

FACTORS INFLUENCING THE EFFECTIVENESS OF MAINTENANCE OF CONSTRUCTION EQUIPMENT

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ABSTRACT

The objective of this study was to establish the factors influencing the effectiveness of maintenance of Construction Equipment (CE). The methodology used included literature review, observation, interviews, and questionnaire. The established factors influencing the effectiveness of maintenance of CE include: wrong perception of users of the effect of maintenance on productivity and on effectiveness of the machine; failure of the owners and users to comprehend the importance of outsourcing maintenance, which denies the companies the opportunity of using specialised expertise of OEM personnel trained in maintenance given that the companies have maintenance personnel with a low level of skills. Therefore to improve the effectiveness of maintenance of CE it is recommended that the mindset of the owners and maintainers of CE be changed through training regarding the effect of maintenance on productivity and effectiveness of CE and that the maintainers are given the ability to understand the OEM recommendations.

Keywords: *effectiveness of maintenance, construction equipment, maintainability, availability, productivity.*

INTRODUCTION

Road transportation in Tanzania is characterised by high cost and low quality services due to the backlog of infrastructure maintenance and rehabilitation of the road network and equipment, inadequate institutional arrangements, inadequate capacity caused by the low level of investment in resources, and the lack of enforcement of safety standards and environmental sustainability (Malongo, 2004).

The high frequency of equipment failures at road construction sites, accompanied by low productivity, high maintenance costs and the shortened useful life of the CE raises concern over the effectiveness of the CE maintenance practice (Malongo,

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2004; TRA, 2004). The CE problem is detrimental to the development of the national economy and the construction industry. The lack of good reliable equipment causes the business volume of local contractors to be small, leading to their failure to meet contract time schedules. It also means that they deliver sub-standard work, which makes them less competitive in the construction industry market (Malongo, 2004; TRA, 2004).

The construction industry in Tanzania plays a significant role in socio-economic development, consuming approximately 50% of the annual national development budget (Mlinga, 2006). Its contribution to the national economy is 5.5% out of the total growth rate of 6.7% (Balozi, 2006). Therefore, the issue of CE maintenance needs to be looked at keenly in terms of ensuring the availability of enough reliable equipment. The CE need is evidenced by the fact that the majority of local contractors have basic equipment only, which invariably is inadequate for carrying out most of the projects. The problem is compounded by the fact that there are no reliable leasing companies from which to could hire equipment. The equipment is now a source of loss instead of profit (Ngibwa & Baitan, 2004). The rate of construction work progress, the quality of the work and the profit margin of a contractor greatly depend on the condition and serviceability of the plant and equipment used. Observations have shown that, while there is a lack of CE, the mechanical condition of that which is available is poor as a result of poor maintenance. The use of inexperienced and poorly paid CE operators and mechanics contributes largely to the poor repair or maintenance of such equipment and the inappropriate use of such equipment¹.

The failure of local contractors to meet their contract time schedules could be the result of a reduction in the number of useful hours of the machine brought about by the failure of hire firms to supply equipment capable of giving good performance at the right time. Faulty and poorly maintained equipment results in lower productivity. The failure to optimally utilize the existing equipment is caused by the poor selection of the CE, poor management of equipment use (poor project management); and poor equipment maintenance (Rweyemamu, 2006). To maximise the return on equipment investment, a gradual increase in the rate of equipment availability and utilisation is needed. Bamber *et al*, (1999) commented that effective maintenance can significantly contribute to improving production through value addition.

Therefore, the main objective of this research work was to establish the factors influencing the effectiveness of maintenance of CE. Specifically, the study assessed the perception of CE users concerning the contribution of maintenance to the productivity and effectiveness of CE, as well as their perception of the importance of outsourcing CE maintenance. Furthermore, the authors sought to establish other operational factors that affect the effectiveness of the maintenance of CE.

THEORETICAL BACKGROUND

The price of CE is steadily rising due to the high-level technology incorporated into the machines. The huge investment in CE ought to be rewarded by a high rate of return on the equipment. To drive up the rate of return it is necessary to exploit the full potential of the equipment, to reduce costs, improve production performance and increase profitabilityⁱⁱ. This is done by increasing the rate of equipment availability and utilisation through its proper selection, use, disposal and maintenance (Duffuaa, *et al.*, 1999; Gransberg, *et al.*, 2006).

