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Mixed Reality in the Construction Industry of Nigeria: Drivers and Barriers to its Adoption

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ABSTRACT
Introduction
In the modern era of the construction industry, mixed reality (MR) technologies, including virtual reality (VR) and augmented reality (AR) significantly have an impact on construction automation and architectural engineering industries. Mixed Reality (MR) refers to combination of digital and physical world, unlocking natural and inherent 3D human, computer, and environmental interactions. Since 2000, MR technologies development has progresses rapidly (Delgado et al., 2020; W. Du et al., 2022). These technologies provide a way to access project information digitally through the connection of the physical world to the digital world, which lead to digital disruption and digitizationof the otherwise technology-against the construction industry (Rankohi& Waugh, 2013). In the construction industry, these technologies have numerous advantages and benefits which include site visit virtually (Albahbah et al., 2021; Lucas & Gajjar, 2022). In addition, communication among stakeholders is improved with the help of MR(VR and AR), also offers a clear visualisation for designers and engineers, which leads to better understanding of projects both ongoing and upcoming (Delgado et al., 2020).

I. BACKGROUND

Mixed Reality technologies (MRTs) have been adopted widely in different areas including manufacturing, education, and information technology (IT), due to their affordability and accessibility (Sepasgozar, 2020). In terms of embracing the MRTs, the mining sector is one of the sectors to embrace it. The VR solutions as shown by research can embrace health and safety (occupational) by providing VR training for coal miners.Experienced professional trained workers using motion capture system, joystick, Head Mounted Displays (HMDs) and working methods as shown by research. Result reveals that VR technology is an effective platform that trainees can be protected from dangers exposure and risks that are common in the mining environment (Pedram et al., 2017) and the VR training system developed has been found to support the mining industry and can improve the overall training experience using Magic Leap devices (Cao &Cerfolio, 2019).

Significant attention has been gained in the healthcare sector through MRTs due to their capabilities and innovative approaches. Research has indicated recently that the usage of MRTs in the healthcare industry both surgical and clinical traininghas been improved and will continue to increase (Julieta D., 2017). A study on the usage of MRTs was conducted between 2005 and 2015 in the healthcare sector and revealed that Mixed Reality, especially virtual reality (VR) has grown in the areas of pain management, eating disorders, cognitive and rehabilitation (Jeelani et al., 2017).

In the gaming sector, the use of mixed reality (MR)has also increase drastically. This technology also plays a drastic role in the education sector. The use, benefits, and the challenges of MRTs has been researched in detail in the study of Balali et al. (2018).There is an increasing trend by research towards online studies and distant learning that has led to the increased use of MRTs (Williams et al., 2014). A teaching system based on AR has been developed by researchers that shows increase in the level of student motivation and encourages innovation by enabling students to design outputs during courses (Noghabaei& Han, 2020). In addition, VR-based tool that provides solution to the challenges faced by student was developed for visualising structures (Ullah et al., 2020).

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It has been shown that VR technology can assist in solving problems encountered by people, thereby allowing them to interact with devices that are digital (Sandeep Sugla, 2023). The AR and VR markets according to Ribeiro (2018) are expected to grow by 2025 to a size of $80 billion. Data from a report in the UK on public goods revealed that MRTs are the advanced technologies that are primaryused in enhancing efficient groundwork deliveryand preservation, and aid in risk management and accountability. In the United States (USA) similarly, the government initiatives in IT capability involves the usage of the MR (Delgado et al., 2020).

Mixed Reality in the Construction Industry

The Manufacturing Technology Centre (MTC) in 2017, conducted a study in construction related companies to determine the level of maturity and reliability of Mixed Reality (MR).It was indicated by the result that among the construction company workers, only 37% had few knowledge related to Mixed Reality (Cruz, 2018; Davila, 2019). It was estimated in the research of Davila, (2019) that in the United Kingdom 34.4% of construction companies uses thesetechnologies. In addition, the study of DeFanti et al. (2009) revealed that among the 22 investigated industries, the Architecture, Engineering and Construction (AEC) industry was the lowest in the adoption and usage of the Mixed Reality (MR) technologies.

There have been limited studies on mixed reality technologies (MRTs) studies, their implementation and adoption in construction engineering, training, and education despite the rapid development of virtual reality (VR), augmented reality (AR) and other supporting MRTs (Hong et al., 2016). Virtual reality has been implemented although in architecture, construction education and engineering (Kerawalla et al., 2006), which uses the head mounted display (HMD) and can lead to serious discomfort and poor depth perception problems (Drascic& Milgram, 1996). The information available given by augmented objects conflicts often with the real-world environment information, which result in perpetual unpredictability and cue conflicts (Noghabaei et al., 2020). Due to the continuous advancement of technology globally, the obstacles during implementation that appear can be overcomed quickly. Mixed Reality (MR)are new technologies in the market with the perception that they cannot be used fully in practice is not correct (Noghabaei et al., 2020).

