An empirical study on the Benefits of Augmented Reality Technology (ART): A Nigerian construction industry context

Abstract

Augmented reality (AR) is the combination of real and computer-based images and scenes to bring about a unified and improved view of the world. The study assesses the benefits of augmented reality technology (ART) to the industry so that productivity in construction can be enhanced. A survey of construction professionals involved in the built environment was carried out in Lagos State, Nigeria. Architects, Project managers, Engineers, Quantity surveyors, and Builders were engaged in the survey and they were sent a well-structured questionnaire. Convenience sampling techniques was adopted in choosing those professionals. The collected data was analysed using both descriptive and inferential statistics. The five most important benefits of ART are: improved team collaboration and communication; enhanced repairs, rehabilitation, and maintenance; improved communication / real-time information retrieval; accurate automated measurement, and low-cost virtual training in operating heavy construction equipment. The results showed that there were nine (9) out of fifteen (15) benefits with no significant difference while the other six (6) have a significant difference in the opinions of professionals. A post-hoc test revealed that there lies a significant difference between the Architects and Quantity surveyors as well as between the Quantity surveyors and Project managers on the benefits of AR while there is no significant difference for other professionals**.** The study concluded that AR improves collaboration and communication between workers on construction sites. It is therefore recommended that the Nigerian construction industry should create awareness programs and platforms to inform its professionals and upcoming ones on the benefits of using AR in the industry.

Keywords: Augmented reality, Construction professionals, Construction industry, productivity

1. INTRODUCTION

Augmented Reality (AR) was first coined by researcher Tom Caudell, at Boeing in 1990, which is from the field of computer science research interface. AR is viewed by many authors in different ways. It is defined as a technology that provides other information generated by a computer, which is imputed into the user's view of a real-world scene (Wang and Dunston, 2017). Also, AR is seen as the superimposition of computer-generated digital information over real world view, in other words, AR is a technology that broadens our physical world by adding levels of digital information, it involves a visualization technique that brings about an improved version of reality by the reprocessing of computer-generated graphics or images, data, and sound on the users view of a real environment (Rankohi and Waugh, 2013).

The effect of this technology on the world cannot be over-emphasized, because it has brought about the creation of different means and techniques to ensure that operations are effectively and efficiently carried out (Liu, 2009). Information Technology (IT) is seen to be playing a major role in the evolution and improvement of the construction industry around the globe and it has become a key element in bringing about productivity and quality for construction works (Shakil et al., 2017). However, due to the complex nature of construction projects, the need for IT applications has increased. Therefore, to further harness the application and importance of IT to construction projects, ART has widely been recognized as one of the most promising technological applications to construction projects (Chi et al., 2013).

The construction job site is changing rapidly as the two-dimensional paper drawings are giving way to three-dimensional models and a new interactive experience called AR, which is a technology that could bring about the much needed growth and development in the industry. The construction industry can realize numerous benefits with the use of ART because it makes visualization to be done easily and abridges the effort of designers and architects by a great deal. Project real-time visualization is enhanced when the smartphone camera of users is being placed at a specific location or for scanning a specific image. This will benefit professionals in giving deeper insights into the details of the project to clients (Kodeboyina and Varghese, 2016). Furthermore, ART bolsters the way humans and digital machines work together by providing real-time information to increase efficiency, manage cost, improve safety and boost project confidence by increasing project life cycle (Zitzman, 2019).

In advanced technological countries ART is being adopted for use at different stages of the construction phase and it has since been beneficial. These countries include New Zealand, UK, USA, China, Australia, Malaysia, and so on (Pejoska_Laajola et al., 2017; Zhou et al., 2017; Sirakaya et. al., 2018; Palmarini et. al., 2018). Other areas where AR is used are science and engineering educational institutions, medical training, tourism and advertisement, manufacturing, and military (Yen, Tsai, & Wu, 2013). Few empirical studies have been conducted on ART in developing counties such as Nigeria. Oluwaranti et al. (2015) evaluated how augmented reality-based mobile learning applications can improve the learning of students in STEM (Science, Technology, Engineering, and Mathematics). The students assess the augmented reality mobile learning application based on the following criteria such as ease of use, learnability, and effectiveness. The result was above average which implies it improves the learning of students.

