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RESEARCH ARTICLE

Analysing the influence of offsite construction logistics on the performance of construction projects

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Abstract

Coordinating the logistics of workers, equipment and materials from varying locations can be challenging. This is a concern for project managers because disruptions in construction work leads to losses in production and business. Research into offsite logistics in construction tends to focus on factors that can optimise the performance of construction logistics. Another theme in the literature focuses on the application of digital technologies in construction logistics. However, investigations that examine the dynamics associated with offsite construction logistics and their implications on the performance of construction projects is limited. This study analyses the influence of offsite construction logistics on project performance. This study adopted a survey approach with a structured questionnaire that was administered to 200 construction practitioners and obtained data from 176 respondents on key aspects of offsite construction logistics indicating an 88% response rate with a reliability of 0.911. The results of this study revealed that integrating construction equipment and digital technologies in offsite operations has a positive and significant influence on the time performance of construction projects. The findings of this study are of value to construction professionals struggling to manage disruptions or delays and seeking to improve the way they manage offsite logistics involving multiple parties. The study contributes to the literature on construction logistics by extending our understanding on key aspects of offsite logistics that significantly impact on the performance of construction projects. This study argues that offsite construction logistics can be managed to overcome disruptions or delays by integrating the use of digital technologies in monitoring work flow and construction equipment in concrete works amongst others.

1. Introduction

Coordinating the logistics of workers, equipment and materials from varying locations can be challenging [1-4]. This is because offsite processes in construction often do not proceed precisely as planned which leads to overruns in cost or time. This is a concern for project managers because construction work is very competitive. A twenty-year review on studies in construction logistics showed growing trends targeted at improving efficiency in projects [5]. This shows that offsite logistics is an important aspect of construction

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management and raises questions on the way offsite logistics can be improved in construction sites.

The concept of offsite logistics tends to vary in literature. Some authors conceptualise offsite logistics as supply logistics or the logistics of supplying materials. For instance, Muya et al. [6] focused on the supply logistics of construction materials in a review study. Other authors present offsite logistics as processes involving the movement of equipment and materials that is external to a site. For example, Serra and Oliveira [7] described the control of suppliers as external logistics in a review study on logistics in construction. Recent authors conceptualise offsite logistics as supply chain logistics that involves information flow. For instance, Whig et al. [8] focused on supply chain logistics and decisions driven by data. The above authors show that the concept of offsite logistics is highly debateable.

Discussions on offsite logistics exists in the construction or operations management literature. Two main themes dominate the discussions on offsite logistics. Firstly, some studies assume that the secret to a successful project is by focusing on logistic factors associated with handling or conveying construction resources [6, 9]. Authors that share this assumption explore ways of optimising logistic processes by focusing on logistic factors.

Other studies assume that project success can be achieved by simply integrating digital technologies to logistics process involving construction work [10, 11]. Authors that share this assumption explore ways of improving efficiency in construction by adopting digital technology. However, what is missing in literature are investigations that examine the dynamics of offsite logistics and their implications on time performance in construction. This study examines the intricate aspects of offsite logistics and their influence on project time performance in construction. This approach shifts the debate on offsite logistics from factors and digital technologies and focusses on implications on project performance. The objectives of this study are: to evaluate the factors affecting the way offsite logistics is managed; to evaluate the extent of integration of construction equipment and digital technologies in offsite logistics in construction; to determine the influence of offsite logistics on project time performance. Based on this aim, this study presents the following hypothesis to test these relationships.

H0: There is no relationship between level of construction equipment integrated in offsite logistics and time performance of construction projects.

H1: There is a relationship between level of construction equipment integrated in offsite logistics and time performance of construction projects.

H0: There is no relationship between level of digital technologies integrated in offsite logistics and time performance of construction projects

H1: There is a relationship between level of digital technologies integrated in offsite logistics and time performance of construction projects

2. Literature review

2.1. Logistic factors in offsite logistics

The way resources in construction are handled (i.e. loading or offloading) or conveyed is an important component of offsite logistics [12-14]. This is because time spent in conveying resources to a point of use can make or mar project activities. Most studies on construction logistics tend to focus heavily on the material aspects at the expense of other constructions resources such as workers or equipment [5, 15-17]. This approach prioritises one resource components over another, whereas all resources play a significant role in the outcome of a project.

