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JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT
ISSN 1392-3730 print/ISSN 1822-3605 online
2012 Volume 18(1): 91–105
doi.org/10.3846/13923730.2011.604541

SUSTAINABILITY OF MECHANISATION IN THE NIGERIAN CONSTRUCTION INDUSTRY

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Received 04 Jan. 2010; accepted 28 Dec. 2010

Abstract. The study evaluates the level of mechanisation and its sustainability, the relationship between mechanisation and its sustainability and between mechanisation and project outcome. To achieve these, a field survey involving a sample of eighty projects was conducted with the aid of questionnaires. Data were collected on the production methods adopted in excavation and concreting, whether or not the use of plant for the operations were sustainable and the initial and actual delivery time and cost of the projects sampled. The data were analysed using ranking, mean, t-test and Spearman correlation test. The study reveals that the levels of mechanisation and sustainability of mechanisation in the two operations are slightly above average. It also reveals that the level of sustainability of mechanisation has significant influence the level of mechanisation while of mechanisation has significant influence on quality standards and productivity. The study concludes that there is a strong need for measures that will improve the level of mechanisation and its sustainability in the industry and recommend the introduction of plant mobilisation fund by clients, incentives on importation of construction plant and an effective and functional lease market for construction plant as some of the measures that will improve mechanised construction.

Keywords: construction industry, mechanisation, Nigeria, project outcome and sustainability.

1. Introduction

The importance of plant and equipment in the achievement of project objectives seems to be increasing on daily basis. There are numerous problems encountered in the delivery of construction projects worldwide that need urgent and drastic solutions because they have far reaching consequences on the industry. One of these problems is the long delay experienced in project delivery. Research studies (Ogunlana, Promkuntong 1996; Okuwoga 1998; Majid, McCaffer 1998; Shi *et al.* 2001; Ng *et al.* 2001; Aibinu, Jagboro 2002; Choudhury, Rajan 2003; Koushki *et al.* 2005) identify delay as a global problem in the construction industry. A survey of the delivery time of construction projects in Nigeria reveals a delay of between 50 and 420% (Elinwa and Buba 1993). Another problem is the excessive cost-overrun experienced in the delivery of construction projects. Most projects overshoot their budgets to an extent that renders clients bankrupt that is unable to continue with their financial obligations. Still another problem bedevilling the industry is poor quality standards or workmanship. Tam *et al.* (2000) maintain that quality management is far more difficult to achieve in construction than in other industries. Senge'enge (2000) cited in Materu (2000) identifies poor quality of services and products as one of the critical issues which have adverse impact on the performance of contractors in Tanzania. Studies (Okedele 2008; Lagos State Physical Planning Authority 2008) discover that Nigeria is bedevilled by numerous cases of building collapse and that the phenomenon is one of the major challenges facing the built environment in Nigeria. In a study of the importance attached to time, cost and quality, Idoro (2008) discovers that Nigerian clients attach greater importance to quality than project delivery time and cost and that client will be willing to forgo time and cost for good workmanship.

These and other problems have adverse consequences not only on the construction industry but also on the entire economy. Okpala and Aniekwu (1988) observe that delay in project execution is responsible for time and cost overruns experienced in the delivery of projects. Elinwa and Joshua (2001) discover that delay is the most important factor for project abandonment and contractor failure. One of the ways of solving these problems is the application of plant and equipment (P&E) in project execution. Surely, manual method of construction cannot provide any solution to the numerous problems facing the construction industry rather it will aggravate them. Manual method is fast giving way to mechanised method in the efforts to increase productivity, meet increasing complex specifications, construct or actualise the growing complexity of modern designs, utilise the numerous new construction materials that are being introduced into the industry, meet the tight schedules and targets placed by clients' demands, implement control measures required to bring projects on track and ensure effective and efficient utilization of the numerous resources involved in the

construction of projects. New P&E are being developed and produced regularly in response to the needs of the industry. Seeley (1995) asserts that increased mechanisation of construction work can speed up construction and reduce the overall cost of construction while Olomolaiye *et al.* (1998) maintain that the adoption of advanced technology affects productivity. In appreciation of the important role that P&E play in achieving project objectives, clients now consider the P&E possessed by prospective contractors as a major criterion for the award of contracts. Plebankiewicz (2009) identify P&E possessed by contractors as one of the three criteria that are used to determine the technical ability of contractors during prequalification. In response to this development, contractors often embark on efforts to own construction plant and equipment in order to be able to compete favourably with their counterparts during tendering. They do not stop there; they also stipulate mechanised methods in their production method statements during tendering. They also ensure that the methods stipulated in their tenders are adopted when eventually contracts are won and have to be executed. However, one issue which is the ability to sustain the P&E procured by contractors is important in the quest to mechanise the construction industry.

Considering the enormous fund committed to the procurement of P&E in the attempt to mechanise construction operations, it becomes imperative to critically investigate whether or not contractors give adequate attention to how the P&E used in project execution can be sustained. This is necessary to promote mechanised production process in the construction industry and to ensure that both clients and contractors derive the benefits of mechanisation. This study investigates the sustainability of the use of P&E in project execution in the Nigerian construction industry. The aim of the study is to identify ways not only to increase the level of mechanisation of construction operations but also to sustain it. In the attempt to achieve this aim, the study determines and compares the levels of mechanisation and its sustainability in two selected construction operations. It also evaluates the relationship between the levels of mechanisation and its sustainability and the relationship between the level of mechanisation and project outcome.

2. Hypotheses of the study

Four research hypotheses were postulated in the attempt to achieve the objectives of the study. The first research hypothesis states that the levels of mechanisation of excavation and concrete operations are not significantly different. The results of this hypothesis will provide an insight into whether or not the level of mechanisation varies from one construction operation to another. The second research hypothesis states that the extent to which selected KSIs of mechanisation is obtainable in excavation and concrete operations are not significantly different. The results of this hypothesis will make stakeholders to know whether or not the sustainability of mechanisation varies from operation to operation. The third research hypothesis states that the extent to which selected KSIs is obtainable in excavation and concrete operations is not significantly correlated with the levels of mechanisation of the operations. The results of this hypothesis will provide an insight into whether or not Nigerian contractors consider sustainability in the selection and use of P&E during project execution. The fourth hypothesis states that the level of mechanisation of construction operations has no significant correlation with project performance. The results of the test of this hypothesis are expected to assist Nigerian contractors to know whether or not the application of P&E in project execution has an influence on project outcome. Since the essence of using P&E is to ensure that a project is delivered to time, within budget and to required quality standards, the test of this hypothesis is an indirect measurement of the effectiveness of the application of P&E.

3. Variables of the study

The variables used to achieve the objectives of the study were classified into four categories namely construction operation, mechanisation and sustainability factors and project outcome. The construction operations selected for the study are excavation and concreting. Mechanisation consists of the level of mechanisation of construction task and the level of mechanisation of construction operation. For the purpose of evaluating the level of mechanisation of construction tasks in excavation operation, four tasks namely: digging/excavating foundation; removal of excavated materials from foundation bed; loading of excavated materials and transporting excavated materials were used while five tasks namely: loading of concrete materials; mixing of concrete; transportation of concrete; casting of concrete and curing of concrete were used for the purpose of evaluating the level of mechanisation of construction tasks in concrete operation.

