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Effect of Mechanisation on Occupational Health and Safety Performance in the Nigerian Construction Industry

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Abstract: The need to improve productivity, quality standards, efficiency and performance in construction projects has brought about increased use of Plant and Equipment (P&E). This study evaluates the level of mechanisation and its relationship to the Occupational Health and Safety (OHS) performance of the Nigerian construction industry. The purpose of the study is to ascertain the influence of mechanisation on OHS performance and raise the commitment of contractors to effective OHS management. To achieve this, a questionnaire survey involving 45 projects was conducted. Data were collected with the aid of structured questionnaires and analysed by percentages, means, *t*-tests and Spearman's correlation tests. The results indicated that increased mechanisation leads to increased rates of accident and injury and that the level of mechanisation varies from one operation to another. The study concludes that mechanisation can worsen the OHS performance of the industry when it is not effectively managed. The findings suggest that stakeholders should put effective measures in place aimed at controlling OHS performance before using new or additional P&E. They also suggest that stakeholders of specific contractors should provide more attention when setting up an OHS management plan, particularly a hazard management plan regarding the on-site use of P&E.

Keywords: Concreting, Excavation, Mechanisation and OHS performance

INTRODUCTION

The importance of the use of plant and equipment in construction works appears to be increasing on a daily basis. Manual methods are rapidly giving way to mechanical methods in the effort to increase productivity, meet increasingly 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 tight schedules and targets placed by clients' demands, implement control measures required to bring projects on track and ensure effective and efficient use of the numerous resources involved in the construction of projects. New plant and equipment are being developed and produced regularly in response to the needs of the industry. Seeley (1996) asserts that the increased mechanisation of construction work can speed up construction and reduce overall costs. Recognizing the important role that plant and

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equipment play in achieving project objectives, clients are placing even greater emphasis on the use of plant and equipment by identifying plant and equipment ownership of prospective contractors as a major criterion for awarding contracts. In response, contractors often embark on efforts to own construction plant and equipment in order to compete favourably with their counterparts during tendering. Furthermore, contractors also stipulate mechanised methods in their production method statements during tendering and are bound to implement those methods when executing a contract.

Mechanisation is associated with hazards because the use of plant and equipment is prone to accidents and injuries. Studies have confirmed that the construction industry is one of the most hazardous in the world (Kartam, 1997; Carter and Smith, 2000; Whitelaw, 2001). In most countries, the rates of accident and injury in the construction industry are higher than those in other industries. For developed countries, Loushine et al. (2003) found that the United States (US) construction industry accounts for more than 22% of all occupational fatalities in the US even though it employs less than 7% of the country's workforce. Health and Safety Executive (HSE) (2009a) reported that Britain's construction industry, which is one of the largest industries and provides employment for 2.2 million people, is also one of the most dangerous, recording more than 2,800 deaths from injuries received on the job in the last 25 years. The situation in developing countries is the worst among the nations of the world; studies have found that accident and injury rates in many developing countries, such as Nigeria (Idoro, 2004; 2007), Thailand (International Labour Organisation, 2005) and Tanzania, are considerably higher than those in European countries. Mbuya and Lema (1996) believe that in most developing countries, safety considerations in construction project delivery are not prioritised, and following safety measures during construction is considered a burden. Enshassi et al. (2008) also found that, in many developing countries, the legislation governing Occupational Health and Safety (OHS) is significantly limited when compared with that in the UK. These authors further report that rarely any special provisions are provided for construction workers' safety, and the general conditions for workers are often not addressed. Previously, Lee and Halpin (2003) found that in many countries that have safety legislation, the regulatory authority is weak or non-existent, and employers support regulations only superficially. Koehn et al. (1995) further found that injuries are often not reported in many developing countries, and the employer provides only some form of cash compensation for an employee injury. This action has several implications for the construction industries in developing countries. Rowlinson (2003) observed that the cost of accidents accounts for 8.5% of the total tender price in the Chinese construction industry, and the Nigerian construction industry exhibited nearly all of the same characteristics found in developing countries. The construction industry has no legislation governing OHS or regulatory authority on OHS. Consequently, accidents and injuries are not reported, and OHS is disregarded or ignored by clients, consultants and contractors. The result is high rates of accidents and injuries (Idoro, 2007; 2008).

Although an increased level of mechanisation of construction works is a positive development for the construction industry, the phenomenon must be accompanied by further measures directed at controlling any associated hazards. Therefore, the evaluation of contractors' efforts towards mechanisation and the effect of the efforts on Occupational Health and Safety (OHS) performance in the Nigerian construction industry is prompted. The study specifically examines the levels of mechanisation achieved in excavation and concrete works and the influence on OHS performance. The aim of this study is to determine whether growing efforts towards mechanisation will have any influence on the already poor OHS situation in the Nigerian construction industry. The objective is to determine the levels of mechanisation adopted in selected construction operations and the correlation of mechanisation with OHS performance. Therefore, two hypotheses were postulated. The first hypothesis states that the level of mechanisation in concrete works is not significantly different from the level of mechanisation in excavation works. The hypothesis was postulated to discover whether or not the level of mechanisation in one operation has any influence on the level of mechanisation in another operation. The second hypothesis states that the level of mechanisation has no significant correlation with the OHS performance of contractors. The hypothesis was proposed to determine whether or not the application of plant and equipment in construction works has any influence on OHS performance.