Adedokun-Shittu et al. (2019) also examine the effectiveness of mobile based AR institutional technology (MBARIT) on high school students in Osun State, Nigeria. It was revealed that students performed really well when taught with MBARIT as they reacted to this positively. The aforementioned studies were only limited to upcoming professionals (students) in the adoption and effectiveness of these technologies. Moreover, most developing countries like Nigeria have failed to explore the benefits of such technology in carrying out their operations and are still using the traditional method which has slowed down the growth and development of the construction industry (Royal Institute of Chartered Surveyor, 2015). This research will examine the benefits of AR to professionals in the built environment which makes this research different from previous researches. Conclusively, this study seeks to give resounding insight about ART, and the benefits gained in adopting this new technology for construction projects in Lagos state.

2.0 LITERATURE REVIEW

2.1 Benefits of Augmented Reality Technology (ART) for construction projects

The benefits of ART are not identified from the perspective of the consumers. Users are not aware of some benefits derived from technology while others want to know whether if AR would give back the investments made in implementing the system, for example, investment in AR retail solutions, maintenance systems, and marketing (Martinez et al., 2014).

2.1.1 Improvement in scheduling quality and budget management

The scheduling part of the construction work can be influenced greatly by the use of AR. This displays the as-planned vs as-built structure to give a progress visualization (Behzadi, 2016). AR has several merits; observers do interact with both virtual, actual objects and monitoring the progress of construction by comparing the as-planned and as-built status of the project **(**Rankouhi and Waugh, 2013). The survey of architects and engineers by Meža, Turk and Dolenc (2015) revealed that AR is much better on tablet PC to Gantt chart or other 3D models for construction monitoring. It was noted that it is possible to visualize and calculate the work that has been done on-site compared with the planned schedule. Many other researchers like Wang et al. (2014) opined that when AR is connected to material tracking, this ensures that needed materials are timely delivered on-site.

2.1.2 Project 3D/4D visualization and display

AR system can be defined as the process of combining the virtual objects and the real-world, which can relate in real-time and has three-dimension registration of virtual objects. Research has also revealed that the usability and project documentation of AR in various formats includes the viewing of schematics on tablets, 2D plans, BIM on a PC, and 4D display. The comparisons showed that AR was at least one grade better than any other presentation technique (Meza et al., 2015).

AR enables teams to perform walkthroughs of an entire project before it is executed in order to examine its details and components for accuracy. This foreknowledge can stop cost overruns and schedule delays, and can help to discover any errors before they materialize (Zitzman, 2019).

2.1.3 Enhanced team collaboration and communication

When AR is used on construction projects, it enables communication and collaboration on-site (Pejoska et al., 2016). Construction drawings are the major communication tool adopted in the construction industry. Two-dimensional drawings have been used in delivering construction projects and managing facilities. Traditionally, the construction team carry construction drawings to site and a lot of effort is involved in ensuring correct drawings are used to obtain the information needed. AR gives fast information to project stakeholders so that early decisions can be made to reduce cost and time delay for projects (Bae et. al., 2013). Some companies are developing

lightweight devices to reduce the difficulty in information and communication retrieval (Yeh et. al., 2012).

However, when 3D objects are represented in 2D drawings there are several limitations encountered. For example, there is the problem of understanding horizontal and vertical elements together with 2D drawings, where complex connections and multiple faces are not fully visualized or illustrated (Suk et al., 2017). Thus it is vital that information is transferred from a 2D representation to an imaginary 3D representation in order to identify many predefined symbols on the drawings. Also, the architects and contractors can collaborate better to ensure any necessary changes and check for buildability issues during the design and construction stages (Yoders, 2018).

2.1.4 Safety, efficient management, and planning of construction projects

Safety management and visualization system (SMVS) was proposed by Park and Kim in 2013 where integration of AR, Building Information Modeling (BIM), game technologies, location tracking were carried out. A case study was conducted and a prototype was developed and tested and the outcomes of the case study revealed the potentials of ART in enhancing safety risks, increasing risk perception of workers and improving communication between workers and construction managers in real-time.