Six Key Sustainability Indicators (KSIs) namely: adequate workload for P&E, available skilled mechanics to repair P&E, economy in the use of P&E, availability of adequate fund for the purchase of P&E, adequate depreciation provision for P&E and initiative in investing on innovation were used in the study. The first three KSIs (adequate workload for P&E, available skilled mechanics to repair P&E and economy in the use of P&E) were obtained from discussion with some of the heads of construction sites identified during the preliminary survey. Two other indicators namely: availability of adequate fund for the purchase of P&E and adequate depreciation of P&E were added to cater for replacement of plant while initiative in investing on innovation was included to evaluate continuous process improvement. Six parameters namely: contractors' assessment of production rate of construction operations, contractors' assessment of quality of works, project time-overrun, project cost-overrun, ratio of time-overrun to initial contract period and ratio of cost-overrun to final contract sum were used as indicators of project outcome.

4. Conceptual framework for the study

In the attempt to evaluate the sustainability of mechanisation of construction operations, four categories of varia-

bles stated above were used. Excavation and concrete works are just two of the numerous but the commonest operations in construction project delivery. Each of the operations consists of a number of tasks which can be performed by mechanical or manual method. The number of tasks performed by mechanical method among the tasks that constitute an operation indicates the level of mechanisation of the operation. This level of mechanisation can be sustained in present and future projects when certain conditions which are termed key sustainability indicators (KSIs) are present in the P&E used. This implies that the level of mechanisation of an operation can be influenced by the extent to which the KSIs are obtainable in the P&E used for the operation. Furthermore, the acquisition of P&E involves huge financial commitment and its application is expected among other things to bring about increased speed of construction, reduced cost and improve the quality standards of construction works. These can be regarded as the most important parameters of project outcome. In other words, the level of mechanisation is expected to influence the outcome of a project.

The above explains the relationship between the variables used for the study which will be established in the study. This relationship is expressed in the conceptual framework presented in Fig.1.

5. Previous studies

As applicable in the manufacturing industry, mechanisation of production processes in the construction industry is fast becoming the order of the day. The reasons for this are not farfetched. Horner (1982) discovers that the degree of mechanisation and the method of construction are two of the ten factors that affect construction productivity. Chang and Borcherding (1985) consider equipment availability as one of the factors that affect productivity. Kazaz and Ulubeyli (2004) maintain that in Turkey, the labour-intensive production is still in use and that this has made construction one of the most unproductive sectors. Alinaitwe *et al.* (2009) opine that the main reason that productivity growth has been poor is the level of technological change in the industry. Zakeri *et al.* (1997) in a study of Iranian construction industry and Kaming *et al.* (1998) in a study of Indonesian construction industry put labour cost at between 20–50% of the total project cost. As a result of the labour-intensive nature of construction process, Gambao *et al.* (2000) opine that the construction process results in relatively high costs while Kazaz and Ulubeyli (2004) state that labour becomes a more important input in the production phase.

The cost, quality and productivity implications of manual production process have necessitated growing concern for more plant input in construction process especially in building projects. Chikara (2006) opines that in a mechanised building project, the costs of plant can vary from 5–10% of the direct costs whereas in highway construction projects, the costs can get as much as 40% of the project direct costs. Examining specific construction plant, Ulubeyli and Kazaz (2009) maintain that the use of suitable concrete pump on the job site improves site

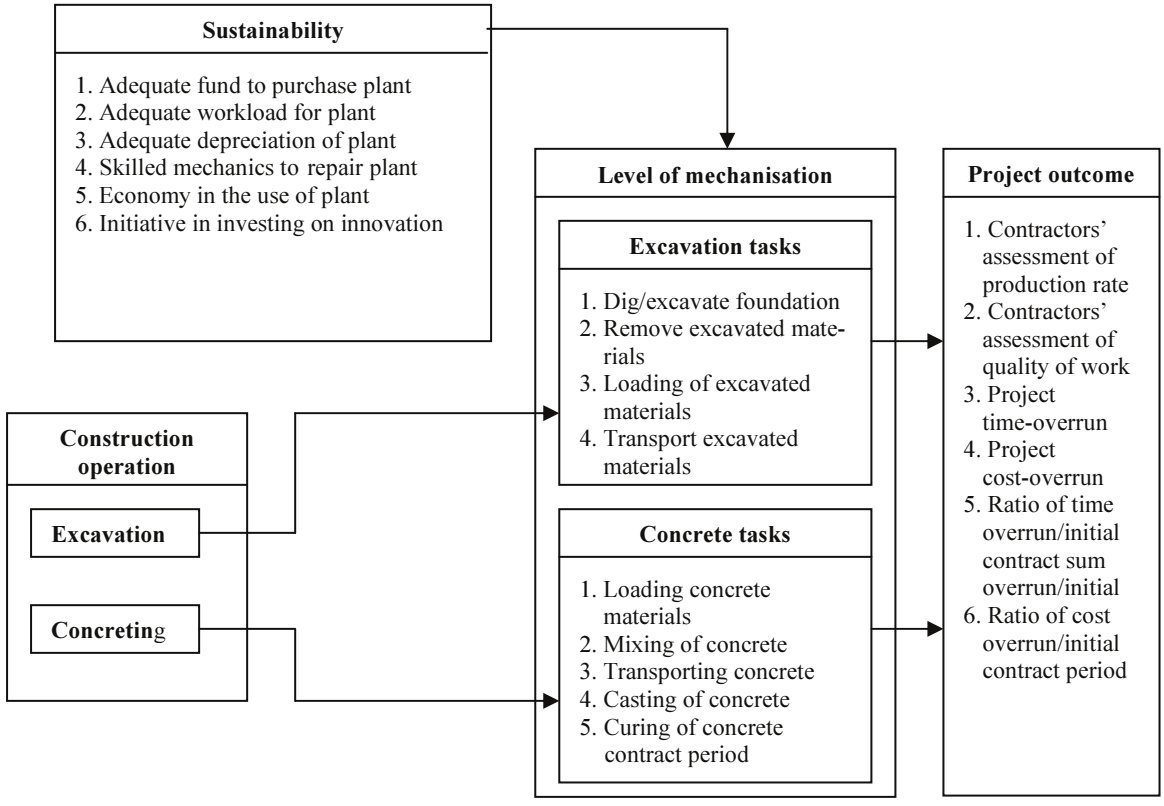

Fig. 1. Conceptual framework for evaluating the correlation between the level of mechanisation and project outcome

productivity, increases the quality of products and services and reduces the duration and cost of the task of casting concrete. The Free Dictionary (2010) states that mechanisation refers to the use of machines either wholly or in part to replace human or animal labour. It states further that unlike automation which may not depend at all on a human operator, mechanisation requires human participation to provide information or instruction. Idoro (2008) describes mechanisation as the process of applying the use of mechanical plant in carrying out a task. He opines further that the level of mechanisation can be explained in two ways namely: the number of P&E employed or the number of activities carried out by mechanical plant in an operation.

