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Drivers and Barriers of Using Web-Based Asynchronous Communication Tools for Monitoring Construction Projects

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Abstract: Construction project monitoring (CPM) is becoming more expensive and error-prone for clients with multi-location projects and consultants. The persistent problem of late decisions that occur on-site, mostly reported after significant time has elapsed further reduces monitoring efficiency. This study examines drivers and barriers to the use of Web-based asynchronous communication tools (WACT) for CPM in the Construction Industry. Copies of structured questionnaires were administered to 485 construction professionals on active construction sites comprising construction managers, architects, quantity surveyors, and engineers in Lagos and Abuja who are involved in CPM and 256 (53%) were returned. Exploratory factor analysis (EFA) extracted 5 drivers and 4 barriers to the use of WACT for CPM. Factors were ranked using mean and standard deviation. The degree of agreement between the two domains was compared using the Kendall coefficient of agreement. Results show that project monitoring efficiency (PME) factors ranked highest amongst drivers for use of WACT for CPM. Other drivers, that equally ranked high, are project monitoring cost (PMC) and project monitoring time (PMT) factors. Construction industry culture (CIC) factors ranked highest as a barrier with organisational personnel (OP) and technology adoption (TA) factors equally of significant rank. The Study identified latent drivers and barriers to the use of WACT for CPM. Results also revealed construction professionals are willing to use WACT for CPM but are skeptical about its seamless use to take over the traditional monitoring methods. It is recommended that client agencies that fund multi-location projects like the United State Agency for International Development (USAID) or Tertiary Education Trust Fund (TETFund) in Nigeria should develop models for the use of WACT for CPM. Similarly, consulting firms can reduce overhead on travel expenses and improve monitoring efficiency by hosting such tools on their projects.

Keywords: Asynchronous communication, construction project monitoring, construction professionals, consulting firms, web-based asynchronous communication tools.

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1. Introduction

The uniqueness of every construction project and its multiplex implementation in dynamic environments usually demand quick responses to many situations of variability, interdependence, nonlinearity, and speed (Sanchez et al., 2019). These responses are expected from professionals in different fields who handle the fragmented construction processes (Akinradewo et al., 2017; Dhanesh et al., 2020). Many times, professionals who handle construction projects are geographically dispersed from each other and the project location. As a result, CPM often requires the assembly of construction professionals on project sites (Mossalam, 2017) thereby making CPM manual, expensive, time-consuming, and error-prone (Yang et al., 2015; Wang et al., 2021). In addition, monitoring efficiency is further reduced by late reporting of changes in Construction documents such as specifications, or errors in contractors' compliance with work specifications (Gomez-Ferror, 2017). Time lost on projects due to monitoring inefficiency and the quantity of rework required to correct errors from late documented events exerts a huge burden on project cost and time (Tengan and Aibavboa, 2018).

From another perspective, the impact of the recent Covid-19 outbreaks on construction activities (Ogunnusi et al., 2020; Osuizugbo, 2021) and the incessant safety challenges plaguing professionals' propensity to travel (Gloria and Rwang, 2020) are also high. This contributes negatively to proper CPM, especially in the Nigerian Construction Industry (NCI). This is because the face-to-face monitoring technique remains the dominant tool for monitoring construction-related projects (Mossalam, 2017).

CPM is vital to project success (Tengan and Aigbavboa, 2016; Denicol et al., 2020) because efficient onsite monitoring of construction projects allows the timely intervention and resolution of matters that are peculiar to the project (Yang et al., 2015). To achieve efficiency in project monitoring, however, the use of effective communication systems and tools is required (Cervone, 2014), especially at this time when the industry struggles to deliver projects on time and within budget (Denicol et al., 2020). Effective communication between project stakeholders is a fundamental aspect of the project life cycle and has been identified as a key factor for successful project monitoring (Cervone, 2014; Akinradewo et al., 2017; Abdul-Rahman and Gamil 2019).

Globally, digital systems are evolving and are becoming compellingly more relevant in the discharge of construction activities. Ajah and Chigozie-Okwum (2019) posited that digital systems are replacing the traditional ways businesses design interactions; and how end-users/stakeholders receive services, information and goods, thereby driving digital growth across many industries and economies. In the construction industry, new innovations and technologies are rapidly emerging that can significantly deliver higher value for construction clients while industrializing and equally digitalizing the construction industry (Pullen et al., 2019; Sacks et al., 2020). For instance, Alto and Kyrill (2017) lauded the emergence of web-based communications systems which have completely dissolved geographically dispersed borders of participants and aim to help improve CPM efficiency. Equally, Whyte (2019) identified that construction participants need to embrace digital transformation in order to achieve better value, efficiency, safety and quality within the constraints of limited resources. CPM transformation can be achieved through the adoption of mature technologies that can integrate work teams using project information management systems (Luo et al., 2017) and creating digital models using asynchronous communication tools suitable to project types and locations (Tee et al., 2019).