Li et al. (2018) noted that to improve the abilities to recognize safety risks promptly and accurately, ART has been studied and used in the supervision, inspection, and strategizing of construction process. Safety must be the most paramount priority for construction companies. In the United States, 16% of accidents in 2011 was linked to the construction industry (Albert et. al., 2014). Many companies invest in safety training and program for workers which can be used in the purchase of AR. This is much lesser because most equipment used are smartphones or high-end gear. Smartphones are mostly used because of numerous possibilities of applications that they provide. These applications are cheaper and more efficient in enhancing safety (Agrawal et. al., 2016). They can detect potential hazards when the application is run. By the combination of digital and physical views, AR will help construction teams to be more efficient and there will be confidence in any projects being executed (Zitzman, 2019).

2.1.5 Improving real-time information retrieval

Instead of looking, searching and mapping related information that is required in the construction site, the AR system provides access to right information where it is needed. This can be achieved by superimposing progress and as-planned information to the user's sight concerning the physical environment (Zollmann et al., 2013). These AR systems give quick entry to information which aids project managers to make decisions on corrective actions to reduce cost and delays caused by discrepancies. To minimize the difficulties for on-site information retrieval many companies are starting to develop lightweight mobile devices (Behzadi, 2016).

The combination of digital documentation and information with one's physical view is a game-changer. Required information such as the location of cables, pipes, ventilation and walls can be easily toggled on and off. When information can be retrieved in this manner, it enables construction workers to monitor a project effectively against its building plan and ensure its successful completion. AR gives a vital information database for users to check a building's progress virtually against its planned schedule, which offers an additional level of project management. This application will become indispensable as the industry continues to experience unproductivity (Zitzman, 2019).

2.1.6 Promotes greater use of BIM implementation

Storage and retrieval of defect data can be visualized with the help of advanced technologies such as BIM and AR. These technologies provide large opportunities to improve the quality of construction work. In adopting these technologies, workers and managers can automatically confirm the results of activities by augmenting virtually created information onto real objects or even photos taken of the work performed on-site. (Heinzel et al., 2017).

Danker and Jones (2014) suggested that the adoption of BIM and AR in the construction sector will continue to increase with the emerging technologies. The combination of BIM and AR together with Wireless Sensory Network and 3D Scanning will increase and bring synergies between BIM and other digital technologies. This will bring about efficiency in the project lifecycle. The applications are considered currently as the most valuable to practitioners and industry because they can improve the communication between contractors, architects, and sub-contractors. AR can also help with the composite visualizations of the big picture and with the testing and refinement of design models or iterations.

2.1.7 ART can enhance the user experience

Physical environments combined with virtual reality can create an immersive feeling for the user. ART is a highly interactive technology and it is ideal for learning by doing. In virtual reality, the interaction possibilities range from basic to complex features. The basic interaction includes playing videos, moving 3D models, scaling objects, and so on. Complex interactive features include the interaction between physical and virtual objects or embedded intelligent virtual tutors i.e. tangible interfaces (Martinez et al., 2014).

Recently, AR has been adopted with tablets, smartphones, and other wearable mobile devices, which creates a cross-platform multi-user environment. This allows users to view and edit digital information that is being overlaid to the real-world environment. It gives the user an improved experience with wide exposure and access to additional or supplementary information (Danker and Jones, 2014).

2.1.8 ART ensures situational awareness

ART is the process of integrating real-world objects with virtual components for the user not to differentiate the changes in the real world. The virtual component is usually interactive and this gives the user the feeling that the object is present in the view even though it is physically absent (Raajana et al., 2012). On the other hand, AR is recognized as the most promising technology to aid mobile workers with improved situational awareness. It also helps the workers to shift their attention from work targets to external devices or manuals. Presently, hardware developments such as integrated sensors and increased computing power now enable the demand for AR applications on tablets and mobile phones. A new generation of wireless optical see-through data glasses for example, by Epson and Meta, started a new usage pattern which is enabled by commodity level depth cameras and supported by sophisticated computer vision technology (Gheisary and Irizarry, 2011).