From the above description, one can say that in a fully mechanised process, tasks are performed using mechanical effort while human effort is limited to the operation of machines. Scholars claim that the use of mechanical plant in an operation has numerous advantages. Aluko (1971) observes that capital intensive manufacturing industries have lower average cost than labour intensive ones in Nigeria therefore, expatriate owned industries struggle to reduce labour cost by substituting capital for low production labour. Seeley (1995) opines that increased mechanisation of building operations speeds up production and reduces cost of construction. Akinsola and Adenuga (2004) observe that industrialization brought about modern P&E which increase productivity, efficiency and consequently, reduce costs. Fisk and Reynolds (2005) argue that careful investigation of construction methods is one of the ways of realising improvement in the overall cost of projects. Koskela and Bellard (2003) identify mechanisation as one of the most important attributes of manufacturing and assert that this attribute makes the industry more efficient and productive than construction. There is no gainsaying in the assertion that P&E play significant role in the achievement of the objectives of every project. It increases the speed of construction thereby minimising prolonged delivery period and delay. It helps to reduce the final cost of projects, to ensure effective and efficient utilisation of resources, reduce wastage and achieve good workmanship or quality standards. The need for improvement in the workmanship and quality standards of construction works among construction contractors especially the indigenous ones has become an important issue. Idoro (2010) discovers that Nigerian clients give preference to expatriate contractors in the award of contracts and that this preference is sustained by better workmanship and quality of materials among other factors. This advantage that expatriate contractors have over their indigenous counterparts is traceable to the use of mechanised methods therefore; indigenous contractors have to improve on their production methods if they expect the same preference in the award of contracts as their expatriate counterparts. Giving these benefits, it is essential for stakeholders in the construction industry especially contractors to promote increased use of P&E in project execution. This can be achieved by promoting measures that will sustain the use of P&E in construction operations which is termed sustainability.

Related to mechanisation is the concept of "Just-In-Time" (JIT). Vokurka and Davis (1996) describe JIT as a strategy of providing the right materials in the right quantities and quality, just in time for production. JIT management strategy was developed for the manufacturing industry for the purpose of reducing production time thereby improving productivity. Monden (1998) regards JIT as Toyota Production System while Norris (1992) observes that JIT contains a body of knowledge that involves a comprehensive set of principles and techniques for the manufacturing industry. Researchers have discovered that the implementation of JIT management strategy has recorded numerous successes in the manufacturing industry. Schonberger (1982) describes it as the most important productivity enhancement management innovation in the 20th century. Zhu *et al.* (1994) discovers that the innovation makes operation faster and eliminates waste while Cheng and Podolsky (1996) opine that it improves customer service and builds organisational competitiveness. Low and Chan (1997) opine that it is used to achieve continuous improvement.

The success achieved through the implementation of the management strategy in the manufacturing industry made researchers to suggest the adoption of JIT philosophy in the construction industry. Tommelein and Li (1999) and Pheng and Min (2005) consider Ready Mixed Concrete (RMC) which is an important construction material in countries like United States, China and Singapore as a perishable commodity that the JIT management strategy can be applied in its production process. Based on the characteristics of the production process of RMC, Pheng and Min (2005) identify several elements of JIT when applied in RMC batching plants. The duo classifies these elements into five key factors namely: JIT customer strategy, JIT vendor strategy, JIT production strategy, quality control strategy and management commitment and employee involvement strategy. Of all the five key JIT factors, the production strategy is closest to mechanisation. The elements of the strategy according to Pheng and Min (2005) are reduction in machine set-up time and in-house lot size, automation, group technology, cross-training, preventive maintenance and schedule stability. In two separate case studies conducted in United States, Tommolein and Li (1999) discover that the practices for managing concrete supply chain upstream in terms of raw materials acquisition or prerequisite work on site are not tailored toward the JIT production strategy.

In the study on the application of JIT management in ready mixed concrete industries in Chongqing, China, Pheng and Min (2005) discover that both the traditional BOQ system and the JIT system are adopted to manage the procurement of raw materials in the RMC industry of Chongqing, China and Singapore. They observe that when RMC suppliers adopt JIT purchasing to mobilise aggregates, sand and concrete admixtures from vendors simultaneously, they can operate faster, eliminate waste, achieve continuous improvement, improve customer service and build organisational competitiveness. The inference from the studies on the use of JIT in construction is that although the system is still unpopular,

however its implementation in RMC industry is an indication that the system is gradually being introduced into construction.

Sustainability has featured prominently in construction projects in recent times. It is used in several senses with the most prominent being the impact of construction on the environment. World Commission on Environment and Development (1987) describes sustainable development as meeting the basic needs of the public and satisfying their aspirations for a better life without jeopardising the ability of future generations. Shen *et al.* (2007) maintain that in sustainability, emphasis is placed on the balance among social development, economic development and environmental sustainability. Apart from using construction to achieve sustainable environment, the term is also used to mean other things. Materu (2000) opines that participants at an annual contractors' workshop in Tanzania describe sustainability in four ways. First, sustainability is described as the ability of local contractors to participate competitively and undertake works effectively and grow both in local and international markets to satisfy market demand. Secondly, the participants describe sustainability as the ability of contractors to meet current and future needs of the contracting industry. Thirdly, they define sustainability as the ability of local contractors to participate competitively, execute works effectively, meet challenges of the environment and develop in order to meet the demand of infrastructure development. Fourthly, the participants also view sustainability as the ability of contractors to participate and execute works effectively and competitively to meet existing construction demand with continuous growth and performance improvement, sharing work opportunities and resources in a supportive environment. Ofori and Toor (2007) also describe sustainability as a process or state that can be maintained at a certain level indefinitely. Of all the descriptions above, the last best describes the concept of sustainability used in this study. Although, sustainability has to do with a defined level of a process or state, the concept generally applies to maintaining or improving upon a defined or existing level. In other words, sustainability refers to a stable and progressive state or process. Sustainability in this study therefore describes the ability of contractors to sustain or improve upon the existing level of application of P&E in their production methods. Several factors can contribute to the capacity of contractors in this respect including the initiative in investing on innovation however; in this study five of these factors namely: economy in the use of P&E, availability of adequate fund for the purchase of P&E, availability of skilled mechanics to repair P&E, adequate depreciation provision for P&E and adequate workload for P&E are used.

6. Research methods

The study adopts a questionnaire survey approach to achieve its objectives. In the approach, a field survey of eighty recently completed construction projects was carried out. To obtain the sample, a preliminary survey was conducted to identify recently completed projects across Nigeria in 2008 because of lack of reliable data of such projects and the factors that promote continuous use of plant in the tasks that the respondents used plant for. From the preliminary survey, 116 projects were identified and used as the population frame of the study. Five KSIs namely: availability of skilled operators to operate plant, availability of mechanics to maintain plant, condition of plant, workload available for plant and cost of using plant for an operation were suggested by the heads of the sites in the preliminary survey. The 5 KSIs were reviewed to obtain 3 KSIs while 3 other KSIs were added to make 6 KSIs as stated in the variables of the study above. Skilled operator was removed because contractors arrange for operators before plant are deployed to sites while skilled mechanics to repair plant and the condition of plant were considered as the same. The study sample was selected from the population frame by purposive sampling. In the selection, it was observed that some of the respondents did not supply all the information required in the research instrument therefore, 80 respondents with the highest response to the information requested were selected. The respondents were either engineers or builders who were the head of the contractors' staff on site.