Maintenance refers to the coordinated integration of the operations, maintenance, engineering support, training, and administrative areas of any process in order to increase the efficiency, reliability and safety of the processⁱⁱⁱ. Maintenance is triggered by a number of factors, such equipment failure or planned preventive maintenance or just the condition of the equipment and is meant to keep the equipment in good working order. Equipment repair restores it or its components to a condition substantially equivalent to its originally intended and designed capacity, efficiency or capability. Maintenance of equipment has a strong impact on achieving a fully operational mode of the facility (Ling and Wang, 2008).

Maintenance management involves the planning and control of the maintenance activities of a plant or equipment. This would normally involve the management of maintenance stores (Wireman, 1990). Productivity, Safety, Cost, Quality and Timeliness of the equipment are the focus of a quality assured maintenance management (QAMM) programme, which incorporates scheduling, procedures and work/systems control (Banga & Sharma, 1983).

Productivity of the CE is defined as equipment efficiency or the ratio of equipment output (capacity and availability of CE) per unit of equipment maintenance input (resources investment) over time^{iv}. Productivity is a performance metric and is greatly influenced by factors beyond the equipment itself, including operator actions, material availability, scheduling requirements and maintenance practice. Maintenance restores or maintains the CE installed capacity, which thus affects availability, assuming there is proper utilisation of the equipment. Effective application of this productivity requires that equipment performance is tracked

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using the metrics for equipment reliability, availability and maintainability (Blanchard, *et al.*, 1995).

Logistics support refers to the provision of a maintenance planning framework for the management of the material, service, information and capital flows that are required. It includes the increasingly complex information, communication and control systems required in today's maintenance environment^v. The logistic support framework will include support and test equipment that ought to be identified, acquired, used and supported by management actions, procedures, techniques and support items from the acquisition stage and use to the disposal stage of the equipment (Gransberg, *et al.*, 2006).

With scarce logistical support, productivity can be enhanced by: (i) using Predictive Testing & Inspection (PT&I) technology with remote sensing of equipment status replacing periodic and on-site manual inspection (PM); (ii) Increasing PM crew capabilities to reduce the number of separate crews required; (iii) Replacing PM schedules with PT&I schedules; and (iv) Process improvement/Re-engineering (Gransberg, *et al.*, 2006). An optimum combination of PM, Condition Based Maintenance (CBM) and Breakdown Maintenance (BM) will ultimately provide reliable equipment at the right time by controlling the availability and performance of maintenance variables like personnel, the work process, materials, spare parts, tools, information and their logistics support^{vi}.

CE, besides being expensive, has to work in rough conditions. Since the timely and economical completion of a work depends on the satisfactory performance of the equipment, then the need for proper maintenance cannot be over-emphasized (Niebel, 1994). The direct CE maintenance costs are related to the cost of spare parts, labour, modifications, administration, downtime, training, and contracts. The indirect maintenance costs are related to the loss of capacity, the loss of markets and the loss of production as well as capital costs. Failure analysis helps to manage the operational costs through optimising the cost and frequency of maintenance (Edwards, *et al.* 2003; Blanchard, *et al.*, 1995).

Maintenance planning involves developing the maintenance concept during CE acquisition for achieving, restoring and maintaining the operational capability for the life of the CE based on the "Level of Repair Analysis (LORA)" or specific criteria. Maintenance planning defines the tasks, actions, techniques and support for attaining specific equipment readiness and work environment objectives (Blanchard, *et al.*, 1995).

Planning for quality maintenance of CE is difficult as it is normally carried out under pressure and at random workplaces and times. It is rendered harder by the complicated measurability and un-repetitiveness of the maintenance process

(Higgins, 1988; Tripathi, 2002). Maintenance planning, which commences with identifying maintenance needs, maintenance deficiencies, the work required, changing conditions, research, modification and evaluation activities, should be made clear to everyone involved. Detailed estimation and allocation of resources to various tasks must be done in reference to the OEM recommendations and the availability of resources^{vii}.

CE management is more and more about asset management, and whether the owner decides to build a team to keep maintenance operations in-house or turn maintenance and repair tasks over to their dealers, is a matter of reasonable costs, maximum equipment uptime, and reliability. The in-house team model can be thought to give the owner total control over all costs, allowing for custom-tailored procedures for specialized, one-of-a-kind equipment, and it works for companies that can handle their own field repairs. However, the team approach is labour-intensive and requires a commitment to ongoing training to keep technicians and support personnel up to date with new technologies and regulations in the industry. On the other hand, outsourcing CE maintenance to an OEM dealer provides fleets with OEM-trained technicians who are knowledgeable in the latest diagnostic and service procedures, which is much better for the owner (Krause, 2011).