Variables and a Conceptual Framework for the Study

A number of variables were selected to achieve the objectives of this study. These variables were categorised into two groups: mechanisation and OHS performance. The level of use of plant and equipment in the two most common construction operations in a project, namely, excavation and concrete works, were selected as the variables of mechanisation, and the activities that constitute each of the two operations were regarded as subvariables of mechanisation. For the study, four activities involved in excavation works were categorised as topsoil excavation, excavation to reduced levels, trench excavation and removal of excavated materials. Six activities involved in concrete works were categorised as loading of concrete materials, batching of concrete materials, mixing of concrete materials, transportation of concrete, casting of concrete and curing of concrete. For this study, we chose four variables of OHS performance: rates of accident, injury, accident per worker and injury per worker rate.

The efforts to reduce the hazards associated with mechanisation are reflected in the accident and injury rates of the industry. Increasing rates of accidents and injuries to workers with an increased level of mechanisation implies a lack of efforts aimed at controlling the hazards caused by mechanisation, whereas decreasing rates of accidents and injuries with an increased level of mechanisation implies that contractors have taken measures to control the hazards caused by mechanisation. Incorrect use of plant, use of defective plant and careless acts by plant operators are not uncommon on construction sites and can result in accidents, thereby increasing accident and injury rates. This would indicate that there is a relationship between OHS performance and the level of mechanisation. This relationship is presented in the conceptual framework developed for the study. The framework (Figure 1) shows that the variables of OHS performance are related to those of mechanisation. The relationship expressed in Figure 1 shows that the parameters of mechanisation will influence the parameters of OHS performance. In the relationship, the parameters of mechanisation are independent variables, whereas those of OHS performance are dependent variables.

Previous Studies

Mechanisation has several utilities when applied to manufacturing processes, as it does when applied to construction processes. Idoro (2008) describes mechanisation as the process of applying the use of plant and equipment in carrying out a task. He further states that the level of mechanisation can be explained in two ways: the number of plant and equipment employed or the number of activities performed by plant and equipment in an operation. The latter explanation is

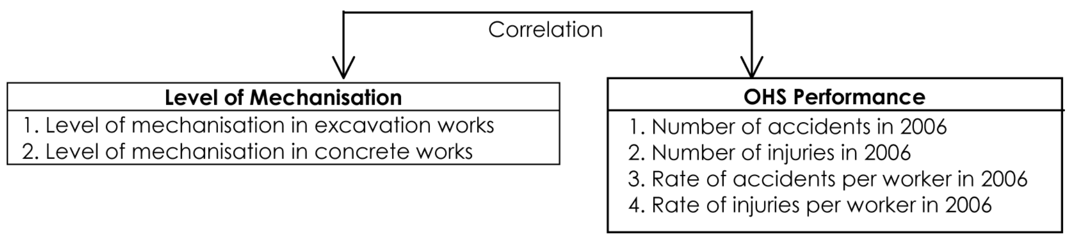

Figure 1. Conceptual Framework of the Correlation between the Level of Mechanisation and OHS Performance

adopted for this study because construction operations involve a number of tasks or activities that can be carried out either manually or mechanically. By nature, some tasks can be performed only manually, some using a combination of manual and mechanical efforts and others can be fully performed only using both plant and equipment. Scholars claim that the use of plant and equipment in a construction operation has numerous advantages. Seeley (1996) acknowledged that increased mechanisation of building operations speeds up production and reduces construction costs. Akinsola and Adenuga (2004) observed that industrialisation brought about modern plant and equipment, which increased productivity and efficiency and, consequently, reduced costs. Fisk (1997) argued that the careful investigation of construction methods was one way to improve the overall cost of projects. Koskela and Bellard (2003) identified mechanisation as one of the most important attributes of manufacturing and claimed that mechanisation makes the manufacturing industry more efficient and productive than the construction industry.

