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A Brief Discussion on Augmented Reality and Virtual Reality in Construction Industry

Shakil Ahmed[1], Md. Mehrab Hossain[2], Md. Ikramul Hoque[3]

[1, 2, 3]Dept. of Building Engineering and Construction management, KUET, Bangladesh

E-mail: ashakilmondol@gmail.com

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Abstract. Augmented Reality (AR) and Virtual Reality (VR) a kingdom-of-the-art technology for superimposing information onto the real world, has recently started to have an effect on our everyday lives. AR and VR technologies based application are becoming more mature and versatile than before. This study outlines a number of the potential applications of AR and VR to a variety of construction problems. For conducting these study a number of AR and VR application generating tools (Autodesk Revit, Unity 3D, Vuforia, EnTiTi Creator, Autodesk Navisworks Manage, Primavera) and a comprehensive literature review. Augmented Reality is successfully used in construction project scheduling, progress tracking, worker training, safety issue, time and cost management, quality and defects management in this study. And Virtual Reality is effectively used as a visualization tools, worker training technologies, safety management tools, and quality and defects management tools in this study. Also AR and VR are used for developing a network that allow the possibility of having conferences with those who are geographically far off from each other. The study could be helped to explore the potential fields of using AR and VR technologies in construction industry effectively as advance time and cost saving profitable tools.

Keywords: Augmented Reality; Virtual Reality; Construction Industry; Construction Management; Advance Construction Technology

1. Introduction

Throughout the 20th century and beyond, the world has seen huge modifications in an extensive types and variety of aspects. In our regard, there has been a massive transformation and advancement within the construction industry all over the world. Through constructing larger and better things, the industry has revolutionized approach, methods, techniques and strategies (Arhami et al., 2013; Sadeghi, 2015; Sadeghi & Karava, 2014). Similarly, in order to overcome the shortage of fit workforce, the construction industry has taken advantage of technologies to better recruit and preserve new workers in construction profession (Escamilla & Ostadalimakhmalbaf, 2016; Khanzadi, Dabirian, Mohammadpour, & Makhmalbaf, 2011). One of the technological tool employed by the construction industry is called virtual reality, wherein a three-dimensional, computer-generated environment can be explored and interacted through a person. Augmented reality stocks the same concept, but in place of to interact in a non-existing surrounding (digital fact), augmented reality makes use of existing environment at the same time as implementing virtual elements to appear as if both are together at the same time (Satoh, Ohshima, Yamamoto, & Tamura, 1998). Augmented Reality (AR) is a kind of interactive, reality-based display environment that takes the capabilities of computer generated display, sound, textual content and effects to enhance the user's real-world experience (Loijens, Brohm, & Domurath, 2017). Augmented reality combines real and computer-based scenes and images to deliver a unified but enhanced view of the world. The Virtual Reality (VR) is the computer-generated simulation of a three-dimensional image or environment that may be interacted with in an apparently real or physical manner by a person the use of special digital system, which include a helmet with a display screen inside or gloves outfitted with sensors (Whyte, 2003a).

The breeze of utilizing AR and VR technologies in practical programs, such as education (Chen, Chi, Hung, & Kang, 2011; Dünser, Steinbügl, Kaufmann, & Glück, 2006; Liarokapis et al., 2004; Phan & Choo, 2010; Wang, Dunston, &

Skiniewski, 2004), design (Haller, 2006; Schranz, 2014; Wang & Dunston, 2006, 2008), manufacturing (Nee, Ong, Chryssolouris, & Mourtzis, 2012; Novak-Marcincin, Barna, Janak, & Novakova-Marcincinova, 2013; Pentenrieder, Bade, Doil, & Meier, 2007), construction (Behzadan & Kamat, 2007; Schall et al., 2009; Yabuki, Miyashita, & Fukuda, 2011), and entertainment (Bates, 1992; Domschitz, 2009; Zhang, Wu, Yang, & Wang, 2011) reveals an excellent capability for improving current technologies and offering a better quality of life. A detailed assessment of AR and VR in architecture, Engineering and construction can be found in (Alcínia Z Sampaio, Ferreira, Rosário, & Martins, 2010; Wang, 2009; Webster, Feiner, MacIntyre, Massie, & Krueger, 1996). A detailed method of mapping AR and VR into the specific activities in construction can be found in (Dunston & Wang, 2011; X. Li, Yi, Chi, Wang, & Chan, 2018; C.-S. Park, Lee, Kwon, & Wang, 2013).