The construction industry worldwide is currently facing the challenge of completing projects on time and on budget (Denicol et al., 2020). Monitoring inefficiency adds additional time and cost to projects (Wang et al., 2021). Therefore, improving monitoring efficiency through the adoption of innovative technologies such as WACT is key to reducing the negative impact of monitoring inefficiency. In essence, the research question for this study are: what are the drivers and barriers to using WACT for CPM; which driver and barrier impacts the adoption of WACT for CPM. Therefore, this study investigates the drivers and barriers to using WACT for CPM in Nigeria with a view to identifying latent drivers and barriers affecting its adoption.

2. Background

Asynchronous communication refers to the transmission of end-to-end data at a point in time without continuous streaming or the use of external signals (Jeerge, 2015). Data sent through asynchronous communication do not expect immediate responses. As a result, asynchronous tools for communication allow data storage and data accessibility at the receivers' convenience (Thorne, 2018). Presently we use several asynchronous communication tools like text messaging, e-mails and still photography but these tools are stand-alone packages and not integrated into a comprehensive system that would enhance their effectiveness for construction monitoring. Integrated asynchronous communicated tools that use computer imagery exist and they have been posited to improve PME (Ranaweera et al., 2013).

2.1. Web-based Asynchronous Communications Tools

Many developers have evolved asynchronous communication tools such as Bulletin Boards, Basecamp, Quip, and Asana. Some of these tools are adaptable for construction monitoring but being new technologies, they are not largely embraced for construction projects (Rasheed and Adebiyi, 2019). Various studies have shown that the construction industry has a reputation for being slow to adopt and integrate new technologies on a large scale (Winch, 2003; Sheffer and Levitt, 2010) and Nigeria is no exception (Rasheed and Adebiyi, 2019). Also, the focus of research into photographic computer vision, particularly in construction, has been more on the interrelationship between artificial intelligence (machine learning), object tracking, and detection of construction activity (Arashpour et al., 2021). However, despite the numerous positive contribution it has to areas such as construction productivity, safety and quality, adoption and implementation of the outcomes of computer vision research in the industry is still not immediately embraced (Arashpour et al., 2021).

Early studies (Sproull and Kiesler 1991; Dennis and Kinney, 1998) argue that synchronous communications like face-to-face meetings, phone calls, video calls and live web-based meetings are better than asynchronous communications because of the immediate nature of responses. More recently, researchers have found that more detail can be communicated asynchronously, and therefore there is an opportunity to make informed decisions about the subject during feedback, and such data can be easily queried (den-Otter and Emmitt, 2007; Thorne, 2018). Synchronous communication requires both the sender and receiver to be on the data exchange at the same point in time, on the other hand, asynchronous communication allows the sender and respondents to attend to the matter at their own times within the period allotted for responses (Chevrou et al., 2016; Panteli et al., 2018). A key benefit of asynchronous communication is that the data sent in both directions is already logged by default making it easy to retrieve for reference. On the other hand, synchronous communication requires an immediate response no matter what the other party is doing. Records of such data transfer may only be kept with notes, logs or asynchronous records. Establishing reasonable times for synchronous communications, particularly with geographically dispersed teams, has always been a source of delays in disseminating critical information for monitoring purposes (Thorne, 2018). Asynchronous communication systems utilize remote check-in systems which help monitoring team members oversee activities easily (Thorne, 2018). This allows geographically dispersed members of the construction monitoring team to access portals for sharing what they are working on, progress on work stages and other information generated on the project without disrupting anyone's time and work schedule.

Thorne (2018) explains that integrated WACT uses central portals for sharing participants' current work status with visible information for everyone involved in CPM. It also includes a project management system (PMS) and a digital photo interface that creates a workflow that allows participants to track changes and progress as they occur. A continuous chat system and dashboard with still and short clip site capture completes the communication system which makes it suitable as a monitoring system.