Organising maintenance involves job design, setting time standards, work measurements and project management. Job design is a plan of the CE maintenance activity to be executed. The major objective of job design is to prepare a work programme that gives flexibility to the skilled workforce to work across functional borders when needed (Niebel & Freivalds, 2003; Duffuaa, *et al.* 1999).

By using maintenance performance level indicators and data analysis, the management can point out inefficiencies and ways to better execute maintenance requirements through performance reviews, employing alternative procedures and avoiding waste. These analyses should be based on personal observations of the work being performed, customer feedback, supervisor evaluation, and metrics evaluations^{viii}.

After going through the background information, the authors are able to come up with the following emerging issues that need attention:

- The huge investment in CE ought to be rewarded by a high rate of return on the equipment. To drive up the rate of return it is necessary to exploit the full potential of the equipment, to reduce costs, improve production performance and increase profitability. This could be effected through well planned maintenance;
- Maintenance of CE has a strong impact on achieving fully operational CE;

- Maintenance restores or maintains the CE installed capacity and thus affects availability of the CE (i.e. it affects the productivity of the CE);
- Productivity, Safety, Cost, Quality and Timeliness of the equipment are the focus of a QAMM programme;
- Outsourcing CE maintenance to an OEM dealer provides fleets with OEM-trained technicians who are knowledgeable in the latest diagnostic and service procedures, which is much better for the owner.

METHODOLOGY

The study began primarily with a literature review regarding maintenance of CE. The literature review pointed out a number of emerging issues that need to be addressed to fulfill the objectives of the research. After the literature review, the authors developed a procedure or method for gathering maintenance data from the field (construction sites, maintenance units, hire units and their allied organizations). The tools used were the structured interview and a questionnaire. Questions that focus on identifying the factors influencing the performance of CE maintenance were prepared in the form of a questionnaire and distributed to maintenance crew and operations crews and owners/contractors.

The study targeted contractors involved in public projects, which, according to Mhegi (2007), are estimated to number over 400 per annum. The population of the study was large enough to justify the use of sampling. Purposively sampling was used to sample only those contractors involved in public projects and the sample chosen represented people with a reasonably high degree of accuracy, precision and comprehensiveness. Data were collected from the three main groups of stakeholders in the CE maintenance context: the equipment users (contractors and “force accounts” units of Ministry of Works (MoW), TANROADS and PMO-RALG); the equipment maintenance units (both government and private) and the regulators (Contractors Registration Board – CRB, Engineers Registration Board – ERB and Association of Consulting Engineers Tanzania – ACET).

ANALYSIS AND INTERPRETATION OF THE FINDINGS

Profile of Respondents

The types of data collected from the three categories of respondents (i.e. the maintenance units, user units, and regulatory bodies) are shown in Table 1. The targeted respondents from the maintenance units numbered 40, five from each unit of the eight surveyed. The targeted respondents from equipment users units numbered 16, comprising an operator and a construction supervisor from each unit. Four regulatory units of the equipment maintenance unit were visited and all of them responded.

Table 1: Sample representation

Target	Method used	Number of Respondents who answered the questions on:				
		Influence on productivity	Logistics support	Equipment maintenance philosophy	Maintenance practice vs. OEM recommendations	Influence of working condition
Maintenance units (8)	Q	32	32	-	-	-
	I	-	-	34	32	30
User units (8)	Q	16	-	-	-	-
	I	-	-	-	-	16
Regulator units (4)	Q	-	-	-	-	4
Total		48	32	34	32	50

Key: Q = Questionnaire

I = Interview

Users' Perception of the influence of maintenance of CE on effectiveness and productivity of equipment

One of the factors that influence the effectiveness of maintenance is the perception of the users and owners of CE concerning the impact of maintenance of CE on its effectiveness and the productivity. Therefore, the author was interested in finding out the perception of the users and owners of the equipment of the contribution of maintenance to its effectiveness. Therefore, in the questionnaire the users were given a number of factors representing the effectiveness and productivity of CE and they were requested to rate the influence of maintenance of CE on those factors on a scale of 1 to 4. Table 2 presents the summary of the responses of the users, whereby in column 1 there is a list of equipment performance factors, and in the other columns are the ratings of the respondents on the strength of the influence of maintenance of CE on those factors in column 1. The overall mean rating was

2.5, which leads us to infer that the users consider that the influence of maintenance on effectiveness of the equipment is between low medium and medium, which implies that equipment maintenance does not have a strong impact on the effectiveness of the equipment. This is a wrong perception regarding the influence of maintenance on the effectiveness of the equipment. That is why one may find that maintenance of CE is not given due attention because the users have failed to appreciate its impact on the effectiveness of CE. Appreciating the impact of maintenance on the effectiveness of CE would cause the maintainers of CE to improve their standard of maintenance.