Despite the numerous advantages gained from the use of plant and equipment in the production of construction products, mechanisation also has several disadvantages. These disadvantages include the hazards associated with increased mechanisation and major concerns about the impact of mechanisation on OHS. Increased mechanisation can lead to increased numbers and severity of accidents and injuries, which will have adverse effects on OHS in construction sites. The opinion, however, is divided on the impact of mechanisation on OHS performance. A study by HSE (2006) evaluated the causes of accidents and injuries in the Scottish construction industry and compared the OHS performance of the country's construction industry with that of the rest of Great Britain (GB). The study found that, for the period of 1996/97–2000/01, Scottish bricklayers suffered 835 fatal and major injuries per 100,000 workers compared to 552 injuries reported in the rest of GB. Scottish plumbers and heating engineers suffered 262 fatal and major injuries per 100,000 workers compared to 176 injuries in the rest of GB. Finally, Scottish steel workers suffered 2,106 fatal and major injuries per 100,000 workers compared to 1,252 injuries in the rest of GB. Based on these findings, the report stated that the overall accident and injury rates were higher in Scotland than in the rest of GB because there are proportionally more manual workers in the Scottish construction industry than in the rest of GB. In other words, the report attributes the higher accident and injury rates of the Scottish construction industry to a greater dependence on manual methods of construction than in the rest of GB. However, the same study found that, for the period of 1996/97–2000/01, Scottish roofers, tillers and cladders suffered 663 fatal and major injuries per 100,000 workers compared to 1,004 injuries in the rest of GB. Scottish plant operators suffered 160 fatal and major injuries per 100,000 workers compared to 268 injuries in the rest of GB. Finally, Scottish forklift operators suffered 312 fatal and major injuries per 100,000 workers compared to 616 injuries in the rest of GB. These findings indicate that the Scottish construction industry (with a greater percentage of manual workers) indeed has higher accident and injury rates in some trades and lower rates in other trades than the rest of GB, where mechanisation is higher. It is also important to note that the Scottish construction industry (with a higher rate of manual workers) recorded a lower injury rate than the rest of GB, even when the rest of GB had a lower manual employment rate (jobs with more mechanically-oriented works such as roofers, cladders, plant and forklift operators). The findings of the study suggest that the rate of manual or mechanical employment may not actually be responsible for the differences in accident and injury rates between Scotland and the rest of GB. This may explain why the study concludes that the differences in accident and injury rates between Scotland and the rest of GB could emerge from other factors, such as types of construction work, client profiles, physical environment and personal characteristics.

In a related study, Enshassi et al. (2008) identified complexity or difficulty caused by problematic site conditions, workers' awareness of required work tasks and the associated hazards, the need to speed up work to complete a project on time, bad weather and type of owner or employer as some of the factors that affect accident and injury rates in every construction industry. Two other studies (Sawacha et al., 1999; Abdelhamid and Everett, 2000) found that accidents at work occur because of either unsafe working conditions or unsafe workers' acts, and both studies agree that the latter is the most significant cause of accidents at construction sites. Aksorn and Hadikusumo (2007) identified some of these unsafe acts as working at improper speeds or faster than normal speeds; improper lifting, handling and moving of objects; incorrect use of tools and equipment; use of defective equipment and tools; and refusal to wear Personal Protective Equipment (PPE) at work. The condition of plant and equipment used can also influence accident and injury rates. The use of second-hand plant and equipment, which are predominantly used in developing countries such as Nigeria, are also associated with higher rates of accidents and injuries than use of new plant and equipment, which are predominantly used in more developed countries.

The findings of the studies reviewed above suggest that mechanisation indeed has an impact on OHS. A report of the immediate causes of accidents in Britain (HSE, 2009b) showed that four of nine routine violations related to the use of plant and equipment were identified as the immediate causes of fatal accidents and injuries on construction sites. Namely, the driver of a HINB (lorry-mounted crane with hydraulic articulated boom) operated the lift in an unsafe manner, a heavy goods vehicle reversed without a banksman, the operator did not use the company-supplied crane equipment and the operator did not wear a lap belt on a dumper. Five situational violations that caused accidents and fatal injuries on sites were also related to plant and equipment use. Namely, the operator proceeded with a crane hire lift despite the absence of a competent plan; an attempt was made to swap lift car support straps while under a load; a 5-minute repair was made in an unsafe manner at a height (level) above ground; inappropriate support was used for an equipment lift; and a dumper was driven on a spoil heap without a lap belt. These findings show that the use of plant and equipment affects the rates of accident and injury on construction sites.

The importance of measuring the safety performance of an organisation cannot be over-emphasised. Dingsdag et al. (2008) stated that, based on workers' compensation claims and incidents of injury and illness, there is a clearly demonstrable need to evaluate safety performance on construction sites to improve the performance of the industry. Safety performance describes the OHS status of the construction work environment. The methods used by researchers to evaluate OHS performance can be classified into two categories: negative performance or lag indicators and Positive Performance (lead) Indicators (PPIs). Negative performance indicators are otherwise regarded as traditional "outcome" safety performance indicators, Lead Time Indicators (LTIs) or lag indicators. Dindsdag et al. describe lag indicators as negative indicators because they are associated with measuring negative performances or failures such as Least Time Injury Frequency Rates (LTIFRs), the number and frequency of injuries sustained in an organisation per year, which was obtained by dividing the number of injuries by one million hours worked per year. These authors acknowledged that lag indicators should be the foremost, reliable, comparable, standardised and objective measures and the parameters recognised by OHS regulations for evaluating safety performance in all industries and countries. However, the authors also observed that lag indicators have been recently condemned because they measure only failures and do not have the capacity to improve OHS performance.