AR and VR technologies have many applications that could benefit a project with accelerated working site training and safety, design development and communication with involved parties from the owner all the way down to the laborer, and help to exceed owner's expectations and decrease project costs (Behzadi, 2016). Augmented Reality and Virtual Reality are being used in the world of construction engineering and management by placing a 3D model in the front of the eyes of the consumer, consultant and contractor and starting up a learning experience unlike any seen before (C.-S. Park et al., 2013). In this way, it permits for an individual to interact with real-world projects and deal with defects, risks and accidents before they even occur. Through creating exposure to a project before it physically exists, AR and VR create a unique gaining knowledge of opportunity for the inexperienced and construction-savvy person alike by means of presenting the opportunity to locate and fix a project's flaws in a safe, hazard-free environment all in real time (Lin, Duh, Li, Wang, & Tsai, 2013). AR and VR are the future of construction as they are used in various important parts of projects. Worker's safety training, defects management, quality

management, projects scheduling, information collection, safety management, logistics management, project progress evaluation and so on are conducted by the AR and VR technologies in modern construction process. The objective of this study is to rummage the evaluation of AR and VR technologies in the construction industry.

2. Methodology

The study start with a comprehensive literature review of related journal, conference papers, articles, blogs, books and webpages. Then using some essential tools and application necessary VR and AR applications are developed. Figure 1 shows the flow diagram of this study with each steps and process in brief.

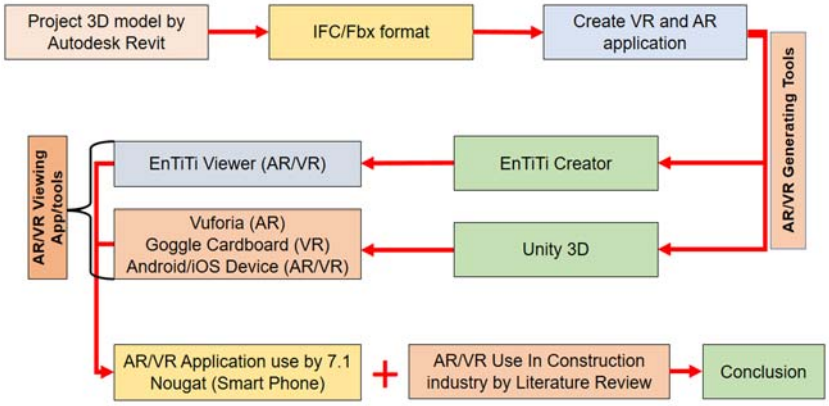


Figure 1. Flow diagram of entire study

From figure 1, at first a 3D parametric model is built with Authodesk Revit 2017. Then the Revit file converted into IFC/Fbx file format. Here two AR/VR application generator are used in this study. For EnTiTi Creator Fbx file is used and for Unity 3D IFC is used. EnTiTi Viewer is used for the review of AR/VR at construction field for those application which are generated by EnTiTi Creator. And Vuforia is used for viewing of those application which are generated by Unity 3D. For all those application are used in this study with an Android 7.1

Nougat version smart phone.

In this study a project management scheduling software Miracle Primavera is used for the simulation of the time liner of the project progress. Autodesk Naviswork is used for the progress tracking of the project. The project schedule of Primavera can be directly used by developing AR and VR application by Unity 3D.

3. Augmented Reality in Construction

Augmented Reality is used in various phase and division of construction project. For bring the automation in construction, AR is the most and obvious things to implement in construction project.

3.1. Scheduling and project progress tracking

Augmented Reality (AR) will enhance the scheduling aspect of the construction project significantly; it is able to show an as-planned vs. an as-built form to allow visualization of progress. Figure 2 shows the scheduling and progress tracking of construction project by AR application. The white color portion of the model is completed and green is not completed but it has to be completed. So the green portion is actually represent the delay of project.