Several studies assume that the secret to a successful project is by focusing on logistic factors [6, 9, 12, 18]. These authors argue that considering this aspect of offsite logistics leads to an efficient management of resources that optimises construction works. For example, Muya et al. [6] put forward an analytical hierarchy model for making numerical judgements on factors affecting material supply logistics such as management capability and concluded that their model is useful

in evaluating the efficiency and cost effectiveness in material supply. This position is not supported because numerical calculations does not necessarily imply efficiency in construction. In the same vein, Edike [17] sampled the opinions of contractors on the aspects of material management that included time expectations and argued that implementing material management practices enables an efficient management of materials. This argument aligns with Muya et al. [6] position on efficiency in work.

In contrast to a focus on materials, Zubair et al. [12] applied an analytical hierarchy technique on factors to select the optimal material handling equipment out of three options and asserted that a selection based on their approach was more suitable and had a positive impact compared to the remaining two alternatives. In the same vein, Berawi et al. [9] sampled the opinions of manufacturers and contractors on factors considered in purchasing materials and choosing equipment for handling materials which included volume. Their opinions were divergent and they argued that project management tools aids selection that optimises work flow. This stance aligns with Zubair et al. [12] position on factors aiding decisions and enhancing work.

Furthermore, Tunji-Olayeni et al. [19] sampled contractors on the impact of logistic factors such as transport risks on material procurement to conclude that logistic factors such as vendor qualities and competence in procurement were critical for a successful procurement of materials. Similarly, Dixit et al. [20] focused on the impact of logistic related factors such as weather condition on resource use and argued that considering those factors lowers the carbon foot print. Based on the discussions above, 15 key logistic factors have been identified in this study and are presented in Table 1.

It can be seen that the above studies assume that the secret to a successful project is by focusing on logistic factors associated with handling or conveying construction resources. These authors examine logistic factors associated with material or equipment and argue that considering this aspect of offsite logistics aids decision making and optimises the logistic processes associated with procurement and resource use. However, investigations that examine the implications of integrating digital technologies or tools in offsite construction logistics on project time performance is limited.

The section that follows presents discussions on digital technologies in offsite logistics and underlines their arguments.

Table 1. Factors affecting offsite construction logistics

Logistic Factors	Source
Project complexity	Tunji-Olayeni et al. [19]
Scope of work	Nguyen and Le [5]
Project milestones	Olubajo et al. [4]
Project duration	Edike [17], Olubajo et al. [13]
Budget constraints	Olubajo et al. [4]
Quality assurance	Tunji-Olayeni et al. [19]
Risks in material handling	Tunji-Olayeni et al. [19]
Volume of materials	Berawi et al. [9]
Weight of materials	Agapiou et al. [15]
Regulations on transportation	Brodskiy [14]
Weather challenges	Dixit et al. [20]
Travel distance	Rajesh et al. [18], Olubajo et al. [13]
Onsite storage capacity	Nguyen and Le [5]
Manpower availability	Donyavi and Flanagan [16]
Equipment management capability	Muya et al. [6], Olubajo [21]

2.2. Digital technologies in offsite logistics

In contrast to studies that focus on logistics factors alone. Other scholars assume that project success can be achieved by simply integrating digital technologies into logistics processes in construction [10, 11, 22-28]. These authors argue that simply integrating digital technologies improves information flow, quality, efficiency and decreases cost of construction. For example, Bowden et al. [22] examined the application of mobile technologies (smart phones and tablets) in logistics and concluded that mobile technologies improve information flow in construction. Similarly, Almohsen and Ruwanpura [23] developed a model and mobile application to change the way materials are ordered and argued that their mobile application helps firms improve their logistics and productivity. This position aligns with Bowden et al. [22] stance on mobile application improving processes.

