Augmented Reality for Construction Project Monitoring: Challenges and Strategies for Adoption in Sri Lanka

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Abstract— Construction project monitoring, which is governing effective decision making and successful project completion, is a key process in every construction project. However, construction project monitoring is not free from barriers, which necessitate the need for technological implementation as a possible solution to overcome such barriers. Though utilising augmented reality leads to achieving immense benefits, but there are challenges identified in implementing augmented reality within the construction industry. Therefore, this study aimed to investigate the challenges and strategies for implementing augmented reality for construction project monitoring in the Sri Lankan construction industry. A qualitative approach was adopted and expert interviews were selected as the data collection technique. Ten experts with experience in both Information Communication Technology (ICT) industry and the construction industry were interviewed to facilitate the in-depth input to the study. The collected data were analysed using code-based content analysis with NVivo 12 Software. The study identified the challenges for augmented reality implementation as the lack of knowledge on hardware and software, lack of accuracy and reliability, higher initial cost, privacy issues, health and safety issues, and lower battery life. Further, providing knowledge on augmented reality through education, training and workshops, carrying out feasibility studies, providing reduced tax-free facilities, using access control methods, implementing proper guidelines, and taking safety precautions have been identified as the possible strategies to overcome the challenges. The paper concludes by mapping the identified strategies to the challenges in implementing augmented reality in Sri Lankan construction industry.

Keywords: *augmented reality, construction industry, challenges, strategies*

I. INTRODUCTION

The construction industry is dynamic in nature, due to the uncertainties in technology and budgets. Moreover, building projects are becoming much more difficult and complex. Therefore, the project teams are facing extraordinary changes due to this dynamic nature in the construction industry (Kalkofen et al. 2011). Therefore, the construction industry is demanding implementable strategies for successful completion of the projects. Bosché et al. (2015) and Chan, Scott and Chan (2004) signified that, effective progress monitoring in construction will ensure successful completion of the project.

Kazin et al. (2009) defined monitoring as collecting, recording, analyzing, and reporting information by concerning key aspects of project performance at the pertinent level of details required by project managers and decision makers. Bosché et al. (2015) have identified Construction Progress Monitoring (CPM) as recognizing the current project status easily, rapidly, and accurately in construction industry. CPM will facilitate to identify the disagreements among the as-built and as-planned progress and enables the construction industry professionals to make decisions on the necessary remedial actions (Golparvar-Fard et al. 2012). In the construction industry worldwide, CPM can be experienced in the forms of manual visual observations and traditional progress monitoring based on field personnel's explanations, which are highly time consuming and error prone (Navon & Sacks, 2007). Further, Roh et al. (2011) have evidenced that an analysis

of large amounts of as-built data and the subsequent manual estimation for construction progress monitoring is time-consuming and prone to error. Manual progress monitoring represents excessively high costs, or ineffective, or even both, due to the significant required workload of experts (Rebolj et al. 2017). To overcome above problems, investigation on new methodologies that allow automatic recognition of as-built performance and visualization of construction progress is dynamic (Lee and Peña-Mora, 2006). Visualizations in real world environments benefit from the visual collaboration between real and virtual imagery. Even though, compared to traditional visualizations, '*Augmented Reality*' (AR) is a very powerful technique to achieve effective visualizations (Kalkofen et al. 2011). Augmented Reality allows the real-time merging of the digital data through specific computer interfaces with data from the surrounding environment (Sungkur et al. 2016). Moreover, AR can provide major benefits on construction such as increased safety, improved collaboration and communication, real time visualization of projects, better-quality scheduling and budget-management, and greater implementation of Building Information Model (BIM) (Heinzel et al. 2017). The AR system has ability to display an immersive view right into the real environment, where the stakeholders stay, visualize the as-planned data into the as-built environment right in place, and alleviate the mental workload suffered by the participants. With this in mind, the difference between the current progress and the planned future progress are able to see and monitor by the workers (Wang et al. 2014). Shin and Dunston (2008) stated that, the project participants can comprehend the project more easily and a consistent shared understanding can be achieved more readily by visualizing complex construction information. Lee et al. (2006) stated that, Progress monitoring with augmented reality technology can improve the coordination process by reducing the time to inform the participants.