Meža et al. (Meža, Turk, & Dolenc, 2015) stated their study that for the monitoring and tracking the construction projects Augmented Reality on tablet PC or mobile is the best option than other 3D models or Gantt chart. They also point out that Augmented Reality have been able to finish is that it is possible to look and estimate the work this is performed on site is in accordance with the proposed schedule of the process. Wang et al. (C.-S. Park et al., 2013) noted that the use of augmented reality for construction project progress tracking as a way to compare the project progress to the schedule. A visual comparison between the planned facilities versus as-built facilities easily display by the AR technologies. Wang et al. (C.-S. Park et al., 2013) also takes monitoring a step in addition and connects augmented reality to material tracking to make sure that the necessary

materials are on site. Golparvar et al. (Golparvar-Fard, Peña-Mora, & Savarese, 2009), Omar & Nehdi (Omar & Nehdi, 2016), Zhou et al. (Zhou, Duh, & Billinghurst, 2008) and Turkan et al. (Turkan, Bosche, Haas, & Haas, 2012) also showed that in construction progress tracking, Augmented Reality is one of the most used functions in advanced construction projects.

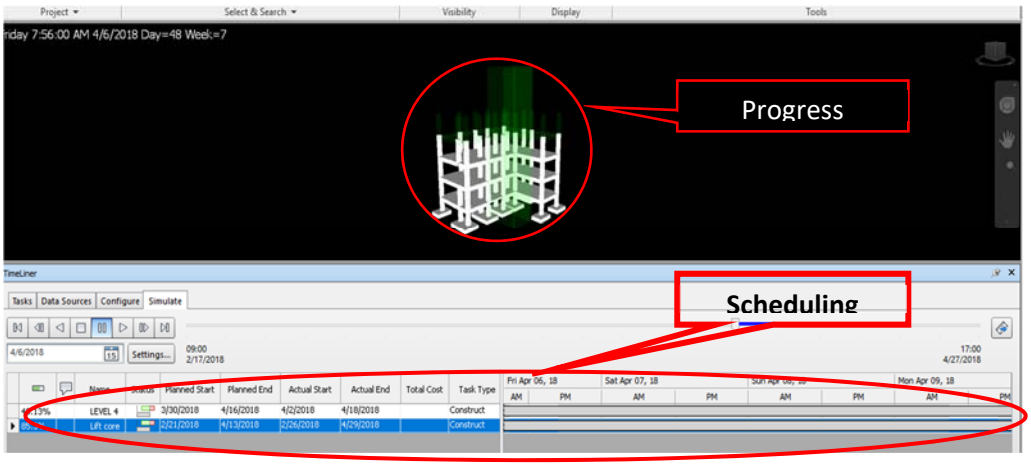
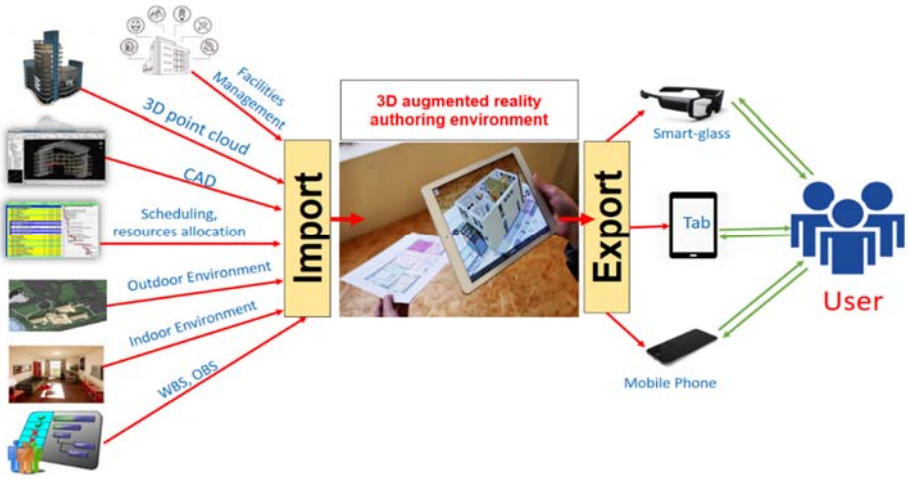


Figure 2. Construction project scheduling and progress tracking by AR technology

3.2. Communication and data acquisition

A great chance to make success a construction project is underlying within the effective communication and information retrieval from the construction site. Pejoska et al. (Pejoska, Bauters, Purma, & Leinonen, 2016) noted their study that access to project information on-work site and effective communication are significantly enhancing with the introduction of different Augmented Reality (AR) programs as compared to more traditional information sources. Figure 3 shows how the AR technologies used for the field data collection in construction industry. It also represents the communication ways between project participants and project information flow.