Besides focusing on mobile technologies, Sardroud [24] proposed an automated system that integrates RFID (radio frequency identification technology) and GPS (Global Positioning System) technology to track or monitor construction materials and concluded that the use of automated technologies provides communication benefits and low-cost solutions in managing resources. In the same vein, Kineber et al. [27] sampled the opinion of construction stakeholders on the application of RFID in construction and argued that the RFID technology benefits stakeholder in monitoring and making informed decisions. This argument aligns with Sardroud [24] position which is interesting for this study in examining the extent to which RFID and GPS systems are integrated in offsite logistics. According to Lu et al. [29] RFID technology also involves the use of barcode systems to facilitate real-time tracking of various materials to reducing inventory levels.

In addition, Oke et al. [26] sampled construction professionals to evaluate the application of augmented reality in construction and concluded that embracing digital technologies enhances work efficiency. In the same vein, Yevu et al. [28] developed a model to examine barriers to the use of digital technologies in procurement in construction and argued that addressing those barriers will increase the adoption of digital technologies in procurement.

Furthermore, Whitlock et al. [11] reviewed studies on the relationship between the application of BIM- building information modelling and construction logistics to conclude that an increased BIM use will lead to effective, efficient and safer logistic processes. Similarly, Ghalehnoei et al. [25] interviewed construction experts on the challenges of integrating BIM into offsite construction in New Zealand and argued that addressing integration challenges for BIM in offsite construction improves the quality and decrease total cost. This argument resonates with Whitlock et al. [11] position on improving efficiency in construction. Based on the discussions above, seven key digital technologies and tools have been identified in this study and are presented in Table 2.

It can be seen that the above studies assume that project success can be achieved by simply integrating digital technologies into logistics processes of construction work.

Table 2. Digital technologies/tools integrated in offsite logistics

Digital technologies/tools in offsite logistics	Source (previous studies)
GPS real time tracking of construction materials	Sardroud [24]
Bar code scanning systems of construction materials	Lu *et al*. [29]
Route analysis/optimisation system	Bowden *et al.* [22]
Construction weighing before loading and transportation	Ying *et al.* [30]
Mechanised lifts/operations offsite	Yevu *et al.* [28]
RFID (radio frequency identification technology)	Kineber *et al.* [27]
Modelling simulation of transported items	Whitlock *et al.* [11]

The above authors examine the application of mobile applications, RFID or GPS technology, BIM in logistic processes and argue that integrating digital technologies improves information flow, quality, efficiency and decrease cost in construction. Nevertheless, investigations that examine the extent and implications of integrating construction equipment in offsite construction logistics on project time performance is limited.

The section that follows presents discussions on equipment in logistics and time performance.

2.3. Offsite logistics of equipment and time performance

Offsite logistics is considered to play an important role on the type of equipment used in a project. This is because construction logistics involves acquiring and coordinating multiple construction equipment [31, 21]. The implication is that several equipment operators and maintenance teams would be involved in the process of construction that also need coordination. According to Ying et al. [32] accurate weighing before loading guides operators on the choice of vehicle to use to ensure safety in transportation and minimise travel time. The implication is that the absence of certain vehicle types for transportation can impact on the duration of a project.

Also, offsite logistics has also been considered to play a crucial role on the performance or survival of construction firms. According to Brewer and Speh [33] and Bettemir et al. [34] construction firms focus on three important objectives namely to: minimise expenses, maximise profit and minimise time. The implication is that logistic processes offsite affects the viability construction firms. Additionally, Alsharef et al. [35] argued that flexibility in the use of construction equipment is essential for effective logistics planning by construction firms and highlighted the importance of precautionary measures when using mixers and cranes.

Moreover, offsite logistics has also been considered to play a critical role on the environment. This aspect of logistics management is gradually gaining prominence because of client or government pressure to protect the environment in construction [20, 36]. According to Ying et al. [30] sustainability in construction logistics can be optimized by reducing the amount of material transport that negatively affects the environment. Based on the discussions above, seven key construction equipment have been identified in this study and are presented in Table 3.