2.1.9 ART aids repairs, rehabilitation, and maintenance

One of the most active research fields in ART is maintenance for the construction industry and there are a lot of research studies that have been carried out in regards to the benefits of using ART for maintenance. Some of the benefits are more safer and efficient procedures and quicker maintenance interventions with fewer errors (Martinez et al., 2014). AR system is also regarded

as CPS that interacts digitally with various IT sensors, systems, and machines to optimize the decision support tool in the maintenance activities. As a result of this, information and knowledge will be made available in a decentralized form at the place of maintenance (Quandt et al., 2017).
Quandt et al. (2017) opined that a successful implementation of a maintenance assistance system in the construction site relies on the following processes which include finding the components to maintain (target) and performing the maintenance activity. Also, the following requirements are important for mobile AR applications in maintenance. They include indoor navigation and orientation as well as support during performing maintenance tasks which includes work documentation. Having a successful implementation such as an AR-based assistance system that helps service technicians in on-site maintenance operations is vital.

2.1.10 Low cost for Virtual Training on operating heavy construction equipment

In recent practice, most of the operators of heavy equipment are constrained to off-site training programs that provide limited chances to experience the real working conditions. As an alternative, training for operators done on-the-job are very costly but also not allowed due to requirements for job trainer and specialized equipment. However, it is only extensive and suitable training that enables operators to control large equipment efficiently and safely. Researchers in the construction industry have started to explore creative methods to effectively train beginners with low cost and reduced hazards (Wang and Dunston, 2007).
Many companies invest a great amount of money in safety training and programs which are very expensive. The cost used to upskill professionals and workers in respect to safety can be minimized with the adoption of AR as it involves the use of high-end equipment to a simple smartphone. Smartphones are mostly used because of the unlimited possibilities that their applications offer. AR applications are very cheap and very effective in improving the safety of humans. These applications can run various scenarios or specific drills that will provide the user with a real-life feeling of a potential hazard (Behzadi, 2016).

2.1.11 Reduction in man-hours

One of the benefits of AR is reduction in project time completion. Time management is an important concept in construction and AR application is developed to reduce the time and cost of construction (Behzadi, 2016). According to Wong et al. (2014), AR technologies bring about

precision in design and construction which reduces rework and defects in construction. AR technologies prevent misinterpretation of designs which minimize the time and cost spent on rework. Kwon et al. (2014) revealed in their study that AR technologies reduced the man hours in the defect management process which in turn minimizes the cost associated with hiring manpower.

2.1.12 AR increases site safety

Safety is one of the critical issues on construction sites. Many construction industry workers are victims of accidents that have resulted in injuries and deaths (Wang & Dunston, 2007). There is an AR application that can enhance safety in construction such as the Pro-Vis AR mobile application. AR technologies help construction workers to effectively have an appreciation of the real objects and hazards in the environment (Wang et al., 2013).

2.1.13 Accurate automated measurement

AR helps in the accurate measurement of an area of a building both inside and outside without errors. The major obstacles to accuracy are lighting conditions and visibility. An AR system can interact with a Wireless Sensor Network (WSN) or measurement system so that it can display to the user the measurements of physical quantities that cannot be perceived with five senses (Daponte, De Vito, Picariello and Riccio, 2013). Presently, the advances in technology are moving AR from the laboratory into the consumer markets and industry (such as the smartphone market and the promising system proposed by Google, called Google Glass).

2.1.14 Promotion of superimposition of virtual objects

AR technologies are superimposing information or objects into the real world which influences our everyday lives. AR can impose virtual 3D objects and information into the real world and videos (Azuma, 1997; Shakil et al., 2017). This additional information is used to augment the real world and helps professionals and workers in different tasks, operations, and monitoring of construction works (Wang, Kim, and Love, 2013).

2.1.15 AR aids in geo-locating data on construction site

AR helps in getting realistic information and data about the immediate environment with the support of the Geographical information system (GIS). Field-based GIS gives geo-referenced,

topographic, and cartographic information of the area when a virtual image is needed to be placed in the real world. A geo-referenced database is required to be created which gives and records the information about every object in the physical environment. Behzadan et al. (2008) proposed a reusable mobile AR framework for general construction purposes that integrates GPS. With the survey theories development and the global positioning system (GPS), people can identify their exact position by referencing control points and applying interpolating processes.