Figure 3. Construction field data and design information acquisition process using AR



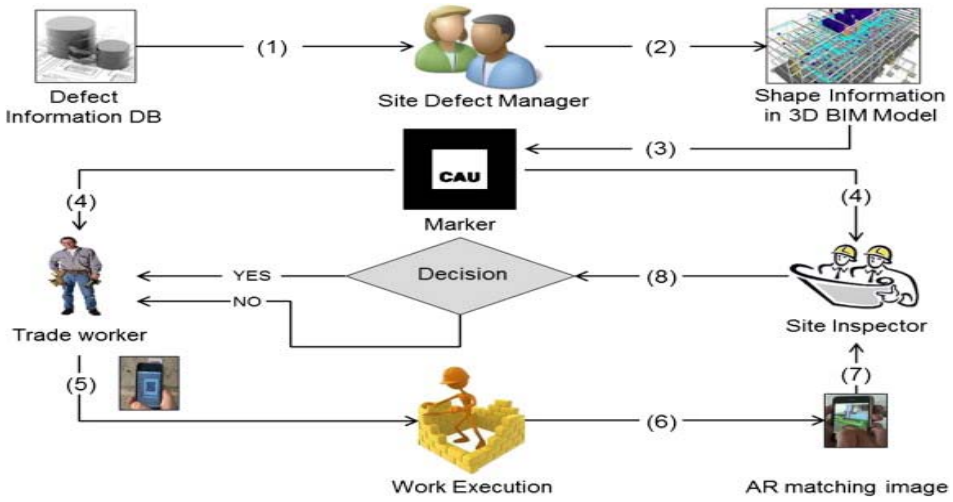
technologies

These Augmented Reality systems allow fast and easy access to information helps project managers to decide on corrective actions to minimize cost and delays due to performance incompatibilities (Bae, Golparvar-Fard, & White, 2013). Yeh et al. (Yeh, Tsai, & Kang, 2012) stated that to reduce the difficulties and complexity for on-site data retrieval many organizations are undertaking to develop light-weight mobile devices. The study also noted, these organizations are working to develop devices that could project construction drawings and related information based on the location of the user. The added visualization benefits of AR technologies allow for better communication between parties when commenting and making suggestions for a particular project. The introduced visualization features and benefits of AR technologies allow for better communication between different parties involved in construction project when commenting and making suggestions and decisions for a specific project (Behzadi, 2016). Klopfer et al. (Klopfer, Squire, & Jenkins, 2002), Golparvar et al. (Golparvar-Fard et al., 2009), Omar & Nehdi (Omar & Nehdi, 2016), Reddy et al. (Reddy, Estrin, & Srivastava, 2010), Van Krevelen & Poelman (Van Krevelen

& Poelman, 2010) and Woodward et al (Woodward et al., 2010) indicated in their study that Augmented Reality is one of the most effective ways to collecting information from construction site and could be a way of effective communication between different stakeholders of project.