Data was collected using structured questionnaires which were administered and collected from the respondents by hand. On mechanisation, respondents were requested to indicate the production methods (manual or mechanical) used to carry out the four selected tasks in excavation operation and the five selected tasks in concrete operation. On sustainability, the extent to which each KSI was obtainable in the two construction operations was measured using five ranks namely: not important, less important, moderately important, quite important and very important. The ranks were weighted as 1, 2, 3, 4 and 5 respectively. Respondents were requested to indicate the rank that best represent the extent to which each KSI was obtainable in the plant or methods used to carry out excavation and concrete operations. On project outcome, respondents were requested to state the initial and actual delivery time and cost of the projects selected. The production rates of plant used for the tasks in the two operations were measured using three ranks namely: below target, on target and above target. The ranks were assigned scores of 1, 2 and 3 respectively. The quality of work achieved in the two operations was measured using five ranks namely: poor, low, average, high and very high. The ranks were weighted as 1, 2, 3, 4 and 5 respectively. Respondents were requested to tick the appropriate rank that represented their assessment of the production rates and quality standards achieved in the two operations.

The level of mechanisation of each of the tasks in the two operations was calculated as the percentage of respondents who adopt mechanical method to carry out the task to the total number of respondents. The level of mechanisation of each operation was calculated as the ratio of the number of tasks carried out using mechanical method by each respondent to the total number of tasks in the operation. The level of sustainability of each KSIs was derived using Relative Importance Index (RII). The RII of each KSI is the Total Weight Value (TWV) divi-

ded by the number of respondents (frequency) for the KSI while TWV is the sum of the frequencies multiplied the weights of the ranks assigned each KSI. Project time-overrun in a project was derived as the difference between the actual and initial contract periods while cost-overrun was derived as the difference between the final and initial contract sums of a project. The levels of mechanisation and its sustainability in each of the two operations were compared using ranking while the test of their differences was done using t-test. Correlation between the levels of mechanisation and its sustainability and between the level of mechanisation and project outcome was tested using the Spearman correlation test.

7. Results

The data collected were analysed in the attempt to achieve the objectives of the study. The results of the analysis are presented as follows.

8. Level of mechanisation of construction operations

The study investigated the level of mechanisation of construction operations in the Nigerian construction industry. For this investigation, the two construction operations namely: excavation and concreting were used. The tasks involved in the operations were identified and respondents were requested to indicate the method (manual or mechanical) used to carry them out. The percentage of the number of respondents who carried out a task by mechanical method to the total number of respondents was evaluated to represent the level of mechanisation of each task. The results of the analysis are presented as follows.

9. Level of mechanisation of tasks in excavation operation

To evaluate the level of mechanisation of excavation operation in the Nigerian construction industry, the four tasks stated above were used. The levels of mechanisation of the tasks in the operation were analysed using percentage. The results are presented in Table 1.

Table 1. Levels of mechanization of tasks in excavation operation

Excavation task	Method	N	%	Rank
Digging/excavating foundation	Manual	52	65.0	1
	Mechanical	28	35.0	2
	Total	80	100	
Removal of excavated materials	Manual	46	57.5	1
	Mechanical	34	42.5	2
	Total	80	100	
Loading of excavated materials	Mechanical	52	65.0	1
	Manual	28	35.0	2
	Total	80	100	
Transporting excavated materials	Mechanical	60	75.0	1
	Manual	20	25.0	2
	Total	80	100	

N – number of respondents

The results in Table 1 show that the level of use of manual method ranks first in digging/excavating foundation (65%) and removal of excavated materials from excavation bed (57.5%) while it ranks second in transporting excavated materials (25%) and loading of excavated materials (35%). The level of use of mechanical method ranks first in transportation of excavated materials (75%) and loading of excavated materials (65%) while it ranks second in digging/excavating foundation (35%) and removal of excavated materials (42.5%). The results indicate that mechanised production method is preferred to manual method for loading and transporting of excavated materials but the latter method is preferred to the former for digging and removal of excavated materials from excavation bed.

10. Level of mechanisation of tasks in concrete operation

Five tasks stated above were selected as tasks in concrete operation in the attempt to evaluate the level of mechanisation of concrete operation in the Nigerian construction industry. The levels of mechanisation of the tasks in the operation were analysed using percentage. The results are presented in Table 2.

Table 2. Levels of mechanization of tasks in concrete operation

Excavation task	Method	N	%	Rank
Weighing/Loading of concrete materials	Manual	42	52.5	1
	Mechanical	38	47.5	2
	Total	80	100	
Mixing of concrete materials	Mechanical	74	92.5	1
	Manual	6	7.5	2
	Total	80	100	
Transporting of concrete	Mechanical	42	52.5	1
	Manual	38	47.5	2
	Total	80	100	
Casting of concrete	Manual	46	59.0	1
	Mechanical	32	41.0	2
	Total	80	100	
Curing of concrete	Manual	58	74.4	1
	Mechanical	20	25.6	2
	Total	78	100	

N – number of respondents

The results in Table 2 reveals that the level of use of manual method ranks first in weighing and loading of concrete materials (52.5%), casting of concrete (59%) and curing of concrete (74.4%) but it ranks second in mixing of concrete (7.5%) and transporting of concrete (47.5%). The level of use of mechanical method ranks first in mixing of concrete (92.5 %%) and transporting of concrete (52.5%) but it ranks second in concrete curing (25.6%), concrete casting (41%) and weighing/loading of concrete materials (47.5%). The results indicate that the application of P&E in carrying out construction operation is more favoured than manual method for mixing and trans-

porting of concrete while weighing and loading of materials for concreting; casting and curing of concrete are more labour-based tasks than mechanical.

11. Comparing the levels of mechanisation of tasks in construction operations

The study also compares the levels of mechanisation of the tasks in each of the two construction operations selected. The percentage of respondents that apply P&E in carrying out each task was calculated and used to compare the levels of mechanisation of the tasks in each operation using ranking. The results are presented in Tables 3 and 4.

Table 3. Ranking of the levels of mechanisation of tasks in excavation operation

Concrete operation	Manual			Mechanical		
	N	%	Rank	N	%	Rank
Transporting excavated materials	20	25.0	4	60	75.0	1
Loading of excavated materials	28	35.0	3	52	65.0	2
Removal of excavated materials	46	57.5	2	34	42.5	3
Digging/excavating foundation	52	65.0	1	28	35.0	4

The results in Table 3 reveal that transportation of excavated materials from excavation point (mechanical – 75%) ranks first in level of mechanization. Loading of excavated materials for transporting (mechanical – 65%) ranks second while removal of excavated materials from excavation bed (mechanical – 42.5%) and digging/ excavating of foundation (mechanical – 35%) rank third and fourth respectively in level of mechanization.