(Insert table 1)

(Insert table 2)

3. RESEARCH METHODS

Research Methodology is a procedure for collecting and analyzing data to achieve a set of objectives. This study adopted a quantitative research method for the collection of data. According to Teddlie and Tashakkori (2009), the analysis of numerical data adopting the techniques describing the phenomenon of concern and looking for significant differences between groups or among variables is called Quantitative research. Data were collected through questionnaires to the targeted population to elicit their opinions on the benefits of augmented reality in construction. A five-point Likert scale was applied for ranking the variables for the benefits where 5 connotes Very high, 4 represents High, 3 denotes Average, 2 signify Low, 1 represents Very low. Okoko (2001) defined population as a process of collecting elements being examined and about which conclusions are to be depicted. Quantity surveyors, Project managers, Architects, Builders, and Engineers were employed for the population of the professionals in Lagos state.

A sampling frame is the complete list of all elements from which the sample is selected (Agbola et al., 2013). This is enabled to check how much sample represents the entire population of respondents where sample was drawn (Kothari, 2009). The sample frame were registered professionals for each profession in Lagos state where we got 1102 architects, 826 project managers, 781 quantity surveyors, 456 builders, and 1314 engineers. 4479 professionals formed the total sample frame. Applying the Yamane formula, the sample size was extracted. The level of precision (e) was 10% and it was calculated as 445 respondents. The sample size is the number of considerations to be selected from the overall population to constitute the statistical sample (Kothari and Garg, 2014). In this study, convenience sampling techniques were used for

distributing the questionnaire and four hundred and forty-four (444) were administered. The means of distributing questionnaires were by hand and through electronic means. At the end of distribution process which was for two months, two hundred and thirty-nine (239) questionnaires were returned and one hundred and sixty-six (166) were suitable for analysis. This implies that the response level is at 37% which is above what Akintoye (2000) stated that normal response rate falls within 20-30%. The reason why some received questionnaires were not included in the analysis was that some parts were not filled i.e. partially filled and also some of the information given by some respondents was not correct.

(Insert table 3)

Cronbach's alpha (α) test or reliability check was adopted which was conducted on a 5-point Likert scale. As shown in Table 3, the value was 0.965. Doloi et al. (2011) noted that values with 0.70 and above were suggested that are reliable and it can be inferred that the applied instrument and scale are reliable to measure the benefits of augmented reality in the construction industry. Concerning the data analysis, frequency and percentile were used for the respondents' background information. Mean and standard deviation were applied in the analysis of the benefits of ART in construction. The Mean Item Score (MIS) was calculated from the Likert scale and this was applied to rank the highlighted benefits. In finding the difference in the opinions of the professionals for the benefits of AR in construction, Kruskal Wallis was applied. Standard deviation was used to determine the disparity and variability between respondent's views.

4. FINDINGS AND DISCUSSIONS

Table 4 summarizes the respondent professions. 32.5 percent of the respondents are Quantity surveyors which are the highest followed by Architects which represent 21.7 percent of the total respondents. The Builders represents 19.3% of the population while 18.1% of the respondents are Project managers and 8.4% of the professionals are Engineers. Regards the professional qualifications, the respondents that belong to a member of Nigerian Institute of Quantity Surveyors/Quantity Surveyors Registration Board of Nigeria (NIQS/QSBRN) are the highest at 31.3% followed by members of the Nigerian Institute of Architects/Architects Registration Council of Nigeria (NIA/ARCON) with 21.7% of the respondents. 18.1% of the population are members of the Nigerian Institute of Builders/Council of Registered Builders of Nigeria

(NIOB/CORBON) while 12.0% of the population belong to the Project Management Institute/Project Management Professional (PMI/PMP) and 8.4% accounts for members of the Nigerian Society of Engineers/Council for the Regulation of Engineering in Nigeria (NSE/COREN). 8.4% do not belong to any association or professional body yet.