Nevertheless, several researchers identified the challenges that are hindering the successful implementation of AR in the CPM in the global context (Noghabaei et al. 2020; Smith et al. 2016; Berryman, 2012). Some of the major challenges associated with the AR implementation have been identified under the data collection, modelling and alignment barriers, hardware limitations, tracking and managing data categories in the previous empirical investigations in the global context. Considering the Sri Lankan context, efficacy of AR has only been focused in the previous studies in construction industry. Despite this, there is a lack on empirical investigations in the area of challenges of successful implementation of AR and strategies to overcome those challenges. Therefore, this paper aimed to investigate the challenges of implementing AR and strategies to overcome the challenges in Sri Lankan construction industry. The paper starts with presenting a comprehensive literature review on AR. Then a brief introduction to methodology is provided. The findings of the research will be then presented under challenges and strategies for AR implementation followed by the discussion of findings. Finally, identified strategies are mapped with the challenges for AR implementation.

II. LITERATURE REVIEW

A. AR as a New Technological Approach for Construction Progress Monitoring

Both civil engineers and computer scientists have drawn much attention in current practice in applying computer vision technology to analyse the recorded images and videos automatically in the sense of CPM. Associations between computer vision and civil engineering researchers (Yuen et al. 2011) and also several interdisciplinary efforts have enabled the measuring, detecting and tracking of civil infrastructure elements, equipment and workers. Consequently, this plays a critical role in construction performance monitoring applications including progress monitoring, quality control, operation analysis, safety monitoring and occupational health assessments (Gong et al. 2011).

From fixed camera viewpoints, time-lapse images can be collected to document the work-in progress (WIP) (Heinzel et al. 2017). These collected images are either compared with one another image or against a 4D BIM which represents the expected state of construction progress (Fard et al. 2009). Several visualization

methods are also proposed to highlight deviations in construction progress. These methods are color coded construction elements based on the metaphor of traffic light colors. (Fard and Peña-Mora, 2007). Further, some studies have highlighted the importance of using 4D Building Information Modeling (BIM) in CPM and laser scanners or image-based 3D reconstruction methods focus to generate 3D point cloud models (Dimitro and Golparvar-Fard, 2014). Further the authors have stressed the possibility of automated progress monitoring technique using the geometrical information. However, it has been identified that none of the above technological approaches would provide enough information on the current stage of construction progress without the real time material information (Golparvar-Fard et al. 2012).

Hence, AR has been emerged to the CPM through combination of a real and virtual objects, interactive in real time, and register the virtual imagery with the real world. More comprehensively, AR allows computer generated virtual metaphors to exactly overlay physical objects in real time (Yuen et al. 2011). AR using real objects in a seamless way, permits the user to interact with the virtual images (Zhou et al. 2008). Additional information of real world can be acquired by interpreting this mixed overlay in devices such as head mounted displays, handheld monitors and see-through glasses.

The application of AR can be comprehensively described through the reality-virtuality continuum, which highlights the "mixed reality" of real and virtual environment (Milgram et al. 1995) as depicted in the below Figure 1.

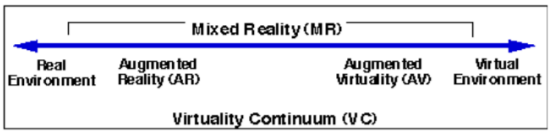

Figure 4: Simplified Representation of" Virtuality Continuum"

Source: (Milgram, Takemura, Utsum, & Kishino, 1995)

According to Figure 1, the real environment and virtual environment will be on the opposite ends of the scale. Two types of augmented environments exist between these two extremes: AR inserts computer-generated content and Augmented Virtuality (AV), taking the real world and real environments as its background and in which a computer-generated world serves as the background while real-world data is merged in and superimposed. (Milgram, et al., 1995). Accordingly, AR will be implemented within the construction environment to achieve the several purposes using the technologies along with AR such as Virtual Reality (VR), and Mixed Reality (MR).

B. Challenges in Implementing AR in Construction Industry

Despite the growing interest in the context of AR in construction environment, several challenges and issues exist, which is essentialy to be addressed to achieve the successful implementation. Some reseachers have categorised the challenges of AR implementation with resepect to the technological, social acceptance and usability aspects (Mekni & Lemieux, 2014). Further, Vakoms (2017) has emphasized that AR implementing challenges can be divided in to two categories namely social and technical challenges. However, several challenges of AR implementation within construction industry have been highlighted in various empirical investigations as described in the below Table 1.