Table 4. Ranking of the levels of mechanisation of tasks in concrete operation

Concrete operation	Manual			Mechanical		
	N	%	Rank	N	%	Rank
Mixing of concrete materials	3	7.5	5	37	92.5	1
Transporting of concrete	19	47.5	4	21	52.5	2
Weighing/Loading of concrete materials	21	52.5	3	19	47.5	3
Casting of concrete	23	59	2	16	41	4
Curing of concrete	29	74.4	1	10	25.6	5

N – number of respondents

The results above indicate that transporting of excavated materials from excavation point is the most mechanised of the tasks in excavation operation with majority of the respondents using trucks for the task. Loading of excavated materials for transporting is the second most mechanised task with majority of the respondents also using loading machines for the task. This result should be expected because loading of excavated materials complement the transportation of excavated materials although; the use of machines to carry out the latter does not imply that the same method should be used for the former. Removal of excavated materials from foundation bed and digging of foundation are the least mechanised tasks with minority of the respondents using plant to perform them. Again these two tasks are closely related because the same plant can be used to perform them.

The results in Table 4 reveal that mixing of concrete (mechanical – 92.5%) ranks first in level of mechanisation of concrete operation. Transporting of concrete (mechanical – 52.5%) ranks second while weighing and loading of concrete materials (mechanical – 47.5%) ranks third. Concrete casting (mechanical – 41%) and curing (mechanical – 25.6%) rank fourth and fifth respectively. The results indicate that concrete mixing is the most mechanised task in concrete operation with almost all the respondents using concrete mixers for concrete mixing. The levels of mechanisation of transportation of concrete and weighing/loading of concrete are about average while casting of concrete and curing of concrete after casting which are below average in mechanisation are the least mechanised tasks with a small proportion of the respondents using P&E for them.

12. Difference in levels of mechanisation of construction operations

The study further attempted to find out whether or not the level of mechanisation varies from one construction operation to another. To do this, the first research hypothesis of the study was postulated. The hypothesis states that the levels of mechanisation of excavation and concrete operations are not significantly different. The ratio of the number of tasks carried out with plant by each respondent to the total number of tasks in an operation was evaluated to represent the level of mechanisation of an operation by each respondent. The hypothesis was tested using the t-test with $p \leq 0.05$. The rule for the acceptance or rejection of the hypothesis is that when the p-value ≤ 0.05, the hypothesis is rejected but when the p-value >0.05, the hypothesis is accepted. The result of the hypothesis is presented in Table 5.

Table 5. Result of t-test for difference in level of mechanisation between excavation and concrete works

Variables compared	N	Mean	t-value	Df	p-value	Decision
Level of mechanisation of excavation work	66	0.6894	4.561	65	0.001	Reject
Level of mechanisation of concrete work	66	0.5758				

N – number, Df – degree of freedom

The results in Table 5 show that the level of mechanisation in excavation (0.6894) and concrete (0.5758) are above average (0.5). This result is an indication that mechanised method is more adopted than manual method in the two construction operations. The results in Table 5 also reveal that the t-value (4.561) is high and the p-value (0.001) for the test of difference between the levels of mechanisation of excavation and concrete operations is lower than the critical p-value (0.05) therefore, the hypothesis is rejected. This result indicates that the level of mechanisation of excavation operation (0.6894) is significantly higher than that of concrete operation (0.5758). It further implies that the level of mechanisation or the application of P&E in construction works varies from one operation to another.

13. Sustainability of the level of mechanisation

To achieve its objectives, the study investigated the sustainability of the level of mechanisation of the two construction operations used for the study. For this purpose, six key sustainability indicators (KSIs) stated above were used. Data collected were the ranks that represented the extent to which the KSIs were obtainable in the plant or methods used to carry out excavation and concrete operations. The RII of the KSIs were analysed and ranked. The results are further presented.

14. Sustainability of the level of mechanisation of excavation operation

The RII which represented the level of sustainability of the five KSIs in excavation operation was analysed. The results of their ranks are presented in Table 6.

Table 6. Level of sustainability of excavation operation

Key sustainability indicators (KSI)	N	TWV	RII	Rank
Economy in the use of P&E	80	296	3.70	1
Adequate fund for purchase of P&E	78	259	3.32	2
Initiative in investing on innovation	80	247	3.09	3
Available skilled mechanics to repair P&E	78	224	2.87	4
Adequate depreciation provided for P&E	76	215	2.83	5
Adequate workload for P&E	78	217	2.78	6

N – number of respondents, TWV – Total weight value, RII – Relative importance index

The results in Table 6 reveal that the extent of achieving economy in the use of P&E (RII = 3.70) is considered as the most obtainable among the KSIs in excavation operation. The extent to which the fund provided for the purchase of P&E is adequate (RII = 3.32) is adjudged as the second most obtainable KSIs. Initiative in investing on innovation (RII = 3.09) is assessed to be the third most obtainable KSI while the extent of availability of skilled mechanics to repair plant (RII = 2.87), the extent of provision of adequate depreciation for P&E (RII = 2.83) and the extent to which the available workload for P&E is adequate (RII = 2.78) are the fourth, fifth and sixth KSIs respectively. The results indicate that majority of the respondents considered the extent to which the P&E they used for excavation is economical, the extent to which the fund provided for the purchase of P&E is adequate and the extent of initiative in investing on innovation to be above average while the extent of availability of skilled mechanics to repair P&E, the extent of provision of adequate depreciation for P&E and the extent of availability of adequate workload for P&E are below average.

15. Sustainability of level of mechanisation of concrete operation

The level of sustainability of the six KSIs in concrete operation was also analysed and ranked. The results are presented in Table 7.

Table 7. Level of sustainability of concrete operation

Key sustainability indicators (KSI)	N	TWV	RII	Rank
Available skilled mechanics to repair P&E	75	288	3.84	1
Adequate fund for purchase of P&E	75	282	3.76	2
Initiative in investing on innovation	80	283	3.54	3
Adequate workload for P&E	75	232	3.09	4
Adequate depreciation provided for P&E	75	231	3.08	5
Economy in the use of P&E	75	205	2.73	6

N – number of respondents, TWV – Total weight value, RII – Relative importance index

The results in Table 7 show that the extent of availability of skilled mechanics to repair P&E (RII = 3.84) ranks highest among the KSIs. The extent to which the fund provided for the purchase of P&E is adequate (RII = 3.76) is assessed to be the second most obtainable KSI. Initiative in investing on innovation (RII = 3.54) is the third most obtainable KSI. The extent to which the available workload for P&E is adequate (RII = 3.09) is considered as the fourth KSI while the extent of provision of adequate depreciation for P&E (RII = 3.08) and the extent of achieving economy in the use of P&E (RII = 2.73) are considered as the fifth and sixth KSIs. The results indicate that the extent of availability of skilled mechanics to repair P&E, the extent to which the fund provided for the purchase of P&E is adequate, initiative in investing on innovation, the extent to which the available workload for P&E is adequate and the extent of provision of adequate depreciation for P&E are above average while the extent of achieving economy in the use of P&E is below average.