3.3. Quality and defect management

Quality management and defect control is one of the important part of

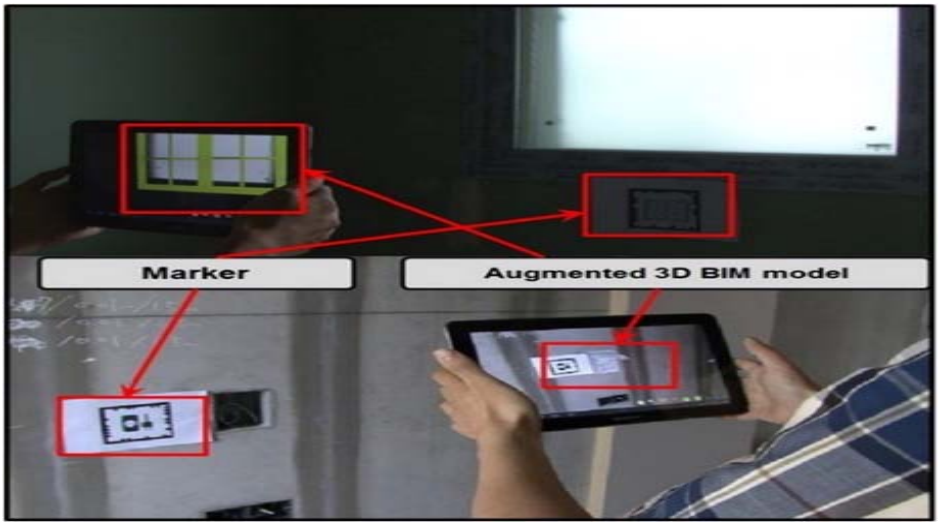


construction management. There are no completed project accepted by client with which is defected or which failed to meet the desired quality. To bring the automation in the quality and defect management system, Augmented Reality (AR) now plays a significant role in global construction. Figure 4 and Figure 5 shows the process of marker based AR technology for defects and quality management.

Figure 4. Process of defect management by AR (Kwon, Park, & Lim, 2014)

Figure 5. AR site-experiment using mobile device (Kwon et al., 2014)

AR technologies facilitate construction management to deal with defects that are probably unnoticed in the inspection process and save time to do so. Park et al (C.-S. Park et al., 2013) noted that if managers realize the core control time points and measures for works to be checked proactively through the defect element ontology, then the worker's performance can be automatically checked at the appropriate time with BIM and AR applied inspection equipment without visiting the workplace. A marker based AR technologies is used for the quality improvement and defects management of construction project and the output is very satisfactory (Kwon et al., 2014). The study (Kwon et al., 2014) concluded as the AR technologies enhance the current manual-based defect management, to reduce site managers' workloads, and prevent construction work defects proactively by utilizing BIM and AR technologies. AR was regarded as a way to carry exceptional additional value and experience of concreteness particularly in close-to-target locations in which the shapes and volume of the planned buildings could be visualized (Olsson, Kärkkäinen, Lagerstam, & Ventä-Olkkonen, 2012).



An effective defect-less facilities management system is developed for the construction project in a modern automated way that facilitate users at more satisfactory level than any time before (Koch, Neges, König, & Abramovici, 2014). AR is also mentioned as a fruitful quality and defects management technologies for on-site construction project (Kim, Park, Lim, & Kim, 2013). To eliminate any defects in piping assembly in construction project an AR technologies based management system is developed and the system concluded with expected outcomes and Showed hope for the future (Hou, Wang, & Truijens, 2013). Some others study (Bulearca & Tamarjan, 2010; J.-Y. Lee, Kwon, Choi, & Park, 2012; Rankohi & Waugh, 2013; Williams, Gheisari, Chen, & Irizarry, 2014) also show how the AR technologies are used in construction quality and defects management system.

3.4. Time and cost management

Time and cost are undoubtedly the major issue of construction process. All the management of construction project is to reduce the time of completion and save the expenses of the construction. So the time and cost management of construction is not a new concept rather it exist in construction process from the beginning of construction history but changing in different form with the changing in time. Figure 6 shows the AR application developed for a construction project to monitor and control the time and cost.

Figure 6. AR application for construction project management (time and cost)

Wang et al. (Wong, Wang, Li, & Chan, 2014) stated that both time and cost saving opportunity is available to the project managers by using AR technologies, which precise projects at the same time as lowering labour work/time and cost efficiencies because of defects and construction rework. A whole lot time and money are wasted because plans or drawings are misinterpreted, or the information is transferred imprecisely from the plan to the real object. The AR technologies unravel issues including lack of manpower inside the management and cost efficiencies in the construction project (Behzadi, 2016). Park et al. (C.-S. Park et al., 2013) and Kwon et al. (Kwon et al., 2014) showed in their study that for the defects and quality management, there are no more physical labours are necessary to conducting defects management process. So a lot of man power are reduced along with their associated cost to conducting these management process. For the construction site's data acquisition, AR technologies use effectively with saving time, reducing labour hours and decrease data acquisition cost in most significant ways (Golparvar-Fard et al., 2009). The AR technologies reduce the defects and rework of construction project that's mean it save time and