Table 2: AR implementation challenges in construction industry

Challenges	**References**
Cost	[1], [7]
Privacy issues	[2], [3] [6], [8]
Social rejection	[3], [7], [9]
Poor experience	[1], [3], [4], [6] [8]
Lack of knowledge	[1], [3], [5], [8] [9]
Health and Safety Issues	[1], [4]
Battery life	[1], [3], [4], [6], [8]
Accuracy and reliability	[1], [3], [6], [8], [9]
Technological limitations	[1], [3], [4], [5], [7], [8]
References: [1] Smith et al. 2016; [2] Berryman, 2012; [3] Mekni and Lemieux, 2014; [4] Busel, 2017; [5] Azuma et al. 1998; [6] Fenais et al. 2020 [7] Vyas and Bhatt, 2017; [8] Wang, 2009; [9] Noghabaei et al. 2020	

As per the literature findings of Table 1, most of the literature sources have highlighted the impact of poor experience, lack of knowledge on technical aspects of AR, accuracy and reliability of the input data to the system, and the existing technological limitations within the construction industry. The unfamiliarity AR applications can be caused for the suffering of enough knowledge or experience on working with implementations. Further, enhanced tracking systems in the AR applications are needed to display the information in highly accurate and reliable way and the devices should contain well-functioning software and hardware to obtain, filter and retain the information and display the exact information (Mekni & Lemieux, 2014). Accordingly, accuracy and reliability are another major challenge that construction industry practitioners are facing with. Moreover, the impact of higher cost requirement, social rejection due to the unfamiliarity, and health and safety issues have been identified in the literature review. Hence, in order to proceed with the successful implementation of AR practices within the construction industry, the strategic solutions are essentially to be provided through an empirical investigation. In the Sri Lankan construction industry context, there is a dearth of research in identifying the challenges of AR implementation and as well as the possible strategies to overcome the challenges.

III. RESEARCH METHODOLOGY

The research problem, which is to identify the challenges in implementing AR and strategies to overcome the challenges in Sri Lankan construction industry needed an in-depth investigation whereas the respondent opinions regarding the challenges and strategies were also required to be collected. Therefore the qualitative approach was selected as the suitable research stance for this study (Naoum, 2007). Further, the study adopted the expert interviews using semi-structured interview guideline as data collection instrument for empirical data collection. The authors identified the importance of employing semi-structutred interview method to this study as interviewers have a structured flow ask questions from interviewees. In this study, data collection was conducted in two steps where initially five expert interviews with professionals in ICT industry and subsequently five expert interviews with construction industry professionals were conducted. Interviewees form ICT industry included Software Engineers, Software Developers and Computer Science Engineers who have more than 5 year working experience within ICT industry. The profiles of experts have been provided in Table 2.

Table 3: Profile of Experts

Industry	Code	Discipline	Experience
Experts from ICT industry	RI1	Software Engineer	> 5 years
	RI2	Software Engineer	> 10 years
	RI3	Computer Science Engineer	> 5 years
	RI4	Software Developer	> 5 years
	RI5	Software Developer	> 10 years
Experts from Construction industry	RC1	Planning Engineer	> 15 years
	RC2	Planning Engineer	> 10 years
	RC3	Civil Engineer	> 10 years
	RC4	Quantity Surveyor	> 10 years
	RC5	Project Manager	> 30 years

The collected data was analysed with code based content analysis using N-vivo software, which helped in organising and exploring a set of unstructured data.

IV. RESEARCH FINDINGS

This study investigated the challenges of implementing AR and strategies to overcome the challenges in Sri Lankan construction industry. Following sections elaborate findings of this study.

A. Challenges of Adopting AR in Construction Industry

The identified challenges of adopting AR in construction industry in literature review were validated during the interviews with experts. All the respondents from both ICT and construction industry highlighted the ***"lack of knowledge on software and hardware"*** as one of the main challenges of implementing AR within construction industry. Hence, the stakeholders of the construction may resist to adopt new

technologies such as AR. More comprehensively, RC3 stressed that people are tending more towards adopting the traditional construction methods rather than going for innovative technology because due to their nature of ***"unwillingness to change".*** Rather, RI2 highlighted the more adaptation of society towards the technological innovations in the daily chores. However, still the adaptation of construction industry practitioners for novel technologies is lacking than the expected level. Majority of the respondents from both the industries have highlighted the ***"higher initial cost"*** as a major challenge of AR adaptation in the Sri Lankan context. More comprehensively, RC1 stressed that ***"higher tax concessions"*** of government have directly affected the higher initial cost of acquiring the hardware and software essential in AR implementation within the Sri Lankan construction industry. Therefore, the investors in construction industry are not comfortable with investing on innovating technology due to its uncertainty of return on investment. Hence, higher tax concessions imposed by the government have also been indirectly impacted to successful adapatation of AR within Sri Lankan construction industry.