Table 8. Result of t-test for difference in the level of sustainability of mechanisation between excavation and concrete operations

KSIs compared	N	Mean	t-value	Df	p-value	Decision
Available skilled mechanics to repair P&E in exc.	72	2.88	1.890	71	0.063	Accept
Available skilled mechanics to repair P&E in conc.	72	2.69				
Adequate fund for purchase of P&E in exc.	72	3.36	–2.311	71	0.024	Reject
Adequate fund for purchase of P&E in conc.	72	3.76				
Initiative in investing on innovation in exc.	80	2.60	–3.589	79	0.001	Reject
Initiative in investing on innovation in conc.	80	2.94				
Adequate workload for P&E in exc.	72	2.79	–1.816	71	0.074	Accept
Adequate workload for P&E in conc.	72	3.06				
Adequate depreciation provided for P&E in exc.	70	2.83	–1.716	69	0.091	Accept
Adequate depreciation provided for P&E in conc.	70	3.01				
Economy in the use of P&E in exc.	74	3.68	–1.494	73	0.140	Accept
Economy in the use of P&E in conc.	74	3.85				

N – number of respondents, Df – Degree of freedom, P&E – Plant & Equipment, Exc – Excavation, Conc – Concrete

16. Difference in levels of sustainability of mechanisation of construction operations

In order to establish whether or not the level of sustainability of P&E varies from one construction operation to another, a test of difference in the six KSIs between excavation and concrete operations was carried out. The second research hypothesis of the study was postulated for this purpose. The hypothesis states that the extent to which selected KSIs of mechanisation is obtainable in excavation and concrete operations are not significantly different. The hypothesis was tested using t-test with $p \leq 0.05$. The rule for the acceptance or rejection of the hypothesis is that when the p-value ≤ 0.05, the hypothesis is rejected but when the p-value >0.05, the hypothesis is accepted. The result of the hypothesis is presented in Table 8.

The results in Table 8 show that the p-values for the test of difference in the extent of availability of skilled mechanics to repair P&E (0.063), adequate workload for P&E (0.074), provision of adequate depreciation for P&E (0.091) and the extent of achieving economy in the use of P&E (0.140) between excavation and concrete operations are greater than the critical p-value (0.05), therefore the hypothesis is accepted. The results indicate that the differences in the four KSIs as obtainable in excavation and concrete operations are not significant. However, the p-values for the test of difference in the extent to which the fund provided for the purchase of P&E is adequate (0.024) and initiative in investing on innovation (0.001) between excavation and concrete operations are less than the critical p-value (0.05), therefore the hypothesis is rejected. The results indicate that the differences in the two KSIs as obtainable in excavation and concrete operations are significant.

17. Correlation between levels of mechanisation and sustainability

Further attempt was made in the study to determine whether or not the level of mechanisation and the level of sustainability of mechanisation are related. The attempt involved the test of the third research hypothesis of the study which states that the extent to which selected KSIs is obtainable in excavation and concrete operations is not significantly correlated with the levels of mechanisation of the operations. The hypothesis was postulated to determine whether or not the sustainability of mechanisation influences the level of mechanisation of the two operations (excavation and concreting) investigated in the study. The levels of mechanisation and sustainability of mechanisation of excavation and concreting operations were measured as described above. The hypothesis was tested using the Spearman correlation test with $p \leq 0.05$. The rule for the acceptance or rejection of the hypothesis is that when the p-value ≤ 0.05, the hypothesis is rejected but when the p-value >0.05, the hypothesis is accepted. The results of the test of the hypothesis are presented in Table 9.

On the influence of sustainability on the level of mechanisation of excavation operation, Table 9 reveals that the p-values for the test of correlation between the level of mechanisation of excavation operation and the extent of availability of skilled mechanics to repair P&E (0.002), provision of adequate fund for the purchase of P&E (0.001), initiative in investing on innovation (0.001), provision of adequate workload for P&E (0.001), adequate depreciation for P&E (0.005) and the extent of achieving economy in the use of P&E (0.001) are less than the critical p-value (0.05), therefore the hypothesis is rejected. The results indicate that the extent to which the six KSIs are obtainable have significant correlation with the level of use of P&E in excavation operation.

On the influence of sustainability on the level of mechanisation of concrete operation, Table 9 reveals that the p-values for the test of correlation between the level of mechanisation of concrete operation and the extent of availability of skilled mechanics to repair P&E (0.001), initiative in investing on innovation (0.001), adequate workload for P&E (0.001) and provision of adequate depreciation for P&E (0.001) (0.001) are less than

Table 9. Results of Spearman test of correlation between the levels of mechanisation and the levels of sustainability of mechanisation of excavation and concrete operations

Variables correlated	N	R	p-value	Decision
Level of mechanisation of excavation operation and				
Available skilled mechanics to repair P&E	66	0.371	0.002	Reject
Adequate fund for purchase of P&E	66	0.412	0.001	Reject
Initiative in investing on innovation	66	0.875	0.001	Reject
Adequate workload for P&E	66	0.408	0.001	Reject
Adequate depreciation provided for P&E	64	0.344	0.005	Reject
Economy in the use of P&E	66	0.416	0.001	Reject
Level of mechanisation of concrete operation and				
Available skilled mechanics to repair P&E	72	0.546	0.001	Reject
Adequate fund for purchase of P&E	72	0.101	0.397	Accept
Initiative in investing on innovation	78	0.950	0.001	Reject
Adequate workload for P&E	72	0.449	0.001	Reject
Adequate depreciation provided for P&E	72	0.542	0.001	Reject
Economy in the use of P&E	72	0.065	0.547	Accept

N – number of respondents, R – Correlation coefficient, P&E – Plant & Equipment

Table 10. Results of Spearman test of correlation between the level of mechanisation of excavation works and project outcome

Parameters correlated	N	R	p-value	Decision
Level of mechanisation of excavation works and				
Contractors assessment of production rate of excavation works	66	0.187	0.133	Accept
Contractors assessment of quality of excavation works	66	0.555	0.001	Reject
Project time-overrun	40	–0.060	0.711	Accept
Project cost-overrun	30	–0.035	0.853	Accept
Ratio of time-overrun/initial contract period	38	–0.196	0.238	Accept
Ratio of cost-overrun/final contract sum	32	–0.031	0.868	Accept

N – number of respondents, R – Correlation coefficient

the critical p-value (0.05), therefore the hypothesis is rejected. The results indicate that the extent to which the four KSIs are obtainable have significant correlation with the level of use of P&E in concrete operation. However, the p-values for the test of correlation between the level of mechanisation of concrete operation and the provision of adequate fund for the purchase of P&E (0.397) and the extent of achieving economy in the use of P&E (0.547) are greater than the critical p-value (0.05), therefore the hypothesis is accepted. The results indicate that the extent to which the two KSIs are obtainable have no significant correlation with the level of use of P&E in concrete operation.

18. Correlation between mechanisation of construction operations and project outcome

The study also investigated the relationship between the use of P&E and project outcome. The reason for this analysis is to determine the effectiveness of the application of P&E in project execution. For this purpose, the fourth hypothesis of the study was postulated. The hypothesis states that the level of mechanisation of construction operations has no significant correlation with project outcome. The parameters used for mechanisation and project outcome are described in the variables of the study above and their measurements are explained in the methods of the study. Data collected were analysed to test the hypothesis using the Spearman correlation test with $p \leq 0.05$. The rule for the acceptance or rejection of the hypothesis is that when the p-value$\leq$0.05, the hypothesis is rejected but when the p-value>0.05, the hypothesis is accepted. The results of the test of the hypothesis are presented as follows.

