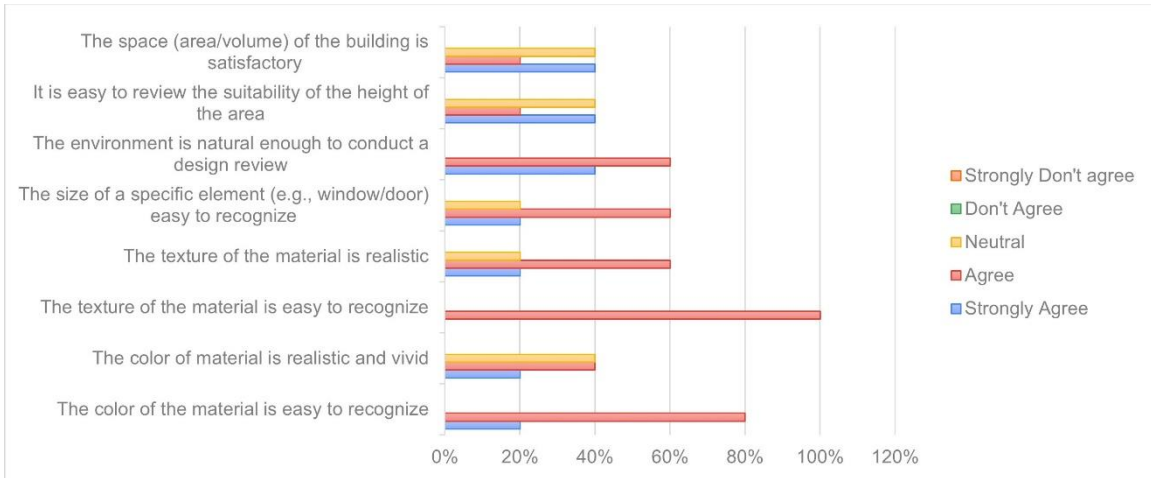
Figure 4: Evaluating spatial experience using Virtual Reality chart, source: Author.