2.2 Asynchronous Communication Tools in Construction

Several systems, models and tools exist in the construction industry that can be adapted for asynchronous communication toward enhancing CPM. For instance, cameras that take still and continuous images such as point-and-shoot, time-lapse and smartphone cameras have often been used on construction sites (Bohn and Teizer, 2010; Yang et al., 2015; Arashpour et al., 2020; Wang et al., 2021), however more common use of the still and continuous imagery cameras are for surveillance, site security and marketing promotions (Arashpour et al., 2020; Wang et al., 2021). Ranaweera et al. (2013) and Yang et al. (2015) averred that continuous image data can be processed in near real-time using multi-view geometry computer conversion methods for progress and quality monitoring. In Nigeria, CPM is mainly carried out using the manual method of Program Evaluation and Review Techniques, Gantt Charts and Critical Path Network Diagrams (Nkeleme et al., 2021). The use of sophisticated innovative technology is however still not very common in the NCI as the industry does not adopt new technologies easily (Rasheed and Adebiyi, 2019).

Similarly, the capture of 3D data on as-built construction sites using photogrammetry, video, or terrestrial laser scanning has been adapted to advance monitoring of construction production (Yang et al., 2015; Jacob-Loyola et al., 2021). Son et al. (2015) discussed the advancements made in this area using on-site spatial survey technologies for the efficient capture of 3D data on as-built civil infrastructure works. In addition to production monitoring, imagery data can also improve knowledge transfer, safety audit, workers training, and compliance checking (Yang et al., 2015; Arashpour et al., 2020). Furthermore, the use of acquired 3D data has effectively been used for dimensional quality control and progress tracking (Son et al., 2015; Jacob-Loyola et al., 2021).

From another perspective, attempts have been made to create asynchronous platforms for field approaches to BIM for CPM (Sacks et al., 2020; Chen et al., 2021; Jacob-Loyola et al., 2021). Efforts to reduce the time spent on collecting performance data by site supervisors have led to a variety of technological innovations for data collection (Sacks et al., 2020; Jacob-Loyola et al., 2021). These technologies are derived from the improvements in computer vision field which utilizes laser-based, tag-based or image-based methods to recognize components and record progress made on construction sites (Ekanayake et al., 2021; Wang, et al., 2021). As a result, the use of computational devices employing digital information from project sites is evident and well recorded in construction (Bohn and Teizer, 2010; Whyte, 2019; Chen et al., 2021; Ekanayake et al., 2021; Jacob-Loyola et al., 2021; Wang et al., 2021). Such technological innovations include GPS/Laser scanning of as-built works (Sacks et al., 2020), computer vision for monitoring progress (Brilakis and Hass, 2020; Chen et al., 2021), radio frequency ID tags and blue tooth low energy scanners (Costin et al., 2012; Sacks et al., 2020). The use of these types of Automated Project Performance Monitoring and Control (APPMC) systems is to enhance CPM through the facilitation of quality feedback (Chen, et al., 2021; Ekanayake et al., 2021).

Other interesting studies reporting the use of integrated asynchronous communication tools are remote viewing derived from activity information. These are obtained through periodic physical progress recordings by Unmanned Aerial Vehicles (Jacob-Loyola et al., 2021). In addition, Lee et al. (2020) studied the prospect of real-time monitoring of construction works using advanced sound classifiers and performance analysis. This method is an audio-based approach to CPM by providing real-time data that can be accessed and reviewed by project participants involved with project monitoring (Lee et al., 2020). Using asynchronous tools for CPM has its benefits because end users of asynchronous communication tools have increasingly sort academic research focused on the applications of image processing and computer vision for CPM in the construction industry (Ekanayake et al., 2021; Jacob-Loyola et al., 2021).

2.3. Drivers and Barriers to Use of WACT for CPM

The literature revealed a wealth of drivers and barriers to the adoption and use of several built-in asynchronous tools for CPM. Twenty-two (22) drivers and twenty (20) barriers were synthesized from the literature. During the synthesis, care was taken to avoid repetitions. The literature reviewed are studies on asynchronous communication, web-based collaborative communication, CPM using asynchronous transmission, and integrated project monitoring with digital vision and still cameras.

These factors were explored in the NCI to identify the latent factors that are drivers and barriers to the use of WACT for CPM.

Table 1 highlights the drivers and barriers synthesized from the literature and a summary of their respective studies and authors.