As per the view of RI5, it is essential to employ a skilled person, whom having the ability of handling and controlling the applicable hardware, software and 3D models using in AR practices. However, according to RC2, the ***"unfamiliarity on new technologies"*** lies within the traditional construction industry professionals would negatively impact in successful implementation of AR within construction industry. In accordance with the opinion of majority of respondents from construction industry, implementing AR will cause for the ***"health and safety issues"*** of the employees within the construction site. RC1 highlighted the ability of originating health and safety issues within construction site due to the utilisation of some hardwares related with AR technology such as smart headphones, smart phones etc. Further, mentioned by RC4, there will be health issues such as eye and ear related problems due to this. Further, real environment covered by 3D environment may increase accidents in the site.

Moreover, RI5 highlighted the possibility of ***"privacy issues"*** due to the implementation of 3D models associated with the AR implementation by entering valuable and confidential project information. According to RC2, any of the employee with access to the computer system of the site can access the model and it will be a security issue for the project details to some extent. RI4 and RC2 mentioned that mismatching between model and actual environment can cause more errors while tracking AR model with the real environment. Therefore, the necessity of hundred percent "accuracy and reliability" of input data have been highlighted by the majority of respondents. Hence, ***"lack of accuracy and reliability"*** can be identified as another major challenge in implementing AR in Sri Lankan construction industry. According to RC2, when implementing AR within construction sites, there should be a portable device to minimize the difficulty of handling. However, when adopting a portable device, ***"lower battery life"*** act as a critical barrier, which must essentially overcome.

B. Strategies to Overcome Challenges of Adopting AR in Construction Industry

In order to avoid the challenge of lacking accuracy and reliability, RI1 proposed to ***"implement AR for the small scale construction project"*** in the initial stage. Hence, it would allow the construction industry practitioners to conduct suitable testings beforehand and seeking the possible technological development in relation to the AR applications in mega scale construction projects. Further, RC2 highlighted the importance of upgrading the education system of the country by ***"including AR practices to the university level education"*** to overcome the challenge of lacking knowledge on software and hardware and unfamiliarity on new technologies. Moreover, RI3 stressed the importance of more ***"academic involvement in the research and development"*** on the area of AR and its practical implications in the construction industry of Sri Lanka. Hence, these studies will provide theoretical contribution in filling the existing knowledge gap related to AR implementation within the construction industry in local context comparative to the global context. RC4 mentioned that ***"conducting workshops and training programs"*** in the organisational level on AR implementation would support to

overcome the challenge of unfamiliarity on new technologies of construction professionals and fill existing knowledge gap regarding AR practices and unwillingness to change to new practices. Further, these programs would facilitate to minimise the control and handling issue in the technology and devices and enhance the awareness on novel technologies.

According to the opinion of RI1, RC2 and RC4, ***"carry out a feasibility study"*** before implementing AR in construction projects would be more suitable to identify risk and possible opportunities of adopting the technology in the Sri Lankan context. Conducting a feasibility study could reveal the possible forecast return on investment. This will address the issue regarding the higher initial cost of technology implementation. To overcome the challenge of higher tax concessions, some of the respondents highlighted the importance of the involvement of government in ***"providing reduced tax fee facilities"*** to motivate the construction industry practitioners who are involving in the AR implementation practices. ***"Using access control methods"*** such as fingerprints, passwords, and ID cards has been highlighted by majority of respondents in the sense of eliminating the privacy issues which can be occurred in the AR implementation. Hence access to data will be controlled and monitored. As mentioned by RI1, RI4, RC4 and RC5, ***"implementing a proper user guideline"*** and training construction industry professionals and workers to carry out proper site safety procedure to minimise on-site accidents and ***"take precautions to reduce health issues"*** that can arise due to negligence while handling the hardwares related to AR implementation are few steps to minimise health and safety issues regarding implementing AR in Sri Lankan construction industry. To overcome the challenge of lower battery life, RI4 mentioned the possibility of ***"using currently available devices to enhance the performance within the capacity".***