Third: Evaluating Satisfaction with Quality of Visual Presentation

Most of the participants with the percentage of 60 to 80% agree that the visualization using Unity game engine and VR technology is realistic and effective in conducting design review, although approximately 60% of them answered that using VR was slightly mentally demanding which is a global problem of VR technology that should be addressed.
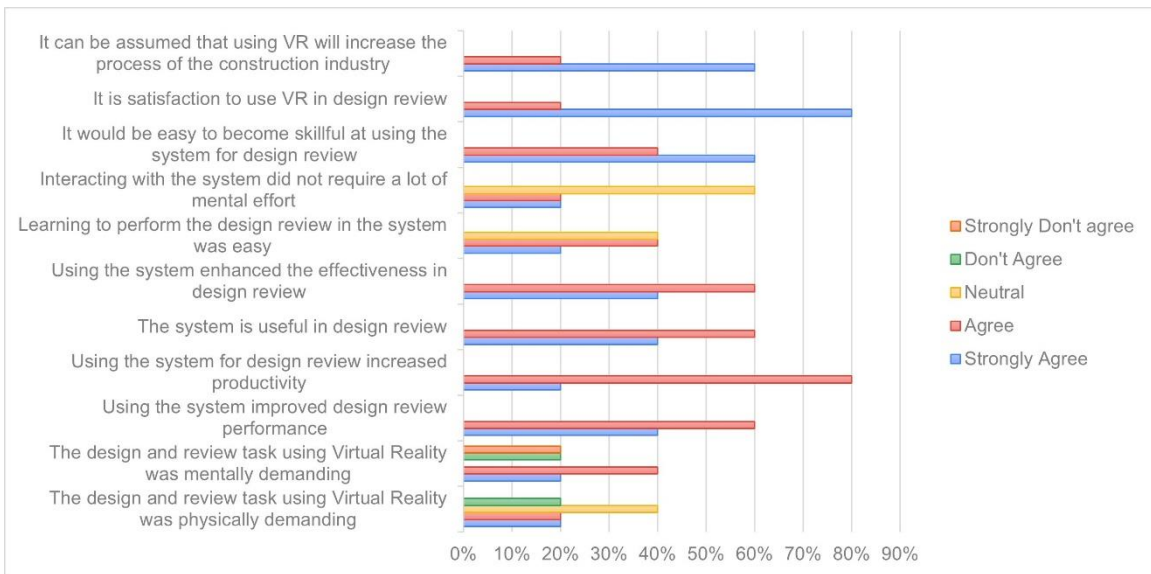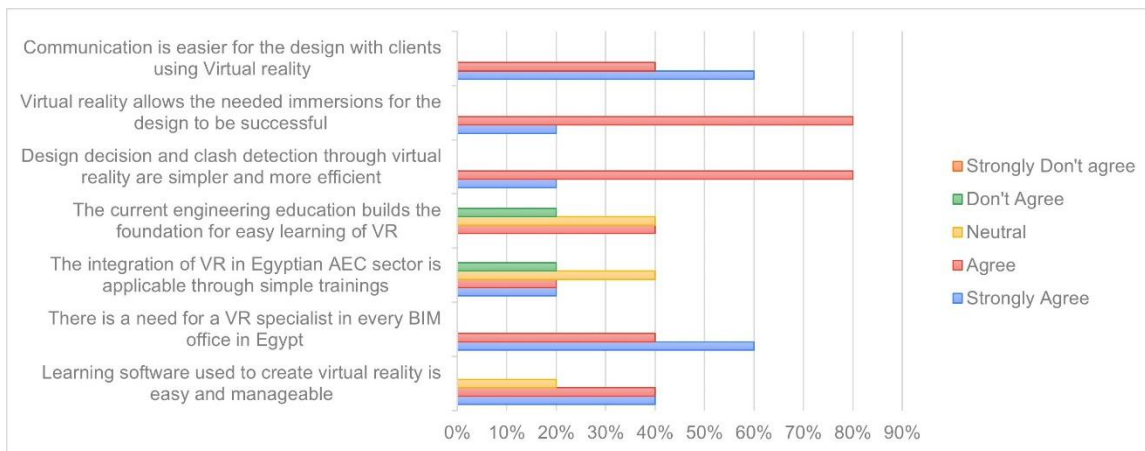

Figure 5: Evaluating Satisfaction with Quality of Visual Presentation Chart, Source: Author

Fourth: Applicability of Virtual reality in Egyptian AEC sector

About 80% of the participants agree that there is a need for VR-BIM implementation in AEC industry, nevertheless, the training required for the creation of interactable applications is crucial.

Figure 6: Applicability of Virtual reality in Egyptian AEC sector, source: Author

Conclusion

The successful implementation of each project in Integrated Industrial Building Design depends on the cooperative decision-making and integration of tools of numerous stakeholders, including architects, engineers, production system planners, and building owners. Researchers and practitioners concluded that the combined power of these technologies is advantageous, improving the ability of architects and structural engineers to communicate design decisions to team members, even though solutions combining BIM and VR are still far from being considered industry standards in the AEC sector. (Podkosova et al., 2022)

Through this research an experiment was conducted on 25 engineers in Cairo to test and evaluate the applicability of VR-BIM integration in current AEC industry, the results of the experiment and questionnaire are:

1- Virtual reality is a successful tool in design review.
2- Learning software used to create virtual reality is easy and manageable.
3- There is a need for a VR specialist in every BIM office in Egypt.

4- The integration of VR in Egyptian AEC sector is applicable through simple trainings.

5- The current engineering education builds the foundation for easy learning of VR.

6- Design decision and clash detection through virtual reality are simpler and more efficient.

7- Virtual reality allows the needed immersions for the design to be successful.

8- Communication is easier for the design with clients using Virtual reality.

This research suggests the implementation of Virtual reality-based design framework in Egyptian construction industry as an approach to reduce the gap of communication between stakeholders and to ensure the successfulness of purposed designs.

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