Above all, offsite logistics is considered to play a significant role on outcome of construction projects. According to Chan and Kumaraswamy [37] and Yağcı et al. [38] logistic delays stems from the geographic location relative to a site. This is because transporting or conveying resources is a key aspect of time performance that is an indicator of project success [4, 32, 39]. According to [5, 14, 20] offsite logistics determine the time that resources arrive on site in appropriate quantities and corresponding costs. The implication is that more attention should be given to travel time associated with offsite logistics in construction. Two aspects of time performance amongst others have been used in the time management studies as indicators for evaluating the performance namely: early start and early finish [4, 37, 40, 41].

Table 3. Construction equipment used in offsite logistics

Construction equipment	Source (Previous Studies)
Concrete mixing trucks	Alsharef et al. [35]
Dump trucks	Olubajo et al. [13]
Hoisting equipment	Olubajo [21]
Concrete mixers	Alsharef et al. [35]
Cranes- Lorry mounted	Alsharef et al. [35]
Low-bed trailer	Zubair et al. [12]
Concrete pump machine	Edwards and Holt [31]

3. Research methodology

This study adopts a survey approach to investigate the intricate aspects of offsite construction logistics and their influence on project time performance. Structured questionnaires were administered to construction practitioners in Nigeria to evaluate the factors affecting offsite construction logistics and the level of equipment and digital technologies integrated in offsite logistics. The decision to adopt a survey is because this approach allows multiple professionals involved in construction an opportunity to express their opinion on offsite logistics. The questionnaire was administered by hand and online to construction practitioners using a random sampling approach that was divided into four parts. The first part of the questionnaire obtained data on the characteristics of the respondents. The second part obtained data on the relative impact of factors that affect offsite logistics that was measured using a 5-point Likert scale as follows: 5-very high impact, 4 – high impact, 3 – medium impact, 2- low impact and 1- very low impact. The third part of the questionnaire obtained data on the level of integration of digital technologies and construction equipment in offsite logistic in construction that was measured using a 5-point Likert scale as follows: 5-Always, 4 – Often, 3 – Sometimes, 2- Rarely and 1- Never. The fourth part of the questionnaire obtained data on the time performance that was measured using a 5-point Likert scale as follows: 5-Always, 4 – Often, 3 – Sometimes, 2- Rarely and 1- Never. A total of 200 questionnaires were administered in this study and 176 participants responded, indicating a response rate of 88%. This resulted in a high data reliability of (0.911) that was determined using a Cronbach Alpha analysis. The data obtained on the logistic factors, level of digital technologies and construction equipment were analysed using mean item score and ranking with SPSS-23. The influence of digital technologies and construction equipment on time performance (early start and early finish) was analysed using Kendal Tau B correlation test with SPSS-23.

4. Findings

The location of the respondents in Nigeria is presented in Table 4 below. Table 4 showed a significant representation from respondents from different regions in Nigeria. The Central region had the highest number of the respondents followed by the South-south and South -west region. Three trans-African automobile routes pass through Lagos in the South-west region and only one pass through Kano in the North-west region. The implication is that higher international road networks exists in the South-west region that is likely to lead to more economic activity and the potential for higher construction logistics.

Table 4. Location of respondents

Geo-economic zones	Location	Frequency
Central Region	Plateau	6
	Niger	109
	Nasarawa	2
	Kogi	1
	Benue	2
	Abuja	11
North-west Region	Jigawa	2
	Kaduna	2
	Kano	6
North-east Region	Taraba	2
	Gombe	2
South-south Region	Edo	2
	Bayelsa	2
	Akwa-Ibom	1
	Rivers	11
South-west Region	Osun	2
	Lagos	13
	Total	176

The characteristics of the respondents is presented in Table 5 below. Table 5 showed that a higher percentage (27.3%) of the respondents were procurement managers. Whereas the lowest percentage (1.1%) of the respondents were section managers. The results also showed that a higher percentage (38.1%) of the respondents were Builders. Whereas the lowest percentage (10.8%) of the respondents were Quantity Surveyors.