cost of the construction project by using AR mobile computing technologies (Kim et al., 2013). There are some others study (Azhar, Khalfan, & Maqsood, 2015; Tang, Owen, Biocca, & Mou, 2003; Van Krevelen & Poelman, 2010; Wang, Truijens, Hou, Wang, & Zhou, 2014) which have explored the opportunity of saving cost and reducing time for the construction industry by using AR technologies.

3.5. Employee training and safety management program

Safety management system is a very concerning issue in modern days in the construction industry. Thousands of people died every year in the world for the construction accidents. And training of employees is another most important things for every construction project. These both issues are not easy at all to perform at desired or standard level. But AR technologies assist both issues to give the employees an effective training and implement the safety management system as the specification. Figure 7 and Figure 8 shows the AR based safety management policy and tools. In both image, Pro-Vis AR a safety management Augmented Reality based mobile app is used.

Figure 7. AR based falling objects protection training and learning application

Figure 8. AR based construction crane safety application

Chi et al. (Chi, Kang, & Wang, 2013) showed in their study that AR technologies could be effectively used for the training of operators heavy equipment in the construction projects. Wang et al. (Wang & Dunston, 2007) also revealed that AR technologies are significantly used for training construction worker to operate heavy and medium construction crane, excavator and assembling equipment. AR technologies is assist the worker and stakeholders to understand various complex design and arrangement is easy and effective way and educate the project involved persons about various project issues (K. Lee, 2012). Izkara et al. (Izkara, Pérez, Basogain, & Borro, 2007) developed a conceptual diagram of Augmented Reality system for the safety at work site in the construction industry. For safety concerns, construction workers need to have and maintain a completely clear understanding of the real objects and safety hazards around them and the AR technologies assist the workers effectively to clear understanding (Stricker, Klinker, & Reiners, 2001). Wang et al. (Wang et al., 2013) developed a conceptual framework for integrating building information modeling with augmented reality for the safety management system in construction industry. So AR technologies are the new approach for the modern construction management particularly in training and safety management system.

4. Virtual Reality in Construction

Human being is immerse into a new dimension with the feeling of real world by the Virtual Reality (VR) technologies. The awesome thing is, VR furnish the opportunity to get thrown into a new dimension with new depth of digitally constructed reality which resembles real life. In construction industry, dealing with the reality for workers and consultants. Construction project often failed for arising problems directly related with incapability, unreachability and inexperience of field personnel and consultants. In that case VR technologies allows them to truly experience a project before it is built. Virtual Reality (VR) technologies are now used in integrated department of the construction industry. It is used as an essential tool for worker training, safety management system, progress tracking, labour management, defects management and so on.

4.1. Worker training

There is no other concern in construction projects before start any project is as important as worker training is. The construction quality and safety of worker mostly depend on proper training of worker (Demirkesen & Arditi, 2015; Rumane, 2016). A construction project gain more profit with excellent success if the worker of this project is highly trained in effective manner (Kerzner & Kerzner,

2017). Traditional training program is not significantly effective because of worker not understanding the reality of work and procedures with associated risk and hazards. Figure 9 shows that a worker get trained for operating heavy construction vehicle by VR technologies

Figure 9. Construction vehicle operating training by VR technology

Virtual Reality (VR) technologies are used for the worker training for the safety issue in construction project (Le, Pedro, & Park, 2015; C. S. Park, Le, Pedro, & Lim, 2015). For operate crane, excavator and others construction equipment VR based training program is effective and proven technologies (Fang, Teizer, & Marks, 2014; Hilfert, Teizer, & König, 2016). Peters et al. revealed that (Peters, Postlethwaite, & Wallace, 2016) by providing VR based training, it is possible to enhance the worker ability in particular construction work. Le et al. (Le, Pedro, Lim, et al., 2015) developed a platform for training the worker who is assigned to steel erection activities in construction. Zhao et al. (Zhao & Lucas, 2015) proposed a framework for a virtual reality training tool for design and installation of electrical systems in construction project. Alcinia et al. (Alcinia Z Sampaio & Martins, 2014) developed some models which are used in e-learning platform and assist professional training for construction field personnel and involved parties. So VR technologies are undoubtedly the effective training tool for global construction industry.