Table 2: Influence of maintenance on effectiveness of equipment

The influence of equipment maintenance on:	Users' rating on the strength of the Influence of maintenance of CE on Effectiveness of CE				Mean
	1	2	3	4	
Performance to attain the designed capacity	0	2	10	4	3.1
Simplicity of equipment operation	0	11	3	2	2.4
Flexibility of equipment use	3	10	2	1	2.0
Comfortability of equipment use	1	10	2	3	2.4
Quality of construction work delivered	0	2	10	4	3.1
Timely availability of equipment	4	8	2	2	2.1
Safety of equipment operation	1	4	9	2	2.8
Economy of equipment operation and maintenance	3	7	4	2	2.3
Maintenance of equipment records and reports	1	4	10	1	2.7
Mean of means					2.5

Key: 1= Low; 2: Below medium 3: Medium; 4: High

When the equipment users were asked to rate the effect of equipment maintenance on equipment productivity at their work sites using the Likert scale of 1 to 4 with 1 = Negative; 2 = Zero (i.e. No influence); 3 = Low positive and 4 = High positive, the results showed a mean rating of 2.6, which can be interpreted as low positive on the given scale. This means that the users are aware that equipment maintenance has an effect on its productivity, but it was not clear to what extent, which is why they believed it had a low positive influence. Again, this is a totally wrong perception of the influence of maintenance on productivity because productivity of CE depends on its efficiency or the ratio of equipment output (capacity and availability of CE) per unit of equipment maintenance input (resources investment) over time, with the availability of CE being a function of the level of maintenance performed on the facility. Therefore, the failure of the users to realise that maintenance has a major influence on the productivity of the equipment will cause

maintenance to be given low priority. This implies that fewer resources will be set aside for maintenance, with the result that there will be no effective maintenance.

Unplanned and unreliable maintenance consumes useful production time of the equipment. When asked about the average length of time in which the equipment is non-productive due to maintenance, the 16 equipment users differed but a mean time of 3.6 hours per day was arrived at. This is almost half of the production time in an 8 hour day. This implies that the equipment is available for 50% of the time only and the factor contributing the most was the maintenance dependent downtimes.

Users' Perception of the Importance of Outsourcing Maintenance of CE

An alternative way of improving the effectiveness of maintenance is to find people with specialised knowledge of maintenance of CE outside the company (i.e. outsourcing maintenance). Outsourcing to an OEM dealer provides the CE fleets with OEM-trained technicians who are knowledgeable in the latest diagnostic and service procedures, which is an attractive benefit for the owners of CE. The authors explored the extent of outsourcing of CE maintenance by the surveyed users of CE. The results show that the mean ratio of maintenance works executed by the maintenance unit crew to the outsourced work was 3:1. This means, therefore, that only about a quarter of the maintenance work of CE is outsourced. The next item was to compare the costs incurred by outsourcing as against equipment maintenance work done by its own maintenance crews. Based on the data collected, the mean ratio calculated was 2:1, which means that the cost of contracting out equipment maintenance work is about a third of the total equipment maintenance costs. But since only a quarter of the work was outsourced, it can be implied that the CE users do not see the importance of outsourcing maintenance work in order to use specialised expertise for the maintenance of the equipment and to improve the effectiveness of maintenance.

Personnel working capacity

The effectiveness of the maintenance of CE depends to a large extent on the skills of the personnel and qualification of the workers. To meet the challenges of more complicated machines, new data-collection technologies, new diagnostic tools, and the ever-changing technological environment there is a need for continuous improvement of the human resources through specialised training and on-the-job training programmes. The authors checked whether or not there are any skills upgrading programmes in the interviewed companies. It was found that 67% of the respondents did not have specialised training programmes in their organisations. However the majority of the organisations (60%) carried out on-the-job training.