Table 5. Respondents characteristics

Item	Description	Frequency	Percentage
Role on project	Project Manager	32	18.2
	Procurement Manager	48	27.3
	Construction Manager	29	16.5
	Site Manager	30	17.0
	Site Engineer	12	6.8
	Store keeper	6	3.4
	Operations Manager	4	2.3
	Section Manager	2	1.1
	Subcontractor	9	5.1
	Supplier	4	2.3
	Total	176	100
Profession	Architect	40	22.7
	Builder	67	38.1
	Engineer	23	13.1
	Quantity surveyor	27	15.3
	Surveyors	19	10.8
	Total	176	100
Educational qualification	OND/HND	24	13.6
	B.Tech/B.Sc	98	55.7
	M.sc/M.Tech	47	26.7
	PhD	7	4.0
	Total	176	100
Professional qualification	NIA	28	15.9
	NIOB	61	34.7
	NSE	33	18.8
	NIQS	28	15.9
	Not registered	26	14.8
	Total	176	100
Years of experience	1- 5 years	70	39.8
	6-10 years	70	39.8
	11-15 years	32	18.2
	16-20 years	3	1.7
	Above 20 years	1	0.6
	Total	176	100
Gender	Male	139	79
	Female	37	21
	Total	176	100
Period working on current project	1- 3 years	140	79.5
	4-6 years	31	17.6
	7-9 years	4	2.3
	10-15 years	1	0.6
	Total	176	100

The result further showed that a higher percentage (55.7%) of the respondents had Bachelor's degrees as their highest level of education. Whereas a lower percentage of respondents (4%) indicated that they had a PhD degree.

The result in Table 2 showed that a higher percentage (34.7%) of respondents were registered members of the professional body- Nigerian Institute of Building (NIOB). Whereas 26% of respondents were not affiliated with any

professional body. The result also showed that a higher percentage (70%) of the respondents had between (1-5)/(5 -10) years of experience. Whereas a lower percentage (o.6%) indicated that they had above 20 years' experience. The result further showed that a higher percentage (79%) of the respondents were men, while 21% were female. The result also showed that (79.5%) of the respondents had spent (1-3) years working on their current projects, while a lower percentage (0.6%) had spent (10- 15) years.

4.1. Factors affecting offsite construction logistics

The relative importance of factors that affect offsite logistics is presented in Table 6 below. Table 6 showed that man power availability ranked highest with a mean item score of 4.03. This is followed by equipment management capability that ranked second with a mean item score of 4.02. The implication is that the presence of skilled personnel with the ability to manage equipment has a high impact on the success of construction logistics. The result also showed that the scope of work ranked third with a mean item score of 4.01. This was followed by budget constraints that rankled fourth with a mean item score of 4.00. The implication is that the amount of work and money apportioned in construction have a significantly high impact on logistics offsite. The above results align with Dixit et al. [20] findings as the skills of workers and equipment were ranked as the most influential logistic factors.

The results showed that travel distance and onsite storage capacity ranked fifth with mean item scores of 3.99. This was followed by the project duration that ranked seventh with a mean item score of 3.96. The implication is that the time associated with transportation to site, duration and available storage space have a high impact on offsite logistics. The result further showed that weather challenges and project complexity both ranked eight with a mean item score of 3.93. This was followed by the volume of materials, and quality assurance that both ranked tenth with a mean item score of 3.89 and the weight of materials that ranked twelfth with a mean item score of 3.86. The implication is that the size of material conveyed and the quality have a high impact on the success of offsite logistics. These results agree with Tunji-Olayeni et al. [19] findings as transportation challenges as late delivery, waiting time, delivery inaccuracies and poor quality of materials were ranked higher as factors that affect construction logistics.