PPIs or lead factors, which were developed in reaction to the perceived inability of lag factors to measure success, are concerned with the evaluation of the safety culture of an organisation. These factors focus on organisation and work processes and structures that can influence OHS performance. According to Sweeney (1994), the processes PPIs measure include the effectiveness of training programmes, OHS structures, OHS representatives and return-to-work rate. Researchers acknowledge that PPIs have the capacity to improve OHS but also criticise them for several shortcomings related to their development and implementation. Most notably, there is an inability to develop reliable national and international standards for PPIs or any other lead factors (Blewett, 1994; Shaw, 1994; Dingsdag et al., 2008). PPIs rely on qualitative measures (Costigan and Gardner, 2000; Choudhry et al., 2007), do not reflect actual success in preventing injury or disease, are difficult to adopt for benchmarking or comparative purposes and are time-consuming to collect and collate. In addition, PPIs may be subject to random variation, may encourage under- or overreporting and measure only the number of events without providing any indication of degree of effectiveness for each measured event. Finally, the relationship between PPIs and LTIs is arbitrary (Dingsdag et al., 2008).

The parameters for measuring OHS performance in the construction industry can also be classified into two categories: objective measurements, which are primarily concerned with accidents and injuries, and subjective measurements, which are based on stakeholders' perception of the OHS status of the work environment. The most common evaluations of OHS performance used by researchers are the objective measurements of rates of accidents and injuries (HSS, 2001; 2003; Bhutto et al., 2004; Kartam, 1997; OSHA, 1999; Koehn et al., 2000; HSE, 2002; Carrigan, 2005). These measurements can be described as mandatory measures, as emphasised in some OHS regulations such as the Factory Act, which stipulates that such cases should be reported. Indeed, the rates of accidents and injuries are the most common measures of OHS performance because they indicate the level of safety on a site. However, researchers have criticised these measures and have recommended a more subjective approach. Trethewy et al. (2000) and Mohammed (2003) both stated that measures based on rates of accidents and injuries suffer from three drawbacks: (a) they measure what happens after an event and are reactive in terms of management response; (b) in the absence of any proactive measure, causal relationships cannot be established; (c) and they are negative in nature and are acknowledged as being unsuccessful measures of safety performance. In view of these drawbacks, Marosszeky et al. (2004) suggested a shift of focus towards detailed management-oriented measurements that have the potential to influence the processes of the project being assessed. A few of these management-oriented measurements include the subjective performance rating used by Jasekris (1996); the Site Safety Meter based on traditional site inspection developed by Trethewy et al. (2000); and access to heights, housekeeping and personal protective equipment used by Marsh et al. (1995).

RESEARCH METHODS

The study adopted a questionnaire survey approach to achieve its objectives. First, a field survey was conducted, for which 80 on-going construction projects were identified through a preliminary survey to serve as the study population frame. From this population, a random sample of 45 projects was selected for the study.

The activities or tasks were identified that constituted the two operations (excavation and concrete works), which were used as subvariables of mechanisation, as stated above. Respondents were asked to indicate the construction method (manual or mechanical) used to carry out each activity or task. Data were also collected on the number of accidents and injuries recorded and the number of workers employed in the selected projects' sites in 2006. Regarding the number of accidents and injuries, respondents were asked to state the number of accidents and injuries reported by site workers to the site manager for which workers were either given medical treatment or excused from duty in 2006. Accidents that did not involve a worker receiving medical treatment within or outside a site or granting permission to a worker to stay away from work were excluded because they were usually not reported, and therefore data would be inaccurate. Regarding the number of workers employed on a site in 2006, respondents were asked to state the number of workers on the monthly payroll of the project site for the months in 2006 when the project was in progress. The number of workers on the site in 2006 was derived as the total number of workers on the payroll for the months a project was in progress divided by the number of the months. This approach to data collection was adopted because the study was conducted in Nigeria, a country that does not fall under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995 (HSE, 2007), which requires construction workplace accidents to be reported. The data were collected using structured questionnaires which were administered to site managers of the projects sampled and collected by hand.

The levels of mechanisation and the manual effort required for each activity in the two operations selected (subvariables of mechanisation) were calculated as the percentage of respondents who use either a mechanical method or a manual method to perform an activity. The level of mechanisation of an operation was derived as the ratio of the number of activities performed by a mechanical method to the total number of activities in the operation. The data collected were further analysed to determine the ranking and to test differences in the levels of mechanisation of the two operations using percentages, means and *t*-tests.

The OHS performance of the respondents was derived by dividing the number of accidents and injuries recorded in 2006 by the number of workers employed. The correlation between the respondents' efforts towards mechanisation and their efforts on OHS performance was determined using Spearman's correlation.

RESULTS

The results of the analysis of data collected are presented below.

Level of Mechanisation of Activities in Excavation Operations

The level of mechanisation of activities in excavation operations was derived as described in the research methods. The data on the mechanisation of the activities in excavation works were analysed to determine the ranking of the levels of manual and mechanical methods using percentages. The results are presented in Table 1.

Table 1 reveals that the manual method ranks first in both excavation to reduced levels (73%) and removal of excavated materials (67%) and second in topsoil excavation (40%) and trench excavation (33%). The mechanical method ranks first in topsoil excavation (60%) and trench excavation (67%) and second in both excavation to reduced levels (27%) and removal of excavated materials (33%). The results indicated that contractors preferred a manual method to a mechanical method for excavation to foundation and removal of excavated materials. However, they preferred to use mechanical plants for surface excavation and very deep excavation.