3. Methodology

A pilot survey of construction sites was carried out within Lagos metropolis and Abuja municipal area council to identify active construction projects that can deploy WACT for CPM. Projects that meet either or all of the following criteria were selected:

Table 1. Drivers and Barriers to Use of WACT for CPM

Sn	Factor	Study	Authors
	Drivers:		
1	Need for innovation	Balancing synchronous and asynchronous communication in design teams	Den Otter and Emmitt, 2007
2	Large data exchange capacity	Diversity of asynchronous communication	Chevrou et al. (2016)
3	Information coverage for progress report	Communication amongst professionals	Akinradewo et al. (2017)
4	Knowledge sharing capacity	Web-based Collaboration	Alto and Kyrill (2017)
5	Team coordination	Web-based Collaboration	Alto and Kyrill (2017)
6	Organisational Benefits	Web-based Collaboration	Alto and Kyrill (2017)
7	Platform for collaboration	Web-based Collaboration	Alto and Kyrill (2017)
8	Need for a metrics to monitor project issues	Project issues management	Mossalam (2018)
9	Information dispersion to more experienced decision makers	Geographically dispersed asynchronous virtual teams	Panteli et al. (2018)
10	Improved Change notification	Cause and effect of poor communication	Abdul and Gamil (2019)
11	Improved progress measurement	Cause and effect of poor communication	Abdul and Gamil (2019)
12	Increased construction complexity	Cause and effect of poor communication	Abdul and Gamil (2019)
13	Faster information dissemination	Cause and effect of poor communication	Abdul and Gamil (2019)
14	Confidentiality of information	Cause and effect of poor communication	Abdul and Gamil (2019)
15	Fast response time to project design issues	Modelling construction management for improving site management practices.	Sanchez et al. (2019)
16	Business process reengineering	Modelling construction management for improving site management practices.	Sanchez et al. (2019)
17	Integration of monitoring to document management system systems (virtual monitoring capacity)	Use of IT for documentation in project management	Dhanash et al. (2020)
18	Need for documentation for dispute / claims resolution	CPM using high resolution automated cameras	Bohn and Teizer, (2010)
19	Quick identification of rework	CPM using high resolution automated cameras	Bohn and Teizer, (2010)
20	Proper tracking of resources	CPM using high resolution automated cameras	Bohn and Teizer, (2010)
21	Improved camera placing technologies	BIM-based optimization for construction monitoring	Chen et al. (2021)
22	User friendly asynchronous tools	Unmanned Aerial Vehicle (UAV) for CPM	Jacob-Loyola et al. (2021)
	Barriers		
1	Organisational culture	Balancing synchronous and asynchronous communication in design teams	Den Otter and Emmitt, 2007
2	Variety in asynchronous information systems	Balancing synchronous and asynchronous communication in design teams	Den Otter and Emmitt, 2007
3	Level of understanding of the works (complexities)	Balancing synchronous and asynchronous communication in design teams	Den Otter and Emmitt, 2007
4	Skills set	Balancing synchronous and asynchronous communication in design teams	Den Otter and Emmitt, 2007
5	Management preferences	Balancing synchronous and asynchronous communication in design teams	Den Otter and Emmitt, 2007
6	Awareness of existing tools	Web-based Collaboration	Alto and Kyrill (2017)
7	Inadequate technology support	Web-based Collaboration	Alto and Kyrill (2017)
8	Data transparency and security	Web-based Collaboration	Alto and Kyrill (2017)
9	Service fragmentation	Web-based Collaboration	Alto and Kyrill (2017)
10	Barrier gaps between research and application	CPM using still images	Yang et al. (2015)
11	Technology Adoption and adaptation	CPM using still images	Yang et al. (2015)
12	Technology trust issues	CPM using still images	Yang et al. (2015)

Table 1. Drivers and Barriers to Use of WACT for CPM (continued)

Sn	Factor	Study	Authors
13	Difficulty in implementation	How industry practice retards diffusion of innovation	Sheffer and Levitt, (2010)
14	Misalignment with current practice	How industry practice retards diffusion of innovation	Sheffer and Levitt, (2010)
15	Lack of innovative knowledge diffusion	How industry practice retards diffusion of innovation	Sheffer and Levitt, (2010)
16	Frequent technology malfunction	Cause and effect of poor communication	Abdul-Rahman and Gamil (2019)
17	High cost of adoption	BIM-based optimization for construction monitoring	Chen et al. (2021)
18	Massive time required to put in place	Vison-based framework for CPM	Wang et al. (2021)
19	Clement weather and environment	Vison-based framework for CPM	Wang et al. (2021)
20	No comprehensive and simple integrated method	Unmanned Aerial Vehicle for CPM	Jacob-Loyola et al. (2021)

1. Highrise buildings above 5 floors.
2. Multifarious projects within a single location
3. Geographically dispersed project sites with the same clients and monitoring consultants.
4. Large infrastructure projects.
5. Projects with full project monitoring consultants.

Forty-nine (49) project sites, were selected in Lagos metropolis, and forty-eight (48) project sites were selected in Abuja municipality. Five (5) questionnaires were distributed to each selected site for the construction managers, architects, quantity surveyors, services engineers, and civil/structural engineers that are involved in project monitoring activities on each of the sites.