To ensure that the CE maintenance crew makes full use of their skills and capacity, they need to be appreciated and motivated. As regards being shown appreciation for the work done by the maintenance crew, the majority of respondents (69%) indicated that their work is not appreciated. This de-motivates the maintenance crews, which may contribute to the poor quality of maintenance work. But 53% of the maintenance crew claimed that they are motivated whereas 47% of them claimed that they are not motivated.

Sufficiency of human resources takes into accounts both qualitative capacity (i.e. skills, qualifications and knowledge) and quantitative capacity (i.e. the number of staff in each category). Regarding the sufficiency of the manpower required it was revealed that 63% of the respondents had sufficient quantitative manpower but 67% of the respondents claimed that there is a lack of skilled and qualified personnel to carry out the different functions. The specific functions to be accomplished at each level of maintenance are to a great extent dictated by the task's complexity, personnel-skill-level requirements and the special needs of the facility. Therefore, if there is no training of maintenance personnel, it means that only a low level of skilled maintenance is being carried out on CE, which will reduce its effectiveness.

Availability of critical spare parts, tools and material

Failure to get the spare parts and material required for maintenance on time increases CE downtime. According to Agoos (2011), the companies that properly manage their spare parts are likely to be the ones that survive in the long run and the cost of spare parts for most CE is about 67% (i.e. two-thirds) of all repair costs. Therefore it is important to ensure that sufficient spare parts are available for maintenance to be effective. When asked about the availability of critical maintenance tools, only 19% of the respondents said that they have sufficient tools, whereas the majority (81%) claimed that there not enough tools to carry out maintenance efficiently.

The status of procurement and the storage of spare parts, tools and material are gauged by a number of variables, such as procurement time, availability of storage facilities, qualification of storekeepers, and the quality of inventory control. The mean time for procuring locally available spare parts was computed to be 1.2 hours. Getting supplies from abroad takes a minimum of three weeks. Scarcity of spare parts and lubricants was witnessed by 72% of the respondents. Scarcity of items is a function of management (inventory control) and external factors (financial and physical). Inventory control is an inescapable function of the management that seeks to improve the performance of their company. However, 53% of the respondents claimed that there is virtually no inventory control and ordering for the stores is carried out in reaction to immediate material requests.

Since there is virtually no inventory control of critical spare parts, tools and material, it means that a high level of maintenance of CE cannot be executed if the critical spare parts are not available. Therefore, the availability of critical spare parts is another factor that affects the maintenance of CE.

Communication and information

For a more effective maintenance practice, there has to be good communication between its maintainers and users. About 53% of the respondent personnel confirmed that communication is good between the two sides. Lack of good communication is caused by external factors (e.g. poor infrastructure) and the non-availability of logistics support for communication. Equipment has to be monitored constantly for its performance at construction sites so that the maintainers are immediately informed of any changes in performance, enabling them to carry out of timely remedial maintenance on the equipment. This is possible only if there is adequate communication between the operators and the maintenance crew.

Maintenance of equipment can be done scientifically by keeping records to serve as guidance for future maintenance measures. About 69% of the respondents confessed that no records are kept for maintenance done on the equipment. Keeping records is possible in situations where the management appreciates the need for historical data for carrying out maintenance properly. Carrying out maintenance without data on previous work on the equipment reduces the effectiveness of maintenance.

Features of the equipment and maintenance facilities

Under the features of the equipment, the elements surveyed were adequacy of logistics support given to maintenance, built-in features for safety, testing and training features and maintainability, and adequacy of handling facilities in operations like lifting. Adequate logistics support given to maintenance should ensure that it is carried out properly and efficiently. About 72% of the respondents said that there is inadequate logistics support for maintenance.

Well designed equipment design has built-in features for safety and testing. About 81% of the respondents commented that their equipment does not have safety features. Such equipment costs more because they are more delicate to operate. Most units do not have these facilities because of their poor financial base, their lack of appreciation for the value of these features and their inability to maintain delicate electronic systems.

Maintainability of the CE

Maintainability determines the easiness and effectiveness with which particular pieces of equipment can be maintained. About 69% of the respondents mentioned

that their equipment has high maintainability, which is largely determined by the proper choice or specification of the equipment at the time of purchase. Handling facilities in operations like lifting and transfer by loading are of paramount importance for facilitating the maintenance of heavy components. 59% of the respondents said that there are inadequate lifting facilities.