Table 1. Ranking of the Level of Use of Manual and Mechanical Methods in Excavation Works among Selected Nigerian Contractors

Excavation activities	N	%	Rank	Excavation activities	N	%	Rank
Topsoil excavation				Trench excavation			
Mechanical	27	60	1	Mechanical	30	67	1
Manual	18	40	2	Manual	15	33	2
Total	45	100		Total	45	100	
Excavation to reduced level				Removal of excavated materials			
Manual	33	73	1	Manual	30	67	1
Mechanical	12	27	2	Mechanical	15	33	2
Total	45	100		Total	45	100	

N = Number of respondents

Level of Mechanisation of Activities in Concrete Operations

The data on the levels of mechanisation and manual effort in activities that constitute concrete operation were analysed to determine the ranking of the level of the methods used (in percentages). The results are presented in Table 2.

Table 2 reveals that the manual method ranks first in batching of concrete (73%), mixing of concrete (73%) and transporting of concrete (67%) and second in loading of materials (40%), casting of concrete (31%) and curing of concrete (13%). The mechanical method ranks first in loading of materials (60%), casting of concrete (69%) and curing of concrete (87%) and second in batching of materials (27%), mixing of concrete (27%) and transporting of concrete (33%). These results

Table 2. Ranking of the Level of Use of Manual and Mechanical Methods in Concrete Works among Selected Nigerian Contractors

Excavation activities	N	%	Rank	Excavation activities	N	%	Rank
Loading of materials				Transporting of concrete			
Mechanical	27	60	1	Mechanical	30	67	1
Manual	18	40	2	Manual	15	33	2
Total	45	100		Total	45	100	
Batching of materials				Casting of concrete			
Manual	33	73	1	Manual	31	69	1
Mechanical	12	27	2	Mechanical	14	31	2
Total	45	100		Total	45	100	
Mixing of concrete				Curing of concrete			
Manual	33	73	1	Manual	39	87	1
Mechanical	12	27	2	Mechanical	6	13	2
Total	45	100		Total	45	100	

N = Number of respondents

indicate that contractors preferred manual methods to mechanical methods for batching, mixing, transporting and casting of concrete but preferred mechanical methods for transportation of materials to the mixing point and loading of materials for mixing and curing of concrete.

Level of Mechanisation of Excavation and Concrete Works

Apart from the level of mechanisation achieved in the subvariables of mechanisation, the study attempted to evaluate and compare the level of mechanisation achieved in the two operations selected. The levels of mechanisation of excavation and concreting operations by each respondent were calculated as described in the Research Methods. The data collected on the level of mechanisation adopted by the respondents were analysed to determine the ranking of the mean level of mechanisation of the two operations. The mean level of mechanisation of each operation was calculated as the average of the ratios of the number of activities performed by mechanical method to the total number of activities in the operation of all respondents. The results are presented in Table 3.

Table 2 shows that the level of mechanisation adopted by the respondents for concrete works ($\overline{X}$=0.57) ranks first and that for excavation works ($\overline{X}$=0.47) ranks second. This finding indicates that the level of use of plant and equipment for construction works by the respondents is higher in concrete operations than in excavation operations.

Table 3. Ranking of the Levels of Mechanisation Adopted by Selected Contractors in Nigeria in Excavation and Concrete Works

Variable	**N**	**Mean**	**Rank**	***t*-value**	**Df**	***p*-value**	**Decision**
Concrete works	45	0.5713	1	5.268***	44	0.001	Reject
Excavation works	45	0.4667	2				

***Difference is significant at $p \leq 0.01$, N = Number of respondents, Mean = Average ratio of the number of activities performed by a mechanical method by all respondents to the total number of activities in an operation, Df = Degree of freedom.

Test of Difference between the Levels of Mechanisation of Excavation and Concrete Works

Further investigation was conducted to ascertain whether the differences in the levels of mechanisation adopted by the respondents in excavation and concrete works are significant. This investigation involves a test of the first hypothesis of the study, which states that the level of mechanisation in concrete works is not significantly different from the level of mechanisation in excavation works. The hypothesis was tested using *t*-tests at $p \leq 0.05$. The rule for the acceptance or rejection of the hypothesis is that when $p > 0.05$, the hypothesis is accepted, but when $p \leq 0.05$, the hypothesis is rejected. The results of the test are presented in Table 3.

The results show that the p-value (0.001) for the test of difference in the levels of mechanisation between concrete and excavation works was less than the critical p-value (0.05); therefore, the hypothesis is rejected. The results also indicate that the level of mechanisation in concrete works was significantly higher than in excavation works in that the levels of mechanisation adopted by the respondents for the two operations differed significantly. The implication of these results is that the level of mechanisation adopted by contractors differs from one operation to another.