Professionals involved in project monitoring activity on the sites are required for the study to ensure the reliability of responses as they affect CPM. The questions are designed to elicit responses about the practitioner's agreement with the factors listed as drivers or barriers to the use of WACT for CPM.

The study received responses from professionals in Lagos and Abuja. These location strata represent areas of high construction activities in Nigeria due to their continuous development and significance as commercial and administrative capitals respectively.

To examine the appropriateness of the data collected for factor analysis, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were computed. Subsequently the study tested for the reliability of the construct to extract the alpha values of the Key drivers and barriers. EFA was used to extract the groupings of the drivers and barriers. Principal Component Analysis (PCA) for factor extraction was applied to reduce the drivers and barriers to fewer numbers.

Finally, the factors were ranked based on their mean and standard deviation to check the internal consistency of responses. A comparison of the rankings was done between the respondent groups using the Kendall coefficient of concordance.

4. Results and Discussions

A total of two hundred and fifty-six (256) responses were received from the 485 distributed questionnaires representing a 52.78% response rate. Table 2 shows the response rate per location.

Table 2. Response Rate

Respondents	Lagos		Abuja		Total
	No. dist.	No. rec.	No. dist.	No rec.	Received
Construction manager	49	31	48	28	59 (61%)
Architect	49	20	48	22	42 (43%)
Quantity surveyor	49	32	48	33	65 (67%)
Services engineer	49	18	48	16	34 (35%)
Civil/ struct. engineer	49	25	48	31	56 (58%)
Total	245	125	240	129	256 (52%)

Sample adequacy was tested using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy with a value of 0.802. Equally, the test of sphericity has a value of $p<0.005$. A measure of values between 0.7 – 0.8 is opined to be good for a KMO test of sample adequacy, (Field, 2009; Yong and Pearce, 2013). Also, Hair et al., (2010) buttress that deriving correlation of $p<0.005$ from Bartlett's test of sphericity indicates the presence of correlation among the constructs. Table 3 shows the results derived from the KMO and Bartlett's test.

Table 3. KMO and Bartlett's Test Results

KMO and Bartlett's test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.802
Bartlett's Test of Sphericity	Approx.Chi.Square	8417.79
	Df	41
	Sig.	.000

Although a sample size of 300 or above is mostly considered appropriate for EFA, Yong and Pearce (2013) posited that where a study exhibits high factor loadings scores above .80, then a smaller sample size above 150 is sufficient.

4.1. Respondents Demography

Quantity surveyors in consulting firms/client agencies form the professionals with the highest response of 67%, while there was also above average response from the Civil/Structural Engineers from consulting firms/client agencies at 58%. Construction managers represent 61% of the respondents. These are mostly trained building engineers or other allied professionals that are engaged with the contracting firms and are involved in construction progress monitoring. The architects and services engineers make up 43% and 35% of the respondents respectively.

Seventy-three percent (73%) of the respondents have additional academic degrees above their first basic qualification and 92% are fully registered members of their respective professional registration body, while all the respondents are members of their professional institutions in different categories.

The professional experience of the respondents is equally high as 65% have above 15 years of experience in the construction industry with 35% having over 20 years of experience. All the respondents have been involved in project monitoring and evaluation for over 5 years with 71% having more than 10 years of experience in CPM.

Respondent demographics show they have the necessary experience in the construction industry and more in CPM. Likewise, the respondents are highly qualified professionals with relevant knowledge of the field of study and are therefore considered suitable for the study.

4.2. Reliability and Validity of Construct

The test of reliability of the construct was achieved by computing Cronbach's Alpha values for each extracted factor. Taber (2018) opines that Cronbach's Alpha above 0.70 reflects the extent to which the different constructs within the factors produce similar measures thereby reflecting high relationships between the factors they measure.

Hair et al. (2010) posited that factor loading in EFA has to be 0.5 or greater to be practically significant. Therefore, this study only considered factor loadings of 0.5 and greater to be relevant in the measurement of factors extracted. Similarly, Hair et al (2010) warned that item loading on more than one factor leads to a cross-loading of variables. As a result, interpretation of the factors becomes difficult. Hence, item loading on more than one factor is not used for analysis.

4.3. Extracted Drivers for the Use of WACT for CPM.

From the analysis of the EFA, factors with less than 3 variables and with weak loadings (<.50) are not considered for this study (Yong and Pearce, 2013). As a result, only factors with at least 3 variables and high loading (>.50) on other variables were extracted and used for this study. The factors were rotated using varimax rotation with Kaiser Normalization. Principal components analysis was deployed to extract factors with communalities with factor groupings having eigenvalues greater than 1.0. and explaining 75.25% of the variance in the data.