4.2. Construction safety management

Construction industry is considered as most hazardous industry for it unique nature of risk and uncertainty. Safety needs to be the top priority to each person associated with our field of work in construction project. Every year thousands of people died due to construction accident (Rozenfeld, Sacks, Rosenfeld, & Baum, 2010). For the reduction of accident rate in construction site, VR technologies open a wide windows for training, monitoring and controlling safety management of construction companies. The construction industry is a complex environment

where excessive accident rates make widespread contributions to cost overruns and time delays. So VR could be played an important role to provide safety training, education, warning, information and a learning platform for safety management in construction industry. Figure 10 represents the opportunity of worker training on health safety issues.

(a)

(b)

Figure 10: (a) Worker training on PPE and (b) worker training on working at height by VR technology

Safety education is essential in promoting a safe and healthy working environment in construction. For that Le at al. (Le, Pedro, & Park, 2015) developed a VR based construction safety education system for experiential learning. Zhao et al. (Zhao & Lucas, 2015) described a framework for

construction safety management and worker training for safety performance. Bhoir and Esmaeili (Bhoir & Esmaeili, 2015) use the VR technologies in construction safety management program and they significantly reduce the rate of accident in result. Sacks et al. (Sacks et al., 2015) showed that VR technologies are highly beneficial for designers to appreciate the implications of designs on safety. These applications of VR could run numerous drills, or unique scenarios that will provide the user a real life feeling of a potential threat. Numerous authors also a nation that progress tracking are not systematically monitored properly, making work sites at risk of potential dangers (Golparvar-Fard, Peña-Mora, & Savarese, 2015). A distinctive method for the use of augmented and virtual realities is how they could improve safety by acquiring better training and education. A research illustrates, as an instance, how the usage of augmented reality proves the excellent training within the shortest time, while also preserving the longest knowledge and skill acquired through the simulator (Sekizuka et al., 2017). There are some other researches (Chittaro, Corbett, McLean, & Zangrando, 2018; Guo, Yu, & Skitmore, 2017; Hilfert & König, 2016; R. Y. M. Li, 2018; X. Li et al., 2018; Sidani et al., 2018) which showed various VR models, platforms and applications could be used effectively on construction safety issue.

4.3. Defect and quality management

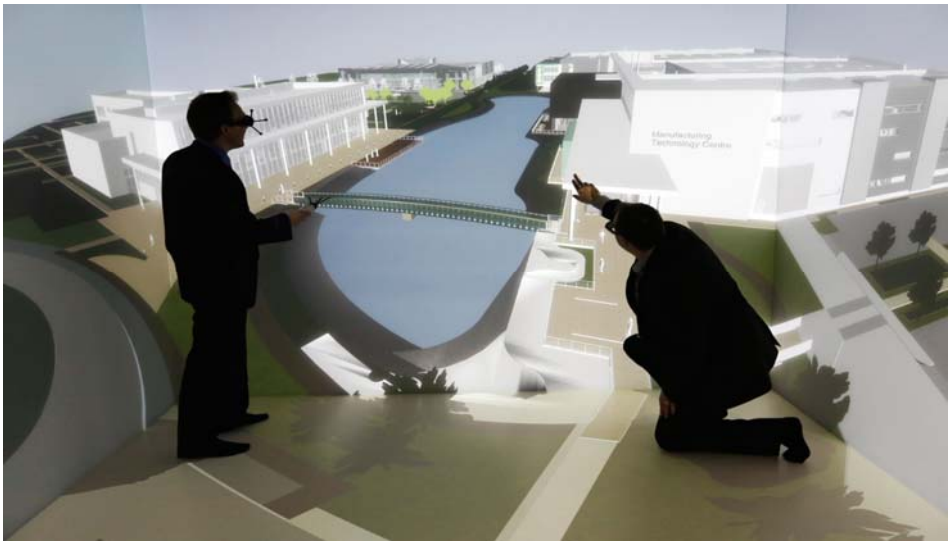
Before the Virtual Reality technologies in construction, the defect management system was very good expertise and time consuming issue. Sometimes the defect is overlooked. But with the help of VR technologies defect management become very easy and effective. Here there is no chance to overlook it. And no physical labour need to proceed this operation. So labour and time both are saved by this method of defect and quality management. Shen et al. (Shen et al., 2010) showed how the VR technologies are used in construction defect management in effective manner than before. Dong et al. (Dong, Maher, & Daruwala, 2006) developed an application for construction defect reporting using VR based mobile and digital workbench technologies from work site to head office without any time and