19. Correlation between mechanisation of excavation works and project outcome

The results of the test of correlation between the level of mechanisation of excavation works and the selected parameters of project outcome are presented in Table 10.

The results in Table 10 reveals that the correlation values for the test of correlation between the level of mechanisation of excavation works and contractors' assessment of production rates of excavation works (0.187), project time-overrun (–0.060), project cost-overrun (–0.035), ratio of time-overrun to initial contract period (–0.195) and ratio of cost-overrun to final contract sum (–0.031) are low and their respective p-values (0.133), (0.711), (0.853), (0.238) and (0.868) are greater than the critical p-values (0.05) therefore the hypothesis is accepted. The results indicate that the level of mechanisation of excavation operation has no correlation with contractors' perception of production rates, project time and cost overruns and the ratios of time-overrun to initial contract period and cost-overrun to final contract sum. However, the correlation value for the test of correlation between the level of mechanisation of excavation works and contractors' assessment of the quality of excavation works (0.555) is high and its p-value (0.001) is less than the critical p-value (0.05) therefore the hypothesis is rejected.

The result is an indication that the level of mechanisation of excavation operation among the respondents has significant correlation with contractors' perception of the quality of excavation works.

20. Correlation between mechanisation of concrete operation and project outcome

The results of the test of correlation between the level of mechanisation of concrete operation and the selected parameters of project outcome are presented in Table 11.

The results in Table 11 reveals that the correlation values for the test of correlation between the level of mechanisation of concrete works and project time-overrun (–0.237), project cost-overrun (–0.230) and the ratio of cost-overrun to final contract sum (–0.036) are low and their respective p-values (0.113), (0.176) and (0.836) are greater than the critical p-values (0.05) therefore the hypothesis is accepted. The results indicate that the level of mechanisation in concrete operation among the respondents has no correlation with project time and cost overruns and the ratio of cost-overrun/final contract sum. However, the correlation values for the test of correlation between the level of mechanisation of concrete works and contractors' assessment of production rates of concrete works (0.263), contractors' assessment of quality of concrete works (0.331) and the ratio of time-overrun to initial contract period (–0.348) are high and their respective p-values (0.020), (0.003) and (0.020) are less than the critical p-value (0.05) therefore, the hypothesis is rejected. The result is an indication that the level of mechanisation in concrete operation has significant correlation with contractors' perception of production rate and quality of work and the ratio of time-overrun to initial contract period.

21. Discussion of findings

The results of the study have revealed that the level of mechanisation varies among the tasks that constitute excavation and concrete operations and that the level of mechanisation of excavation operation is significantly higher than that of concrete operation. These results indicate that the level of mechanisation of construction operations varies from one task to another and from one operation to another. This result is expected because the plant required in one task or operation varies from that of another. This is revealed in the evaluation of the levels of mechanisation of the selected tasks and operations. However, the results of the study show that the levels of mechanisation of loading (65%) and transporting (75%) excavated materials are close and rank next to one another. The same result is applicable to the levels of mechanisation of digging foundation (35%) and removal of excavated materials from the bed of foundation (42.5%). These tasks with levels of mechanisation that are close are known to be those that can be performed by the same plant. These results indicate that the level of mechanisation of some construction tasks do influence those of others especially when such tasks can be performed by the same plant. For such tasks, the production method used for a task may dictate the method to be used for the other. The implication of these results is that the level of mechanisation of construction operations and tasks and indeed the level of sustainability of mechanisation can be increased by emphasising such operations and tasks in the selection and acquisition of construction plant. Moreover, to increase the level of mechanisation and continuously improve construction performance, contractors and other project team members would need to invest adequate fund and initiative on innovation.

The results of the study also reveal that the level of mechanisation of construction operations (excavation – 0.68, concrete – 0.58) is above average. Specifically, only four tasks (transporting excavated materials – 75%; loading of excavated materials – 65%; concrete mixing – 92.5%; concrete transporting – 52.5%) from the nine tasks investigated have their levels of mechanisation above 50%. The levels of mechanisation of other tasks are below average. These results indicate that close to if not more than half of the number of tasks in an operation is carried out manually in the Nigerian construction industry. This is an indication that there is still considerable room for increased level of mechanisation in the industry. The results of the study also reveals that the ranks of three KSIs namely: economy in the use of P&E, availability of skilled mechanics to repair P&E and adequate workload for P&E differ in the two operations investigated. While the economy in the use of P&E is the most obtainable KSI in excavation, it is the least in concrete operation. However, the ranks of the remaining three KSIs namely: adequate fund for the purchase of P&E, initiative in investing on innovation and adequate depreciation for P&E are the same in the two operations. These results tend to indicate that the priorities accorded some KSIs are the same while those of others differ from one operation to another. Contractors need to realise that all the KSIs are important and deserves high consideration because none is sufficient to sustain the use of P&E.

Table 11. Results of Spearman test of correlation between the level of mechanisation of concrete works and project outcome

Parameters correlated	N	R	p-value	Decision
Level of mechanisation of concrete works and				
Contractors assessment of production rate of concrete works	78	0.263	0.020	Reject
Contractors assessment of quality of concrete works	78	0.331	0.003	Reject
Project time-overrun	46	–0.237	0.113	Accept
Project cost-overrun	36	–0.230	0.176	Accept
Ratio of time-overrun/initial contract period	44	–0.348	0.020	Reject
Ratio of cost-overrun/final contract sum	36	–0.036	0.836	Accept

N – number of respondents, R – Correlation coefficient

Another result worthy of note is that initiative in investing on innovation is the third most obtainable KSI in the two operations. This KSI apart from being capable of promoting the sustenance of existing level of mechanisation, it will also keep mechanisation up to date and continuously improve construction process and performance. These results show that there is room for increase in the level of sustainability of mechanisation of construction operations in Nigeria. This can be increased significantly if contractors increase their initiative in investing on innovation, make adequate allowance for the depreciation of P&E annually and ensure that P&E are fully engaged.

The results of the test of difference in the six KSIs between excavation and concrete operations show that the levels of sustainability of mechanisation in the two operations are significantly the same in four KSIs namely: availability of skilled mechanics to repair P&E, provision of adequate workload and depreciation of P&E and economy in the use of P&E. This result can be attributed to the fact that the process or methods of the KSIs are the same from one operation to another. For example, the same mechanics will repair the P&E and the same methods may be adopted in depreciating P&E used in the two operations. However, the levels of sustainability of mechanisation in the two operations are significantly different in the remaining two KSIs namely: provision of adequate fund for the purchase of P&E and initiative in investing on innovation. These results indicate that more fund for the purchase of P&E and more initiative in investing on innovation are more obtainable in concrete operation than excavation operation. These results tend to indicate that concrete operation is giving more priority than excavation operation in the two KSIs.