Two variables (increased construction complexities and improved camera placing technology) loaded weakly on more than one factor and as a result, were not considered for further analysis. Therefore, 20 variables were subjected to further rotation and extraction of communalities. The scree plot revealed a convergence in five (5) iterations and as a result, five factors were extracted from 20 variables with eigenvalues above 1.0, explaining 75% of the variance as shown in table 4 below.

Table 4. Principal Component Analysis - Drivers

Factors	F1	F2	F3	F4	F5
Project Monitoring Process Efficiency (Cronbach's Alpha .981)					
Data exchange capacity	**.850**	-.006	.073	-.061	-.025
Progress report information cover	**.806**	-.067	-.004	-.063	-.107
Organisational benefits	**.806**	-.031	.060	-.024	-.061
Improved progress measurement	**.734**	.014	.101	-.030	.035
Confidentiality of Information	**.724**	-.003	.071	-.004	.033
Project monitoring time reduction (Cronbach's Alpha .892)					
Experience decision makers involvement	-.045	**.845**	.055	-.045	.054
Faster change notification	-.068	**.840**	.034	-.011	.002
Faster flow of info.	-.070	**.820**	.042	-.015	.005
Faster response time	-.031	**.815**	.036	.062	.033
Project monitoring cost reduction (Cronbach's Alpha .791)					
Virtual monitoring propensity	-.007	.071	**.953**	.021	.032
Faster dispute/claim resolution	.011	.045	**.942**	.002	.025
Quick identification of rework	.013	.054	**.934**	.005	.024
Resource tracking capacity	.017	.042	**.927**	.027	.027
Project monitoring collaboration (Cronbach's Alpha .775)					
Knowledge sharing	-.016	-.025	.031	**.845**	-.166
Team coordination	-.015	-.027	.025	**.841**	-.162
Collaborative plat.	-.016	.215	-.024	**.502**	.301
Project monitoring digital innovation (Cronbach's Alpha .821)					
Need for innovation	-.026	-.023	.163	-.089	**.816**
Project issues measuring matrix	-.025	-.031	.151	-.022	**.815**
Business process re-engineering	-.055	-.011	.136	-.074	**.795**
User-friendly Asynchronous tools	-.050	-.012	.068	-.042	**.771**

4.4. Extracted Barriers to the Use of WACT for CPM.

Applying the same parameters of principal component analysis on varimax rotation with Kaiser Normalization, the barriers were extracted through EFA.

Similarly, one variable (clement environment) loaded weakly on more than one factor, hence it was not considered for analysis. In the case of the barriers, the scree plot indicated four (4) iterations and as a result, four factors were extracted from 19 variables with eigenvalues >1.0, explaining 67% of the variance as shown in table 5 below.

Table 5. Principal Component Analysis - Barriers

Factors	F1	F2	F3	F4
Construction Industry Culture (Cronbach's Alpha .775)				
Organisational culture	**.966**	-.082	-.021	.007
Management preferences	**.961**	-.078	-.010	.011
Misalignment with existing practice	**.960**	-.074	-.020	.001
Innovative knowledge diffusion	**.959**	-.069	-.010	.001
Slow Technology Adoption (Cronbach's Alpha .825				
Awareness of existing tools	-.079	**.971**	.015	.027
Data security issues	-.076	**.969**	.017	.021
Barrier gaps between R and D	-.070	**.955**	.020	.014
Technology Adoption	-.135	**.950**	.011	.024
Trust in technology	-.005	**.921**	.010	-.024
Technology malfunction	-.106	**.876**	.023	.004
Available Organisational Personnel (Cronbach's Alpha .801)				
Understanding the complexities of the works	.155	-.081	**.802**	.102
Availability of Skillset	.165	-.020	**.801**	.111
Service Fragmentation	.177	-.073	**.785**	.120
Time to mount and train	.079	-.035	**.720**	.085
Budgetary and Management support (Cronbach's Alpha .715)				
Many systems adopt	-.016	-.027	.025	**.941**
Technical support	-.072	.061	.011	**.906**
Difficulty in implementation	-.065	.051	.041	**.902**
High montage cost	-.055	.015	.000	**.871**
No simple integrated methods	-.080	.025	.041	**.851**

4.5. Ranking of Drivers and Barriers.

The respondents perceived rating of the variables was used to derive the average mean and standard deviation for the drivers and barriers. The standard deviation is a more accurate and detailed estimate of dispersion because it shows the relationship that the set-off scores have to the mean of the sample (Schumacker and Tomek, 2013). The standard deviation will show the perception of the importance of the drivers and barriers where average means are the same from the data collected.