In Architecture, Engineering and Construction industry, mixed reality including VR and AR, are important because the built environment is inherently connected to 3D space, and the industry's professional heavily rely on communication through visual image. Augmented reality (AR) is a technology in construction for improving projects. Immersive and interactive environment is provided by Virtual Reality that can assist architects in designing and planning buildings and cities (Yi-Kai., 2018). Project cost, delivery time and risk can be reduced through the help of VR, while allowing users and customers experience the structure design before it is constructed (Hou et al., 2017). Augmented Reality (AR) in the construction industry has many useful applications that can enhance productivity in construction significantly (Wang, 2009).

Augmented Reality (AR) adoption in the Architecture, Engineering and Construction industry focuses on four aspects; cloud computing, mobile devices, user interface and localization (Wang et al., 2013). The use of Mixed Reality in AEC is however less in general (Delgado et al., 2020). A study conducted in construction companies in 2017 found that only 37% had experience using mixed reality (Yin et al., 2020). Researchers conducted a study on the effects of VR safety training in comparison with the traditional methods, result shows that safety training based on VR is more effective than the traditional methods (Eiris et al., 2018). A platform has been developed by scientists that uses 360^{o} recorded videos (panoramic) from the real world which was integrated into the VR for safety training in construction. The platform according to the result improves hazard assessment skills for workers (Balali et al., 2018).

VR technologies as shown by research are beneficial for safety training and construction, thus can help with schedule control in projects (Noghabaei et al., 2020), better understanding among construction stakeholders is promoted (Woksepp&Olofsson, 2008), design errors and faults are traces by the use of VR (Bille et al., 2014) and clear view of designs that are complex are provided (Liu et al., 2014). VR technologies can also help users to target design area and gain sense of the project, including complex projects/structures (Du et al., 2018) and mutual decision making is facilitated (Shin & Dunston, 2008). A framework for cost estimation was developed using VR technology that uses real-time VR model which allows clients and end users to change walls, floors and other component parts of

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the building/structure and see the impact of the price in real-time (Du et al., 2017). This is highly beneficial to estimators in the construction industry (Frank., 2013). Adopting MRTs in the construction industry has played a significant role by providing training programmes that improves workers activities in the industry.

This research, therefore, aims to study the adoption of mixed reality (MR) in Nigerian construction industry by analysing its drivers and barriers thus helping the industry of developing countries to compete with the developed countries. Technological advancements and achievements in developing countries like Nigeria are lagging in terms of technology adoption and implementation. However, mixed reality technologies (emerging technology) can assist inclosing the gap. There are limited studies however on MR technologies adoption in the context of the construction industry most especially in developing countries like Nigeria, hence this presents the research gap.

Therefore, to bridge this research gap, this study identifies the key drivers and barriers to the adoption of mixed reality (MR) in Nigerian construction industry with the aim of the industry to move towards smart construction industry globally and compete with the construction industry of the developed countries. Mixed Reality (MR) technologies in this study are limited only to Virtual reality (VR) and Augmented reality (AR), while other supportive Mixed Reality technologies are not considered in this study.

II. METHODOLOGY

The method adopted for this study include the use of structured questionnaire in order to assess individual opinion on the topic. Indicators which are relevant to the topic were carefully selected and used in the questionnaire.

Total sum of fifty five questionnaires were used to sample peoples opinion. The questionnaire has two sections (tables),The first section is related to drivers to the adoption of MRTs in construction. This section has twenty nine indicators used in order to identify the most important factors.

The second section (table) is directly related to Barriers to the Adoption of MRTs in Construction and it consist of twenty two indicator which basically relate to the topic.

The results obtained from the questionnaire distributed was statistically analysed with relative importance index (RII) this method of analysis helps to identify the most important factors in accordance to relevance which ranges from 1st to 22nd most relevant factor.

S/N	Drivers to the Adoption of MRTs in Construction	SA	A	N	D	SD	Total (N)	RII	Rank
1	Collaboration between parties is improved using MRTs	24	17	8	4	2	55	0.807	2
2	MRTs adoption will reduce construction budget	22	16	10	5	2	55	0.791	14
3	Top management strategic decision is improved	25	15	9	4	2	55	0.809	1
4	Client requirement for MRTs use in projects	20	18	9	5	3	55	0.778	25
5	New and better service is provided by MRTs	21	17	10	5	2	55	0.787	23
6	Organization work culture is improved with MRTs	23	16	9	4	3	55	0.8	9
7	Reduced overall project spending	22	18	7	5	3	55	0.796	12
8	Labour productivity in projects is increased with MRTs	24	16	8	4	3	55	0.807	2
9	Labour difficulties will drive the adoption of MRTs	21	17	10	5	2	55	0.789	19
10	MRTs improve the understanding of projects	23	18	8	4	2	55	0.803	6
11	MRTs adoption will be derived by government incentives	19	17	11	5	3	55	0.767	29
12	Improves company image and derive its adoption	20	18	10	4	3	55	0.778	25
13	Organizations reputation is	22	16	10	4	3	55	0.791	14