(Insert Table 4)

As for academic qualifications, 53% of the respondents have Bachelor of Technology/Bachelor of Science (BTech/BSc) and 21.7% have Higher National Diploma (HND). Those with Master of Technology/Master of Science (MTech/MSc) degrees represent 21.7% of the respondents while 2.4% are National Diploma (ND) holders. 1.2% did not fill in their academic qualifications.

Figure 1 shows the working experience of the respondents. Those with less than 5 years' experience were 43.4% while 28.9% of the professionals have 6 to 10 years' experience. Professionals with 11 to 15 years working experience were 14.5% of the respondents while 7.2% of them have between 16 to 20 years' experience. 6.0% of the professionals have a minimum of 20 years working experience.

(Insert Figure 1)

Table 5 revealed awareness level and knowledge of ART by respondents. 51.8% of the respondents noted that they are aware of ART. 30.1% are not aware of ART and those that were not sure whether they are aware or not depict 18.1% of the respondents. This means more than half of the population are aware and have knowledge of ART. Their awareness level on ART collaboration with various ICT tools was asked. 50.6% of the respondents noted that they are aware of ART collaboration with various ICT tools and 37.3% are not aware of ART collaboration with various ICT tools. 18.1% of the professionals were not sure if they are aware of ART collaboration with various ICT tools. Also, respondents were asked their awareness level on the benefits of ART. 45.8% of the professionals opined that they are not aware of the benefits of ART while 28.9% are aware of the benefits of ART. 21.3% of the professionals were not sure if they are aware of the benefits of ART.

(Insert table 5)

(Insert table 6)

Table 1 and Table 6 revealed the variables with their codes and also showed the mean rankings by professionals of the benefits of augmented reality. Team collaboration and communication was

ranked first with a 4.37 mean value followed by AR improves repairs, rehabilitation, and maintenance with a mean value of 4.34. Improved communication / real-time information retrieval ranked third with a 4.33 mean score while accurate automated measurement with a mean value of 4.20 was fourth in rank. Low cost for virtual training in operating heavy construction equipment was ranked fifth with a mean value of 4.21 while the sixth-ranked variable is AR enhances the users' experience with a mean score of 4.20. The seventh-ranked variable was AR improves scheduling quality and budget management with a mean value of 4.19 and reduction in man labour hours was ranked eighth with a mean score of 4.16. Project 3D/4D visualization was ranked ninth with a mean score of 4.13 while AR promotes the use of BIM implementation was ranked tenth also with a mean value of 4.13 although with a higher standard deviation. Field (2005) noted that for variables with the same mean score but different standard deviations, the variable with the lower standard deviation is ranked first. This applies to the ranking of each professional in Table 6. For those with the same mean values but having different standard deviations, the lower standard deviation variable was ranked first. AR increases site safety was ranked eleventh with a mean score of 4.11 while AR ensures situational awareness was ranked twelfth position with a mean value of 4.10. The last three ranked variables were AR promotes the superimposition of virtual objects, efficient management and planning, and geo-locating data on construction sites with mean values of 4.07, 4.05, and 4.04 respectively.

(Insert table 7)

Kruskal Wallis test was applied to determine the difference in the views of professionals. Six variables have significant differences in the opinions of respondents. These six variables have p-values less than 0.05. The other nine variables or factors have p-values greater than and equal to 0.05 i.e. there is no significant difference in the views of respondents. This also implies that there are converging ideas of the professionals on these variables.

(Insert Table 8)

In Table 8, the Architects were used to test other professionals in the group to compare their views. It was revealed that the significant difference lies in between the Architects and Quantity surveyors while Builders, Engineers and Project managers have no significant difference in their views regarding the benefits of augmented technology in the construction industry. The same process was conducted for the Quantity surveyor group which became the object of control. It was shown that the Quantity surveyors opposed the perception ratings by the Project managers and Architects.