Table 6 shows the mean and standard deviation of the drivers and barriers together with the ranking of the factors.

Table 6: Ranking of the drivers and barriers.

Factor	Mean	Standard Deviation	Rank
Drivers			
Project monitoring process efficiency	3.99	0.715	1
PMC reduction	3.85	0.814	2
PMTreduction	3.77	1.013	3
Project monitoring digital innovation	2.44	0.765	4
Project monitoring collaboration	2.10	1.002	5
Barriers			
Construction industry culture	3.53	0.917	1
Available organisational personnel	3.42	1.158	2
Slow technology adoption	3.33	0.925	3
Budgetary and management support	2.61	0.841	4

4.6. Kendall's Coefficient of Concordance.

The study received responses from two areas with high construction activities. The data were subjected to Kendall's Coefficient (W) to test the level of agreement between the locations. Field, (2005) posited that the closer the coefficient of concordance is to 1, the more reasonable the level of agreement. The result for Kendall's Coefficient of Concordance is shown in Table 7 below.

Table 7: Coefficient of Concordance

Kendall's Coefficient of Concordance		
N		256
Kendall's (W)		.786
Bartlett's Test of Sphericity	Approx.Chi.Square	8253.48
	Df	41
	p.value.	.000

The results show that the data set is reasonably not independent of each other at 0.79.

4.7. Discussion of Findings.

In CPM efficiency of the methods employed directly affects the basic indicators of cost, time, and quality (Nkeleme et al., 2021). As a result, the drive to improve project monitoring process efficiency ranked highest as a driver with a mean score of 3.99. Process efficiency has measured variables such as the need for increased data exchange (Chevrou et al., 2016), improved progress reporting through automation reporting (Akinradewo et al., 2017), and improved progress measurement (Adbul Rahman and Gamil 2019). Confidentiality of data within the monitoring team is equally a measure that ensures that the right decision maker receives the information on time and therefore, makes informed decisions that would affect the construction progress (Abdul-Rahman and Gamil, 2019) positively. This reduces errors as manual methods of CPM have lately been seen to create (Yang et al., 2015; Wang et al., 2021).

Project monitoring cost has generated a lot of concerns lately in the construction industry, especially with geographically dispersed monitoring professionals (Yang et al., 2015; Wang et al., 2021). The need to converge the monitoring team to the project site for effective monitoring has been seen as expensive and time consuming. The ranking of the PMC reduction factor at 3.85 mean item score and ranked second is consistence with the global worries on PMC. This is more of a concern in Nigeria with the evident strain and security worries associated with frequent travel (Gloria and Rwang, 2020). Projects in many areas in Nigeria suffer due to this challenge, as such, with the use of WACT, such worries can be averted or reduced. Achieving cost reduction in CPM entails having a virtual monitoring capacity (Dhanash et al., 2020), the capacity to resolve disputes and claims faster, quick identification of reworks, and resource tracking capacity (Bohn and Teizer, 2010).

Similarly, the time taken to achieve CPM using manual methods often accounts for the errors associated with the process (Yang et al., 2015; Wang et al., 2021). Efficiency in CPM will reduce time it takes to monitor projects thereby reducing errors. For geographically dispersed teams, Panteli et al., (2018) posited that experienced members of the team often not receiving information first-hand. As a result, quick decisions are not made on time. Communication has been identified as key for PME (Abdul-Rahman and Gamil, 2019). Therefore, having a system that allows a fast flow of information will ensure faster response rates thereby creating avenues to receive change notifications on time. The PMTreduction factor is ranked third in this study as a driver with a mean score of 3.77.

The other drivers from the study are the need for improved digital innovation and collaboration in project monitoring with mean scores of 2.44 and 2.10 respectively. Despite their below average mean score, the factors returned relevant variables from the study. The need for business reorientation in the construction industry has been seen to improve construction site management practices thereby improving project delivery (Sanchez et al., 2019). Therefore, the presence of user-friendly asynchronous tools can help the reengineering of the monitoring process (Jacob- Loyola, 2021). Digital innovation in construction is equally growing (den Otter and Emmitt, 2007), therefore, the need for digital innovation is a valid driver. Also creating a collaborative platform for the geographically dispersed monitoring teams will enhance team coordination, knowledge sharing, and collaboration among monitoring professionals (Alto and Kyrill 2017).

The barriers revealed from this study has construction industry culture ranking first as a significant barrier with a mean score of 3.53. This barrier is prevalent as individual organisations develop cultures, which inform their mode of operations (den Otter and Emmitt, 2007). Culture equally influences management preferences. Where there is no innovative knowledge diffusion, misalignment with current monitoring practices will discourage the adoption of new tools (Sheffer and Levitt, 2010).