Correlation between the Level of Mechanisation and OHS Performance

The test of the second hypothesis of this study attempts to determine whether contractors complement their efforts towards mechanisation with increased efforts towards controlling the level of hazards. The hypothesis states that the level of mechanisation has no significant correlation with the OHS performance of contractors. The level of mechanisation and the OHS performance of the respondents were measured as explained above. The hypothesis was tested using Spearman's correlation test at $p \leq 0.05$. The rule for the acceptance or rejection of the hypothesis is that when $p > 0.05$, the hypothesis is accepted, but when $p \leq 0.05$, the hypothesis is rejected. All data are for 2006, and the results of the test are presented in Table 4.

Table 4 reveals that the p-values of the test of correlation between the level of mechanisation of excavation works and accidents per worker (0.911) and the level of mechanisation of concrete works and accidents per worker (0.400) are greater than the critical p-value (0.05); therefore, the hypothesis is accepted. The results show that the levels of mechanisation of both excavation and concrete works have no significant correlation with accidents per worker rate.

Table 4. Results of Spearman Test of Correlation between Mechanisation and OHS Performance

Variables Correlated	N	R	p-value	Decision	Correlation
Mechanisation of excavation works					
Accident rate	33	0.652	0.001	Reject	S
Injury rate	34	0.842	0.001	Reject	S
Accidents/worker rate	33	-0.020	0.911	Accept	NS
Injuries/worker rate	34	0.506	0.002	Reject	S
Mechanisation of excavation works					
Accident rate	33	0.546	0.001	Reject	S
Injury rate	34	0.619	0.001	Reject	S
Accidents/worker rate	33	0.152	0.400	Accept	NS
Injuries/worker rate	34	0.450	0.008	Reject	S

R = Correlation coefficient; N = Number of respondents, S = Significant, NS = Not significant

However, Table 4 also reveals that the p-values of the test of correlation between the levels of mechanisation of excavation works and accident rate (0.001), mechanisation of excavation works and injury rate (0.001) and mechanisation of excavation works and injuries per worker (0.002) are less than the critical p-value (0.05); therefore, the hypothesis is rejected. The results show that the level of mechanisation of excavation works is significantly correlated with rates of accident, injury and injuries per worker. In addition, Table 4 reveals that the p-values of the test of correlation between the levels of mechanisation of concrete works and accident rate (0.001), mechanisation of concrete works and injury rate (0.001) and mechanisation of concrete works and injury per worker (0.008) are less than the critical p-value (0.05); therefore, the hypothesis is rejected. The results show that the level of mechanisation of concrete works is significantly correlated with rates of accident, injury and injuries per worker.

DISCUSSION OF RESULTS

The study revealed that rates of accidents and injuries per worker are significantly correlated with the level of mechanisation. As contractors include new or additional plant and equipment in their production methods, the rates of occurrence of accidents and injuries tend to increase. The results of the study put the level of mechanisation in excavation and concrete works at 0.47 and 0.57, respectively. Thus, the levels of mechanisation in excavation and concrete operations are near the average levels. The findings imply that mechanical and manual methods are equally adopted in excavation and concrete works by the respondents. The level of mechanisation is, however, expected to increase in the near future because the awareness, emphasis and the need for mechanical plants are growing on a daily basis. Thus, the rates of accidents and injuries are expected to increase as the level of mechanisation increases. Although this study did not investigate possible reasons for this phenomenon, it is clearly related to the fact that the plant and equipment used by most contractors in Nigeria are second-hand and that the technology for the proper maintenance of plant and equipment is not available. The labour-intensive nature of construction is also a contributing factor.

The test of the first hypothesis of the study reveals that the level of mechanisation of concrete operations (0.57) is significantly higher than that of excavation operations (0.47). Because some construction operations attract the use of plant and equipment more than others, the levels of mechanisation will differ from one operation to another. This implies that the rates of accidents and injuries will also differ from one operation to another, with more mechanised operations being likely to record more accidents and injuries than less mechanised operations.

The levels of mechanisation of excavation and concrete operations show a significant correlation with rates of accident, injury and injuries per worker in 2006, indicating that the adoption of mechanical methods has a significant influence on OHS performance in Nigerian construction sites. The use of a plant does not ordinarily cause accidents; rather, accidents are caused by events such as breakdown of the plants and carelessness as well as inadequate skill on the part of plant operators, incorrect use of the plant and use of a defective plant. The implication is that these events or features are present in plants that are used for construction operations in Nigeria.

CONCLUSION

The study has established that the mechanisation of construction operations increases the occurrence of accidents and injuries to workers in the construction industry in Nigeria. The findings indicate that the drive by construction contractors in Nigeria towards adopting mechanised production methods is not complemented by efforts to control the hazards associated with mechanisation; therefore, mechanisation actually worsens the OHS performance of the industry. The study also reveals that the level of mechanisation varies from one operation to another, concluding that additional plant and equipment employed by contractors are likely to increase the rates of worker accidents and injuries in the industry.