Table 6. Factors affecting offsite construction logistics

Factors	MIS	Decision	Ranking
Project complexity	3.93	High Impact	8
Scope of work	4.01	High Impact	3
Project milestones	3.81	High Impact	13
Project duration	3.96	High Impact	7
Budget constraints	4.00	High Impact	4
Quality assurance	3.89	High Impact	10
Risks in material handling	3.79	High Impact	14
Volume of materials	3.89	High Impact	10
Weight of materials	3.86	High Impact	12
Regulations on transportation	3.66	High Impact	15
Weather challenges	3.93	High Impact	8
Travel distance	3.99	High Impact	5
Onsite storage capacity	3.99	High Impact	5
Manpower availability	4.03	High Impact	1
Equipment management capability	4.02	High Impact	2

The results showed that project milestones, risks in handling materials and regulations on transportation ranked thirteenth, fourteenth and fifteenth respectively with mean items score of 3.81, 3.79 and 3.66 respectively as have high impact on offsite logistics. The implication is that deadlines, regulations and risk associated with handling materials have high impact on offsite logistics. The decision column presented in Table 3, was determined using this rule: (0 – 1.49 = very low impact), (1.5 -2.49 = low impact), (2.5o – 3.49= medium impact), (3.50 -4.49 = high impact), (4.50 - 5.0 = very high impact).

4.2. Level of integration of digital technologies or tools in offsites logistics

The level of integration of digital technologies into offsite logistics is presented in Table 7 below. Table 7 showed that the use of RFID ranked first with a mean item score of 3.17. This was followed by the adoption of mechanised lifts/operations offsite that ranked second with a mean item score of 2.96. The implication is that RFID technology and mechanised lift/operations are sometimes used in the logistics operations offsite. The result also showed that weighing construction resources before loading or transportation and simulations that model the transportation of construction resources ranked third and fourth respectively with mean item score of 2.55 and 2.02. The implication is that construction practitioners sometimes make judgements on the suitability of vehicles for transportation with simulations. The above results align with Sardroud (2012) findings as RFID technology was integrated in offsite production.

The result in Table 7 showed that route analysis/optimisation systems and GPS real time tracking of materials ranked fifth and sixth respectively with mean item score of 2.01 and 1.78 respectively. The implication is that construction practitioners rarely used these technologies to monitor the logistic process associated with transporting resources. The result also showed that bar code scanning systems for materials ranked seventh and last with a mean item score of 1.65. The implication is that construction practitioner rarely used bar code scanning systems in managing the logistics of resources offsite. These results agree with Irizarry et al. [10] findings as GIS- Geographic Information System was used to improve the tracking and monitoring of construction supply chains. The decision column presented in Table 7, was determined using this rule: (0 - 1.49 = never), (1.5-2.49 = rarely), (2.5o – 3.49= sometimes), (3.50 -4.49 = often), (4.50 -5.0 = always).

4.3. Level of integration of construction equipment in offsites logistics

The level of integration of construction equipment into offsite logistics is presented in Table 8 below. Table 8 showed that the integration of concrete mixers in offsite logistics ranked first with a mean item score of 4.0. This was followed by the integration of concrete mixing pumps that ranked second with a mean item score of 3.57. The implication is that construction practitioners often use concrete mixers and pumps to transport concrete to construction sites. The result also showed that the use of dump trucks ranked third with a mean item score of 3.45. This was followed by the use of concrete mixing trucks that ranked fourth with a mean item score of 3.00.

Table 7. Level of integration of digital technologies/tools in offsite logistics

Digital technologies/tools in offsite logistics	MIS	Decision	Ranking
GPS real time tracking of construction materials	1.78	Rarely	6
Bar code scanning systems of construction materials	1.65	Rarely	7
Route analysis/optimisation system	2.01	Rarely	5
Construction weighing before loading and transportation	2.55	Sometimes	3
Mechanised lifts/operations offsite	2.96	Sometimes	2
RFID (radio frequency identification technology)	3.17	Sometimes	1
Modelling simulation of transported items	2.02	Rarely	4

Table 8. Level of integration of construction equipment in offsite logistics

Construction equipment	MIS	Decision	Ranking
Concrete mixing trucks	3.00	Sometimes	4
Dump trucks	3.45	Sometimes	3
Hoisting equipment	2.51	Sometimes	5
Concrete mixers	4.01	Often	1
Cranes- Lorry mounted	2.35	Rarely	6
Low-bed trailer	2.34	Rarely	7
Concrete pump machine	3.57	Often	2

The implication is that a major aspect of offsite logistics that involves using construction equipment is in concrete production. The above results align with Olubajo [21] findings as construction equipment were used in concrete work.