The results of the test of correlation between the levels of mechanisation in excavation and concrete operations and the six KSIs indicate that the level of mechanisation in excavation operation has significant correlation with the six KSIs while the level of mechanisation in concrete operation has significant correlation with four KSIs. These results imply that the level of sustainability influences the level of mechanisation of the two construction operations. In other words, the level of mechanisation or the application of P&E in construction operations can be increased by increasing the extent to which the KSIs are obtainable. However, the result of the study indicates the level of mechanisation of concrete operation is not significantly correlated with the provision of adequate fund for the purchase of P&E and economy in the use of P&E. This result is an indication that the availability of fund for the purchase of P&E and the economy in the use of P&E have no significant influence on the use of P&E in concrete operation. In other words, the result implies that the decision of contractors to use P&E in concrete operation is not often based on the fund to purchase the plant or their economy. This result is understandable because the use of P&E especially in concreting is often important in achieving stipulated quality standards or workmanship.

The results of the test of correlation between the level of mechanisation and project outcome reveals that the level of use of P&E in excavation does not influence production rate of work, the delivery time and cost of construction projects. These results do not agree with the assertions made by Seeley (1995), Fisk and Reynolds (2005), Akinsola and Adenuga (2001) and Alinaitwe *et al.* (2009) that mechanisation increases productivity and reduces project delivery time and cost. However, the results of the study indicate that mechanisation does influence contractors' perception of the quality standards of works. These results tend to imply that the application of P&E in excavation operation is only effective in terms of better workmanship but ineffective in increasing productivity, reducing delay in the delivery of construction projects and reducing project cost. The results also show that the use of P&E for concreting does not influence project time and cost overruns and the ratio of cost-overrun to initial contract sum. These results also do not agree with the claim made by Seeley (1995), Fisk and Reynolds (2005) and Akinsola and Adenuga (2001). However, the use of P&E is discovered to influence productivity rate of concrete operation as asserted by Akinsola and Adenuga (2001) and Alinaitwe *et al.* (2009), quality standards of concrete operation and the ratio of time-overrun to initial contract time as discovered by Ulubeyli and Kazaz (2009). These results imply two things. The first is that increased mechanisation can be used to achieve better quality standards in construction works and increased productivity. The second is that mechanisation is partially and not fully effective in the construction industry. For mechanisation to increase productivity and reduce project delivery time and cost, plant must be efficient and effectively engaged. The findings suggest that Nigerian contractors do not carry out adequate planning to ensure effective utilisation of the plant acquired. The use of 'second hand' plant which is the practice in Nigeria and the attendant frequent breakdown which make the plant more idle than active when on site can also make the application of plant to have little or no influence on the productivity of workers and project delivery time and cost. What can be inferred from this result is that there is the need for Nigerian construction contractors to embark on measures that will increase their level of use of P&E in construction project delivery as well as improve the effectiveness of the use of P&E.

22. Conclusions

The study has revealed the level of mechanisation prevailing in the Nigerian construction industry, its sustainability and their correlation and the influence of mechanisation on project outcome. The results have established that the levels of use of P&E for carrying out construction operations is above average and that many construction operations are still labour-based. The results also show that the use of P&E for carrying out construction operations will improve the quality standards of construction works and even productivity. This invariably implies that the incidences of shoddy jobs and building collapse which have been described as the bane of the construction industry can be minimised by increased use of P&E. The

influence that the use of P&E has on project outcome should encourage all the stakeholders in the industry to embark on measures that will promote greater use of P&E in project execution.

However, since construction plant and equipment are imported and very expensive, contractors are bound to face difficulties in encouraging increased use of plant and equipment in project execution. This is evident in the level of mechanisation of the tasks and operations investigated. The findings of the study have shown that the level of mechanisation can still be improved and if this is done productivity and project quality will be improved. However, contractors cannot do this alone without support from their clients and governments. Clients will need to support contractors by giving them financial assistance to procure required plant and equipment for jobs awarded to them in order to encourage mechanised construction. It may not be out of place for clients to introduce or reintroduce plant and equipment mobilisation fund for the contractors they engage. Governments on the other hand would need to put in place financial policies that will encourage the procurement of construction plant and equipment. Incentives such as duty free or reduction will reduce the cost of construction plant and equipment and make their procurement easy.

The study has also shown that the extent to which the six KSIs are obtainable is either slightly above or they are below average that is moderately important. Yet, the study established that these KSIs have significant influence on mechanisation. These results suggest the need for contractors to improve the extent to which indicators of sustainability are obtainable. Nigerian contractors should provide adequate fund for the purchase of plant and equipment, making allowance for their depreciation and eventual replacement, keep them engaged, get skilled mechanics to maintain them and continuously invest in innovation. Nigerian contractors may not be able to get these done alone without support from other stakeholders. Many if not all of these issues can be done by other parties through a lease market for construction plant and equipment. It is therefore necessary for the construction industry in Nigeria to promote an effective and functional lease market for construction plant and equipment that will make the ownership or outright purchase of plant by contractors when they strive to adopt mechanised method voluntary.

23. Implication of the results of the study

The results of the study will create awareness about the benefits that can be derived from mechanisation and the level to which production process in the construction industry in Nigeria is mechanised. Specifically, it will make stakeholders know that mechanised production process can be an effective tool for improving the quality standards of construction works and minimising the incidences of shoddy jobs and building collapse which have been major problems in Nigeria. This awareness and the interest it will create are expected to stimulate increased efforts and investment in mechanised production process and continuous process improvement in the construction industry of Nigeria and other developing countries.

24. Areas of further studies

The study has only established that production process in the construction industry in Nigeria and perhaps those of other developing countries is partly mechanised. It has not investigated the reasons why the industry still relies much on manual effort. There are several problems confronting the industry in the effort to adopt mechanised process and research effort aimed at promoting mechanised production process will be incomplete without investigating these problems and the solutions to them. Further studies on these are suggested to complement the impact of this study.

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MECHANIZACIJOS TVARUMAS NIGERIJOS STATYBŲ SEKTORIUJE

G. I. Idoro

Santrauka

Tyrime vertinamas mechanizacijos lygis ir tvarumas, taip pat ryšys tarp mechanizacijos ir jos tvarumo bei tarp mechanizacijos ir projekto rezultatų. Įvertinti pasirinkta 80 projektų imtis ir atlikta anketinė apklausa. Buvo renkami duomenys apie kasimo ir betono liejimo darbų metodus, apie tai, ar įrangos naudojimas darbams buvo tvarus, taip pat apie pradinį ir realų darbų atlikimo laiką bei imčiai atrinktų projektų kainą. Duomenys analizuoti naudojant rangavimo, vidurkių, t testo metodus ir Spearmano koreliacijos testą. Tyrimas rodo, kad dviejų minėtų darbų atveju mechanizacijos ir mechanizacijos tvarumo lygiai šiek tiek viršija vidurkį. Jis taip pat rodo, kad mechanizacijos tvarumo lygis daro nemažą įtaką mechanizacijos lygiui, o mechanizacija daro reikšmingą įtaką kokybės standartams ir našumui. Tyrime daroma išvada, kad labai reikia priemonių, kurios pagerins sektoriaus mechanizacijos lygį ir tvarumą, bei rekomenduojamos kelios mechanizuotą statybą pagerinsiančios priemonės: klientams įsteigti įrangos mobilizacijos fondą, skatinti statybų įrangos importą ir sukurti efektyvią bei funkcionuojančią statybos įrangos nuomos rinką.

Reikšminiai žodžiai: statybų sektorius, mechanizacija, Nigerija, projekto rezultatai ir tvarumas.

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