workforce loss. Gordon et al. illustrated (Gordon et al., 2003) an automatic quality and defect management model using Virtual Reality and used it in construction project positively. Wong et al. (Wong et al., 2014) stated that Virtual Reality technologies could be used to develop a framework for proactive construction defect management with BIM technologies.

4.4. Visualization

Some decades ago, build the project virtually before the actual project started is a nightmare. But by using VR technologies a virtually project is possible to build a model that feel the real world affection before the project started physically. Visualization of project model contains various parametric information that are not possible before. And it work as a one stop information booth and solution for all department construction team. VR technologies allow person to visit the whole project at its entire inside and outside periphery with the new dimension of real world feeling. VR is used in planning phase for make effective decision with the demand of time. It is also assist the consultant and contractor to design a project with available constructability. And at the after construction period, VR technologies reduce the effort and cost of associated with maintain and facilities management.

A huge number of study conducted on construction visualization using VR technologies over the last three decades. Park et al. (C.-S. Park & Kim, 2013) use an application of VR based technologies to visualize the hazards and risk of construction process. With recent rapid advancement of visualization technologies, recognized research work for improving construction safety management practices has been conducted for identifying safety risks as well as worker onsite training by Virtual Reality (C.-S. Park & Kim, 2013). Field construction can be planned, monitored, and controlled more effectively by the detailed visualization using VR technologies (Kamat et al., 2010). Bouchlaghem et al. (Bouchlaghem, Shang, Whyte, & Ganah, 2005) showed the advantages of construction project visualization using Virtual Reality. Applications of Virtual Reality is provided an interactive, spatial, real-time medium for visualization of project model that promote safety, quality and defect-less of construction project (Whyte, 2003b). There some others study (Cheng & Teizer, 2013; Huang, Kong,



Guo, Baldwin, & Li, 2007; Jayaram, Connacher, & Lyons, 1997; Kopp, Jung, Lessmann, & Wachsmuth, 2003; Shen et al., 2010; Woodward et al., 2010) which described the benefits of VR technologies for visualization of construction project at planning, design, construction and maintain period.

Figure 11. Visualization of project model by VR technology before the actual project

start

5. Conclusion

Construction industry is one of the largest industries in the world. A tremendous change is going on from the beginning of the history of construction industry. Among the so many change, the Augmented and Virtual Reality is bring out an unimaginable modification and advancement in various construction issues. The principle purpose of this study is to explore the changes in the construction industry that are resulting from Augmented and Virtual Reality technologies and their contribution to the overcome various construction issues from last some decades. It is revealed from the study that these incredible improvements in AR and VR technologies are having a great impact on the construction industry in a couple of ways. In this study a various use of VR and AR technologies are showed. Augmented Reality is used in project scheduling and project progress tracking in modern construction process. For the effective and less time-consuming communication between different project participants AR and VR is proven technologies. AR and VR also useful and automated system for quality and defects management in construction project. AR and VR technologies are hugely used in construction safety management and worker training from many past years. Project parametric model visualization and walk through into project before the starting of actual project with the feeling of real world is another great characteristic of AR and VR technologies. Even though AR and VR technologies seem to be a vital tools in the construction industry, there are multiple drawbacks of these technologies. There some limitations and drawbacks is appeared to implement the AR and VR technologies in construction industry. Those drawbacks and limitations are quickly broken by the upcoming generations and the sustained and continual advancement in technology around the world. Assuming that AR and VR technologies will improve with safety, quality, visualization, workforce management and time management, it's far nearly sure

that such technologies will play more important roles in construction for future years.

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