The result in Table 8 showed that the level of integration of hoisting equipment ranked fifth with a mean item score of 2.51. This is followed by the integration of crane-lorry mounted that ranked sixth with a mean item score of 2.35. The implication is that equipment for lifting or carry items vertical or horizontally were rarely used in offsite operations to transport resources. The result also showed that the integration of low-bed trailer in offsite logistics ranked seventh with a mean item score of 2.34. The decision column presented in Table 8, was determined using this rule: (0 - 1.49= never), (1.5-2.49 = rarely), (2.5o–3.49= sometimes), (3.50 -4.49 = often), (4.50 -5.0 = always).

4.4. Influence of integrating construction equipment in offsite logistics on project time performance

The influence of construction equipment in offsite logistics on project time performance is presented in Table 9 below. To ascertain whether there is a relationship between level of construction equipment integrated in offsite logistics and time performance with α=0.05. Hypothesis H0: (There is no relationship between level of integration of construction equipment in offsite logistics and time performance of construction projects) and H1: (there is a relationship between level of construction equipment integrated in offsite logistics and time performance of construction projects) was examined.

According to the findings in Table 9, it can be seen that there is a positive and significant relationship between the integration of concrete mixers and cranes on how early works starts or finishes with a p-values less than 0.05. This agrees with Alsharef et al. [35] argument as the use of these construction equipment was essential for effective logistics planning and this implies that increasing the use of concrete mixers and cranes improves the progress of construction work. The result also showed that there is a positive and significant relationship between the use of low-bed trailers on how early works starts or finishes with a p-values less than 0.05. This result aligns with Zubair et al. [12] findings as integrating material handling equipment optimised the logistics of handling materials as the implication is that increasing the use of a low-bed trailer to convey equipment increases the pace of the construction logistics offsite. Further results show that there is a positive and significant relationship between the integration of dump trucks and concrete pumping machine on how early works starts or finishes with a p-values less than 0.05. This result resonates with the findings of Olubajo et al. [13] and Olubajo [21] on positive outputs using dump trucks and concrete pumps, and this implies that increasing the use of dump trucks and concrete pumps increases the pace of the offsite logistics. However, it can also be seen that there is a no significant relationship between the integration of concrete mixing trucks on how early works start or finish with a p-values greater than 0.05. This implies that increasing the use of concrete mixing truck slows down the logistics.

Table 9. Influence of integrating equipment in offsite logistics on time performance

Correlation between equipment and time performance	N	R -V	P- V	Decision
Concrete mixing trucks				
Early start	176	0.090	0.252	Reject
Early finish	176	0.063	0.422	Reject
Dump trucks				
Early start	176	0.183	0.024	Accept
Early finish	176	0.164	0.041	Accept
Hoisting equipment and machine				
Early start	176	0.470	0.549	Reject
Early finish	176	0.174	0.029	Accept
Concrete mixers				
Early start	176	0.212	0.007	Accept
Early finish	176	0.164	0.037	Accept
Cranes-lorry mounted				
Early start	176	0.208	0.009	Accept
Early finish	176	0.166	0.035	Accept
Low-bed trailer				
Early start	176	0.208	0.009	Accept
Early finish	176	0.166	0.035	Accept
Concrete pumping machine				
Early start	176	0.181	0.023	Accept
Early finish	176	0.166	0.038	Accept

* N= number; R-V = correlation coefficient; P-V= P-Value (significant value).

4.5. Influence of integrating digital technologies in offsite logistics on time performance

The influence of digital technologies in offsite logistics on project time performance is presented in Table 10 below. To ascertain whether there is a relationship between level of adoption of offsite logistics and time performance with α=0.05. Hypothesis H0: (There is no relationship between level of integration of digital technologies in offsite logistics and time performance of construction projects) and H1: (there is a relationship between level of integration of digital in offsite logistics and time performance of construction projects) was examined.