Contractors and stakeholders in the construction industry in Nigeria should be aware that efforts to control the occurrence of accidents and injuries of workers on construction sites vary from one operation to another, with highly mechanised operations requiring more effort than less mechanised operations. Any efforts aimed at increasing the level of mechanisation of production methods, as beneficial and profitable as such approaches may be, demand greater efforts at preventing worker accidents and injuries. The finding that the levels of mechanisation of the two construction operations investigated impact OHS performance suggests that Nigerian contractors need to ensure that plant operators are well trained on safety and operation of the plant. Operators also need to ensure that the plant is in good condition and well maintained. On-site accidents occur because the real hazards are either not perceived or are thought to be less dangerous than they actually are. Before new or additional plant and equipment are used, contractors should ensure that an effective OHS management plan is in place that will identify proposed use of equipment, possible hazards associated with the equipment use and measures to control the hazards. Such safety plans should include hazard analyses in accordance with site conditions and the nature of the construction activities. The apparent benefits of a safety plan are derived from considering precautions before starting any activity and by analysing the hazards associated with each activity.

SUGGESTION FOR FURTHER RESEARCH

The study has established that mechanisation has an impact on some parameters of OHS performance in the construction industry. However, the study does not examine issues related to the control of OHS performance when adopting mechanised production methods. In view of the importance of mechanisation in the industry and the current efforts by contractors to use plants for construction operations, an investigation into the steps that contractors need to take in their drive to mechanise their production processes is suggested.

REFERENCES

Abdelhamid, T.S. and Everett, J.G. (2000). Identifying root cause of construction accidents. *Journal of Construction Engineering and Management,* 126(1): 52–60.

Akinsola, O.E. and Adenuga, O.A. (2004). Strategic maintenance practices as effective tool for improved productivity and efficiency of plants and equipment in construction industry. *Building Quarterly*, 3(1): 10–15.

Aksorn, T. and Hadikusumo, B.H.W. (2007). The unsafe acts and the decision-to-err factors of Thai construction workers. *Journal of Construction in Developing Countries,* 12(1): 1–25.

Bhutto, K., Griffith, A. and Stephenson, P. (2004). Evaluation of quality, health and safety and environment management systems and their implementation in contracting organisations. *Proceedings: International Construction Research Conference of the Royal Institute of Chartered Surveyors (COBRA 2004)*. Leeds Metropolitan University, Leeds, 7–8 September 2004. London: Royal Institution of Chartered Surveyors.

Blewett, V. (1994). Beyond lost time injuries: Positive performance indicators for OHS. Summary Paper. *Positive Performance Indicators: Beyond Lost Time Injuries: Part 1 Issues.* Australia: Worksafe Australia, National Occupational Health and Safety Commission, 1–85.

Carrigan, D. (2005). *Health and Safety: Home Pages.* [Online]. Available at: http//www.hse.gov.uk/publications/indg. [Accessed on 16 March 2006].

Carter, G. and Smith, S. (2000). IT tool for construction site safety management. *Proceedings: Construction IT in Africa Conference*. Available at: http://www.see.ed.ac.uk/IIE/research/ndtman/pubs/w78.pdf. [Accessed on 10 November 2011].

Choudhry, R., Fang, D.P. and Mohamed, S. (2007). The nature of safety culture: A survey of the state-of-the-art. *Safety Science* [Online], 45(10): 993–1012. Available at: http://www.elsevier.com/safetyscience. [Accessed on 10 November 2011].

Costigan, A. and Gardner, D. (2000). Measuring performance in OHS: An investigation into the use of positive performance indicators. *Journal of Construction Health and Safety – Australia New Zealand,* 16(1): 55–64.

Dingsdag, D., Biggs, H. and Cipolla, D. (2008). Safety effectiveness indicators (SEIs): Measuring construction industry safety performance. In Thomas, J. and Piekkala-Fletcher, A. (eds). *Proceedings: Third Conference of the Cooperative Research Centre (CRC) for Construction Innovation: Clients Driving Innovation: Benefiting from Innovation.* Australia: Cooperative Research Centre for Construction Innovation.

Enshassi, A., Choudhry, R.M., Mayer, P.E. and Shoman, Y. (2008). Safety performance of subcontractors in the Palestinian construction industry. *Journal of Construction in Developing Countries,* 13(1): 51–62.

Fisk, E.R. (1997). *Construction Project Administration*. 5th Edition. New Jersey: Prentice Hall.

Health and Safety Executive (HSE). (2002). *Health and Safety Executive.* [Online]. Available at: http://www.hse.gov.uk. [Accessed on February 2004].

_____. (2006). *An Analysis of the Significant Causes of Fatal and Major Injuries in Construction in Scotland.* Research Report 443, 1–256.

_____. (2007). *Managing Health and Safety in Construction (Design and Management) Regulations 2007 Approved Code of Practice,* 44.

_____. (2009a). *Health and Safety in Construction Industry*. [Online]. Available at: http://www.hse.gov.uk/construction/index. [Accessed on 23 November 2009].

_____. (2009b). *Phase 2 Report: Underlying Causes of Construction Fatal Accidents: Review and Sample Analysis of Recent Construction Fatal Accidents,* July 2009. [Online]. Available at: http://www.hse.gov.uk/construction/phase2 [Accessed on 23 November 2009].