When the Project managers became the object of measure, there was a significant difference between the views of Project managers and Quantity surveyors. However, there was no significant difference in the views of Architects, Builders, and Engineers concerning the benefits of augmented technology. All other objects of test for Engineers and Builders on other professionals have no significant difference between them.
Dunnett's test was also used to confirm the result above and the test gave a similar result with the LSD test. The degree of freedom for the post hoc test was 5% i.e. 95% confidence interval level. Table 8 revealed that Quantity Surveyors (QS) and Engineers, Builders and others belong to the same group while QS and Project managers, Architects and QS belong to another group.

As per the survey result, the most important benefit of ART is that it enhances team collaboration and communication, especially because the construction industry is made up of different participants who need to work together to achieve project success. This is in line with Behzadi (2016) and Zitzman (2019) who stated that ART enhances team collaboration and communication by combining physical and digital views, and helps construction stakeholders to improve accuracy, efficiency and project overall confidence. Also, this study corresponds to the research carried out by Martin-Gutierrez et al. (2015) and Pejoska et al. (2016) who affirmed that the presence of AR brings about team collaboration between tutors and students. This implies that the implementation of ART will bring about effective team collaboration and communication which can enhance efficiency, accuracy and productivity in the construction industry.
Also, from the professionals' point of view ART improves repairs, rehabilitation and maintenance was ranked second. This corroborates with Martinez et al. (2014) and Palmarini et al. (2018) who stated that maintenance is a top research area in ART for industry and several studies have elucidated the merits of its adoption. Areas of the field where ART is applied for maintenance include the aviation industry, plant and mechanical maintenance, consumer technology, and nuclear industry. Quicker maintenance interventions with limited errors, safer and more effective processes are few of the acclaimed benefits. AR promotes efficient management and planning was ranked second to the last which does not corroborate with Behzadi (2016) who noted that implementation of AR brings about efficient management of cost. This means that professionals are yet to understand and implement ART in construction management and planning. Also, Wong et al. (2014) in their studies stated that the use of AR technologies enhances time and cost-saving

opportunities in lowering labour. This is partially consistent with the study where it was ranked the mid position. This implies that AR technologies might have not been properly used in the minimization of labour for effective management of construction projects.

Based on the benefits of ART in the construction industry, it was observed that improvement in scheduling quality and budget management was ranked seventh out of fifteen. This partly corroborates Zaher et al. (2018) who stated that AR improves scheduling and progress tracking of projects in the construction industry. This implies that professionals have not well understood the importance of applying the technology in the areas of scheduling and tracking projects. Hui et al. (2017) researched how AR could effectively be used for safety task in construction projects. It was noted that its implementation improves the safety of construction workers. This is partially in line with this study findings where AR increases site safety was ranked eleventh. Thus it appears that the construction industry has not yet maximized the benefits that can be derived from AR adoption.

5. CONCLUSIONS AND RECOMMENDATIONS

The top five benefits of AR in the construction industry as revealed by this study are: team collaboration and communication; improves repairs, rehabilitation, and maintenance; enhances communication / real-time information retrieval; accurate automated measurement, and low cost for virtual training in operating heavy construction equipment. The study contributes to the existing literature by revealing the most crucial benefits in the Nigerian construction industry. The three least ranked benefits are: the promotion of superimposition of virtual objects; promotes efficient management and planning, and aids in geo-locating data on construction sites. The professionals have yet to see the importance of ART in the above areas. These areas of benefits can be maximized by training professionals so that the benefits of AR can be utilized to its fullest. Also, the results showed that there were six out of fifteen variables that have significant differences while the other nine had no significant difference in the opinions of professionals.

In other words, the professionals had similar opinions in their ratings of nine variables while for the other six variables the professionals had divergent opinions in their ratings. Further analysis revealed that significant differences lie between Quantity surveyors and project managers; Architects and Quantity surveyors. It was recommended that the Nigerian construction industry should create awareness programs and platforms so as to inform its professionals and upcoming

ones on the benefits of using AR in the industry. Governments, being the largest client in Nigeria, are also encouraged to implement the use of ART in the execution of projects. This can be done by implementing policies for its users to ensure private clients follow suit. Further studies on AR should be conducted on heavy and civil engineering projects in a developing country to ascertain this study. Also, further researches can be conducted on the usage of ART in educational institutions with the aid of an in-depth interview with disciplines that require digital technology.

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