According to the findings in Table 10, it can be seen that there is a positive and significant relationship between the integration of bar code scanning systems for construction materials and time performance with a p-value less than 0.05. This aligns with Lu et al. [29] findings and implies that increasing the use of bar code scanning technologies enhances time performance. The result also showed that there is a positive and significant relationship between route analysis/optimisation systems and how quick works starts or finishes with p-values less than 0.05. A similar result was observed in Ying et al. [30] with vehicle movements and this implies that analysing routes and optimisation improves time performance. The results further showed that there is a positive and significant relationship between the integration of mechanised lifting/operations offsite and time performance with a p-value less than 0.05. This agrees with Zubair et al. [12] stance on equipment and implies that using mechanised operations offsite enhances time performance. Additional results show that that there is a positive and significant relationship between modelling simulation of transported items and on how quick works starts or finishes with a p-values less than 0.05.

Table 10. Influence of technologies on construction project time performance

Influence of Offsite logistics	N	R -V	P- V	Decision
GPS real time tracking of construction materials				
Early start	176	0.106	0.096	Reject
Early finish	176	0.201	0.002	Accept
Bar code scanning systems of construction materials				
Early start	176	0.136	0.034	Accept
Early finish	176	0.156	0.015	Accept
Route analysis/optimisation systems				
Early start	176	0.222	0.000	Accept
Early finish	176	0.139	0.027	Accept
Weighing before loading/ transportation				
Early start	176	0.128	0.041	Accept
Early finish	176	0.138	0.026	Accept
Mechanised lifting/operations offsite				
Early start	176	0.122	0.050	Accept
Early finish	176	0.166	0.007	Accept
Integrating Radio frequency identification technology				
Early start	176	0.069	0.269	Reject
Early finish	176	0.143	0.021	Accept
Modelling simulation of transported items				
Early start	176	0.187	0.003	Accept
Early finish	176	0.136	0.031	Accept

* N= number; R-V = correlation coefficient; P-V= P-Value (significant value)

This implies that increasing the use of digital technologies, increases the pace of the offsite logistics. The above results align with Yevu et al. [28] and Oke et al. [26] findings as integrating digital technologies positively enhanced work efficiency. However, it can also be seen that there is a no significant relationship between the integration of GPS real time tracking and how early works starts with a p-values greater than 0.05. This result does not resonate with Sardroud [24] position and implies that increasing the use of GPS does guarantee a quick start in the logistics offsite.

5. Conclusion

This study examines the intricate aspects of offsite construction logistics and their influence on project time performance in construction. The objectives of the study were: to evaluate the factors affecting the way logistics is managed offsite; to evaluate the extent of construction equipment and digital technologies integrated in offsite logistics of construction work. To determine the influence of offsite construction logistics on project time performance. The study adopted a survey approach. The results of the study revealed that integrating construction equipment and digital technology into offsite logistics has a positive and significant influence on the time performance of construction projects. This study argues that the integration of construction equipment and digital technologies into offsite logistics processes improves the time performance of construction projects. The study contributes to the knowledge by extending the discussions in literature on construction logistics and providing detailed explanations on the intricate aspects of offsite logistics that significantly influences time performance in construction projects. This study also contributes to practice as construction practitioners can learn from the study outcomes as integrating digital technologies and construction equipment improves offsite logistics.

One limitation of this study is that participants were not given the opportunity fully express themselves with a closed ended questionnaire approach. The study recommends that future research should investigate the way constructions logistics unfolds in a live project.

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Author Contributions

O.O. Olubajo: Conceptualisation, Methodology, Analysis, Investigation, Writing of Original Draft preparation, Writing - Review & Editing. R.O. Olubajo: Conceptualisation, Visualisation, Resources, Project Administration, Editing.

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Not applicable.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

The authors acquired ethics committee permission for surveys implemented in this paper from the School of Environmental Technology Ethics Committee of the University (Date. 04.09.2024).

Conflict of Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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