Health and Safety Statistics (HSS). (2001). *Health and Safety Statistics 2000/01*. UK: Health and Safety Commission, National Statistics.

_____. (2003). *Health and Safety Statistics, Highlight 2002/03.* UK: Health and Safety Commission, National Statistics.

Idoro, G.I. (2004). The effect of globalization on safety in the construction industry in Nigeria. *Proceedings: International Symposium on Globalisation and Construction*. Asian Institute of Technology, Bangkok, Thailand, 17–19 November, 817–826.

_____. (2007). Contractors' characteristics and health and safety performance in the Nigerian construction industry. *Proceedings: CIB World Building Conference on Construction for Development*. Cape Town, South Africa, 14–18 May.

_____. (2008). Effect of mechanisation on project performance in the Nigerian construction industry. *Proceedings: Royal Institution of Chartered Surveyors Construction and Building and Research (COBRA) 2008 Conference*. Dublin, 4–5 September.

International Labour Organisation (ILO). (2005). *Thailand occupational safety and health in the construction industry*. [Online]. Available at: http://www.ilo.org/public/english/region/asro/bangkok/download/background/osh/conth05.pdf. [Accessed on 12 May 2006].

Jasekris, E. (1996). Strategies for achieving excellence in construction safety performance. *Construction Engineering & Management,* 122(1): 61–70.

Kartam, N.A. (1997). Integrating health and safety performance into construction CPM. *Construction Engineering and Management,* 123(2): 121–126.

Koehn, E., Kothari, R.K. and Pan, C. (1995). Safety in developing countries: Professional and bureaucratic. *Journal of Construction Engineering and Management,* 121(3): 261–265.

Koehn, E., Ahmed, S.A. & Jayanti, S. (2000). Variations in construction productivity: Developing countries. *AACE International Transactions,* 14A. Available at: http://elibrary.ru/item.asp?id=6017041. [Accessed 14 November 2011].

Koskela, L. and Bellard, G. (2003). What should we require from a production system in construction. *Proceedings: Construction Research Congress 2003: Winds of Change: Integration and Innovation of Construction*. In K. R. Molenaar and P. S. Chinowsky (eds). Honolulu, Hawai, USA, 19–21 March 2003.

Lee, S. and Halpin, D.W. (2003). Predictive tool for estimating accident risk. *Journal of Construction Engineering and Management,* 129(4): 431–436.

Loushine, T.W., Hoonakker, P., Carayon, P., Smith, M.J. and Kapp, E.A. (2003). Safety and quality management systems in construction. *Some Insight from Contractors*. [Online].

Available at: http://capi2.engr.wisc.edu/cprc/IJIE2003%20 P. [Accessed on 18 March 2006].

Marosszeky, M., Karim, K., Davis, S. and Naik, N. (2004). Lessons learnt in developing effective performance measures for construction safety management. *Proceedings: 12th International Group for Lean Construction (IGLC 2004) Conference on Lean Construction.* LO-School, Helsingor, Elsinore, Denmark, 3–5 August.

Marsh, T.W., Robertson, J.T., Duff, A.R., Phillips, R.A., Cooper, M.D. and Weyman, A. (1995). Improving safety behaviour using goal setting and feedback. *Leadership and Organisation Development Journal,* 16(1): 5–12.

Mbuya, E. and Lema, N.M. (1996). Towards development of a framework for integration of safety and quality management techniques in construction project delivery process. *International Journal of Quality,* 14(5): 1–15.

Mohammed, S. (2003). Scorecard approach to benchmarking organisational safety culture in construction. *Construction Engineering & Management,* 129(1): 80–88.

OSHA (Occupational Safety and Health Administration). (1999). *Construction News.* [Online]. Available at: http//www.osha.gov/publications/osha2202. [Accessed on 12 March 2006]

Rowlinson, S. (2003). *Hong Kong Construction Safety Management and the Law.* 2nd Edition. Hong Kong: Sweet and Maxwell.

Sawacha, E., Naoum, S. and Fong, S. (1999). Factors affecting safety performance on construction sites. *International Journal of Project Management,* 175(5): 309–315.

Seeley, L.H. (1996). *Building Economics*. 4th Edition. London: Macmillan Press Limited.

Shaw, A. (1994). OHS performance indicators for benchmarking: Stage 1. Report of the Worksafe Australian project to develop a benchmarking methodology for occupational health safety. *Positive Performance Indicators: Beyond Lost Time Injuries: Part 1 – Issues.* Canberra: Worksafe Australia, National Occupational Health and Safety Commission, 15–27.

Sweeney, S. (1994). Opportunities/strategies and tactics for going beyond lost time injuries. *Beyond Lost Time Injuries: Part 1- Issues.* Canberra: Worksafe Australia, National Health and Safety Commission (NOHSC), 34.

Trethewy, R., Cross, J., Marosszeky, M. and Gavin, I. (2000). Safety measurement: A positive approach towards best practice. *Journal of Occupational Health and Safety, Aust/NZ,* 16(3): 50–62.

Whitelaw, J. (2001). Safety: What do you think? *New Civil Engineer,* 11(January): 22–24.