V. DISCUSSION OF FINDINGS

As the final step, the study mapped the challenges of implementing AR with the strategies required for overcoming those challenges in Sri Lankan construction industry. The Figure 2 presents the summary of findings. According to Figure 2, the study has identified several challenges of adopting AR in construction industry. Lack of knowledge on software and hardware, lack of accuracy and reliabilty, higher initial cost, privacy issues, health and safety issues, and lower battery life are some of the challenges identified in the empirical investigation, which can evidence in the literature findings as presented in the Table 1 above. In the empirical investigation, the authors have reworded some of the challenges identified in the literature synthesis such as lack of knowledge on software and hardware, lack of accuracy and reliabilty, and lower battery life as per the respondents' comments in the empirical investigation. Some of the challenges such as unwillingness to change, unfamiliarity on new technologies, and higher tax concessions have been highlighted by the respondents as challenges that Sri Lankan construction industry is facing in the implementation of AR in addition to the challenges identified in the literature synthesis. Further, the respondents have identified several strategies to overcome the challenges in AR implementation within Sri Lankan construction industry such as providing knowledge on AR implementation to the construction industry practitioner through university education, conducting workshops and training programs, and research and development procedures. Some additional strategies have also been highlighted, which can be implemented in the organisational, government and also the industry level such as providing reduced tax fee facilities and implementing a suitable user guideline.

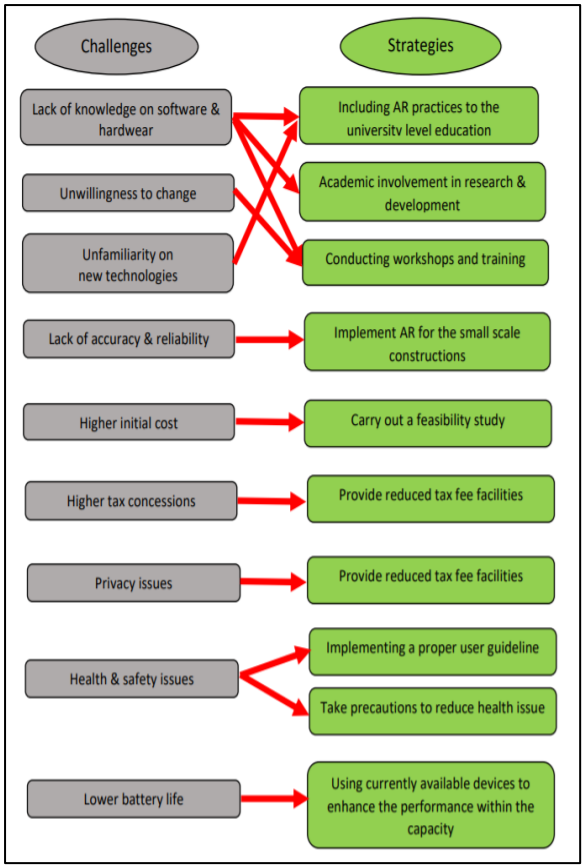

Figure 2: Research framework on challenges and strategies on AR implementation in Sri Lankan construction industry

V. CONCLUSIONS AND RECOMMENDATIONS

There has been a notable growth in application of novel technologies in construction industry practices. Due to the several barriers that construction industry practitioners faced in CPM, the utilisation of new technological approaches such as AR can be identified. However, utilising AR in construction industry is not free from challenges. Therefore, this study aimed to investigate the challenges of implementing AR and strategies to overcome the challenges in Sri Lankan construction industry. This study identified lack of knowledge on software and hardware, unwillingness to change, unfamiliarity on new technologies, lack of accuracy and reliabilty, higher initial cost, higher tax concessions, privacy issues, health and safety issues, and lower battery life as the challenges on AR implementation in Sri Lankan construction industry. In order to achieve the construction project success through AR applications, several strategies need to be practiced to overcome the AR implementation challenges within the Sri Lankan construction industry. Accordingly, the empirical investigation have identified the possible strategies such as providing knowledge on AR and it's applications, conducting workshops and training, carry out feasibility studies, provide reduced tax fee facilities, take proper safety precautions. The study will further guide the Sri Lanakn construction industry to understand the possible strategies to successfully implementing AR. The study contributes to the academic knowledge in the areas of challenges and strategies of implementing AR for CPM in Sri Lanka.

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