Appropriate personnel for specialized monitoring will require training and recruitment in cases where innovations such as WACT is used for CPM. Organisational Personnel ranked second as a barrier with a mean score of 3.42. CPM is fragmented amongst various professionals (Alto and Kyrill, 2017), therefore, ensuring prompt monitoring using virtual means will require that the professionals use a web-based collaborative platform. Assembling the required skill set within the different professionals is a barrier to use of integrated tools (Alto and Kyrill, 2017). Where professionals fail to understand the complexities of the work while applying such tools, the time taken to mount the necessary resources both human and infrastructure is a significant barrier to the adoption of such innovative tools (Wang et al., 2021).

Technology adoption ranked third with a mean item score of 3.33. It is well documented in the literature that the Nigerian Construction industry is slow in the adoption of new technologies for special purposes (Rasheed and Adebiyi, 2019). Slow adoption of integrated still imagery on asynchronous communication platforms for CPM exists because of professionals' lack of trust in technology (Yang et al., 2015), awareness, and fear of data security (Alto and Kyrill 2017). The gap in research and implementation of these systems also still exists (Yang et al., 2015).

Budgetary and management support ranked lowest as a barrier within the factors studied with a mean score of 2.61. Budgeting for new technologies is usually easier when there are many systems to choose from (den Otter and Emmitt, 2007). However, the high montage cost (Chen et al., 2021) can discourage management from budgeting for its adoption. Also, budgeting is made more difficult when there is no single integrated method off the shelf. The efforts to achieve integrated systems are very much high through research (Jacob-Loyola et al., 2021).

5. Conclusions.

The study revealed 5 drivers which include; project monitoring process efficiency; project monitoring time reduction; project monitoring cost reduction; project monitoring collaboration; and project monitoring digital innovations. Also, 4 barriers extracted are construction industry culture; technology adoption; organisation personnel; and budgetary and management support.

PME ranked highest amongst drivers for use of WACT for CPM. Other drivers that equally ranked high are PMC and PMT. construction industry culture (CIC) factors ranked highest as a barrier with organisational personnel (OP) and technology adoption (TA) factors equally of significant rank.

The Study identified latent drivers and barriers to using WACT for CPM. It can be argued that the existence of highly perceived drivers and the low average budgetary/management support barrier suggests that construction professionals are willing to use WACT for CPM, but the prevalence of construction industry culture explains professionals' skepticism on its seamless use to take over the traditional monitoring methods. Therefore, if not for barriers like construction industry culture, unavailability of personnel and slow technology adoption, the use of WACT would have taken over the traditional monitoring methods in the industry. This is evidenced by the low mean in budgetary & management support by the respondents. This study could be a practical guideline for the adoption and application of WACT for CPM. Also, other barriers to overcome include personnel and technology adoption challenges.

The study identified three main drivers which relate to efficiency, cost, and time. This indicates that WACT can be the solution to enhancing CPM, thereby, reducing the contribution of CPM to project delivery challenges, while enhancing challenging areas such as construction productivity, project time, and cost reductions. The study contributes to the understanding of the latent drivers and barriers to the use of WACT for CPM and can further enhance studies in the development of frameworks for WACT adoption.

This study was carried out in Nigeria. Hence a global perspective will further explain the effect of the drivers and barriers to WACT adoption. However, it is recommended that client agencies that fund multi-location projects across borders such as the United State Agency for International Development (USAID); African Development Bank (ADB), or locally like the Tertiary Education Trust Fund (TETFund) in Nigeria should develop models for the use of WACT for CPM. Similarly, consulting firms and construction clients can reduce overhead on travel expenses and improve monitoring efficiency by hosting such tools on their projects. Furthermore, the construction industry should change the organisational culture by training personnel to adopt technology/innovations in order to enhance effective and efficient CPM.

Further studies can develop models for the use of WACT for effective CPM by client agencies and further investigate the effectiveness of such WACT models against the traditional methods for CPM.

Author Contributions

Abdulkadir Rasheed is the lead author and contributed to the conceptualization, review of relevant literature, funding, analysis, software, and drafting of the manuscript. Taibat Adebiyi contributed to the conceptualization, administration, methodology, manuscript development, manuscript review, data collection, and analysis of the study. Ganiyu Amuda-Yusuf contributed to the analysis, funding, and validation of research methods and research findings. Suleiman Suleiman contributed to the manuscript development, editing, review, administration, and collection of data. All authors have read and agreed with the manuscript before its submission and publication.

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