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	improved by its adoption								
14	Risk reduction	23	17	9	4	2	55	0.807	2
15	Visual asset information in real time is provided by MRTs	22	17	9	5	2	55	0.791	14
16	Helps in reducing the cost of damage, repair, and development	21	18	8	5	3	55	0.789	19
17	Visual analysis of ongoing projects is provided by MRTs	20	17	10	5	3	55	0.778	25
18	MRTs are technologies that are reliable	24	15	9	5	2	55	0.8	9
19	Timely feedback is provided by MRTs	22	17	9	5	2	55	0.791	14
20	Real-scale visualization of design is assisted by MRTs	23	18	8	4	2	55	0.803	6
21	User experience is improved with the help of MRTs	21	17	10	4	3	55	0.784	24
22	Better contextual understanding	23	17	9	4	2	55	0.8	9
23	Better impact assessment is provided by MRTs	22	18	8	5	2	55	0.796	12
24	Increase research and development investment in construction	21	18	9	4	3	55	0.789	19
25	Helps in decision making in organizations	24	16	8	5	2	55	0.807	2
26	Multidisciplinary assessments are provided easily	23	17	9	4	2	55	0.803	6
27	Better project delivery contributed by MRTs	22	18	9	4	2	55	0.791	14
28	Market expansion is enabled by adopting MRTs	21	18	9	4	3	55	0.789	19
29	Inexpensive and effective training is provided by MRTs	20	17	10	5	3	55	0.778	25

S/N	**Barriers to the Adoption of MRTs in Construction**	**SA**	**A**	**N**	**D**	**SD**	**Total (N)**	**RII**	**Rank**
1	Lack of knowledge in the market regarding MRTs	20	18	10	5	2	55	0.778	9
2	Ownership and data security issues with MRTs	22	17	8	5	3	55	0.78	7
3	Financial issues	25	15	9	4	2	55	0.8	2
4	Special requirements needed for its implementation	18	19	10	6	2	55	0.76	19
5	MRTs are referred to as immature technologies	19	17	9	7	3	55	0.766	13
6	Cost of training and hardware requirements	23	16	7	6	3	55	0.788	4
7	MRT gadgets require large space	17	19	10	7	2	55	0.76	19
8	Lack of multi-user capabilities	21	18	9	4	3	55	0.784	5
9	Client interest in using MR technologies	20	15	11	6	3	55	0.764	15
10	Time-consuming algorithms in MRTs	16	20	12	5	2	55	0.748	22

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11	High initial and capital investment required by MRTs	26	16	7	4	2	55	0.804	1
12	Insufficient demand for MR adoption in the industry	18	19	10	5	3	55	0.764	15
13	Tracking and mapping issues (low accuracy)	20	16	11	5	3	55	0.764	15
14	Low-resolution display	17	18	12	5	3	55	0.756	21
15	Difficulty in accessing expert knowledge on MRTs	18	20	10	4	3	55	0.776	10
16	Cause of job security concerns	19	16	12	5	3	55	0.766	13
17	Lack of standard for data exchange	22	17	9	4	3	55	0.784	5
18	Aversion to adopting new technologies	23	18	8	4	2	55	0.796	3
19	Skill shortages and difficulty in accessing skilled personnel	21	16	9	6	3	55	0.78	7
20	Lack of time to explore immersive technologies	20	19	8	5	3	55	0.776	10
21	Availability of low-resolution display in MRTs	19	18	10	6	2	55	0.764	15
22	Limitations of power and battery when using MRTs	18	20	9	5	3	55	0.772	12

III. RESULT

From the result of this analysis (RII), the first table which discusses the Drivers to Adoption of MRTs in Construction has the factor Top management strategic decision is improved ranking 1st while Collaboration between parties is improved using MRTs, Labour productivity in projects is increased with MRTs, Risk reduction and Helps in decision making in organizations ranked 2nd . Also factors like Client requirement for MRTs use in projects, Improves company image and derive its adoption,Visual analysis of ongoing projects is provided by MRTs all ranked 25th while MRTs adoption will be derived by government incentives ranked the lowest as the number 29th to be prioritised.

The second result related to Barriers to the Adoption of MRTs in Construction in Nigeria clearly indicate High initial and capital investment required by MRTs as the number 1 ranking while Financial issues and Aversion to adopting new technologies ranked 2nd and 3rdrespectively.
Factor like Low-resolution display and Time-consuming algorithms in MRTs ranked 21st and 22nd respectively.

IV. CONCLUSION

From this paper, It can be deducted that improvement of Top management strategic decision can be considered as the best factor in the category ofDrivers to the Adoption of MRTs in Construction while Government incentives is the least too be considered.

Also High initial and capital investment required by MRTs is classified very important in Barriers to Adoption of MRTs in Construction while Time-consuming algorithms in MRTs are recognised as the least relevant.

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