The most important and difficult stage of equipment maintenance is maintenance planning which is influenced by work requirements and the capacity to handle the work. The maintenance planning variables surveyed were the separation of equipment maintenance functions into quality, time and cost optimisation. 60% of the respondents confirmed that different maintenance functions are carried out together at the expense of quality. Failure to separate functions is caused by the inability of those involved in carrying out all the individual functions, due to the fact that few experts are recruited and those that do exist are badly managed in some of the units.

Identification of maintenance philosophy used in CE maintenance

The researchers interviewed 34 equipment maintenance personnel to find out the strategies employed by their units for maintenance. When asked about the criteria used for replacing components, 66% of the interviewees said that the components are often replaced after failure, 23% said the components are replaced when there is a sign of failure and 11% claimed that the replacement of components is based on Preventive Maintenance (PM) schedules. From these responses, it can be inferred that replacing components is not based on their obsolescence but on their failure. This practice is typical of the Breakdown Maintenance (BM) philosophy.

When asked about the missions of their organisations in regard to maintenance of CE, 34% of the interviewed maintainers said their mission is to generate profits, to maintain safety, and to increase the reliability and performance of the equipment. About 30% of them said that the mission is to provide a reliable service and ensure customer satisfaction, while 21% selected making a profit, and the safety and reliability of the equipment as the mission of their units and 15% described it as to make a profit and provide customer satisfaction only. Reliability of the equipment was mentioned by the majority of the interviewees, indicating the common focus of the missions of the maintenance units. However, reliability of the equipment can only be provided by the PM strategy.

Total Productive Maintenance (TPM) emphasises that operators and other stakeholders should be integrated in the maintenance process for the best maintenance output. As a precondition for TPM, operators should be qualified, skilled and competent enough to operate the equipment and carry out minor repairs. About 66% of the interviewees claimed that their operators are competent

at operating the equipment, have maintenance experience and are integrated in maintenance. Only 15% of those interviewed said that the operators are certified and 9% were of the view that the operators are qualified and competent to operate the equipment and know about its maintenance. About 11% said that their operators can only operate the equipment but are not qualified to repair it.

It is obvious that all maintenance units work for profit during maintenance of the equipment regardless of the maintenance philosophy or concept in use. The survey results reveal that the reliability and safety of equipment operation and maintenance are the main focus of the equipment maintenance units according to 62% of those interviewed. Only 23% of the interviewees said that their units focused on quick maintenance and timely availability of equipment. About 9% claimed that they focused on involving all stakeholders in equipment maintenance, while 7% said that their focus was on the reliability, safety and speed of maintenance and the timely availability of equipment.

Equipment maintenance versus OEM recommendations

Setting benchmarks for equipment maintenance is an essential step in ensuring its quality. The grounds on which benchmarks are set differ with the levels of maintenance to be reached and the philosophy being followed. Out of those interviewed 47% commented that experience and customer priorities are the grounds on which the benchmarks are set, 21% said that their benchmarks are based on Original Equipment Manufacturers (OEM) recommendations and 11% said that their benchmarks are based on the missions of their organisations. The remaining 21% said their benchmarks are based on experience, customer demands, missions and OEM recommendations. Therefore the OEM recommendations should as far as possible be strictly adhered to in order to maximise the benefits and to lengthen the life of these machines. About 66% of the interviewees agreed that the current equipment maintenance practice is not in line with OEM recommendations.

Analysing equipment failures determines the type, mode, cause and magnitude of failures. This should be done regularly so that the signs, trend and characteristics of the faults are noticed. The majority of those interviewed (72%) commented that such an analysis is not regularly conducted. Failure to do this is attributed to lack of knowledge and appreciation of the need for analysis, lack of tools and the expense involved. All fault analyses should be based on OEM recommendations. About 40% of those interviewed mentioned expert personnel observation as the basis for conducting a fault analysis. Only 22% of the interviewees said that analyses conducted were based on OEM manuals, metrics and instruments. 13% mentioned equipment maintenance records kept in files and databases as the guide

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for conducting fault analyses whereas 16% said that they employ customer feedback to analyse equipment faults.

Influence of working conditions on equipment maintenance

External factors, namely economic, technological, social and cultural, political and legal and physical conditions, as well as international laws /agreements constitute the working environment within which equipment maintenance is practised. The influence of these factors could be positive or negative depending on how they are applied.

As technology continues to advance, , keeping pace with it in terms of equipment maintenance is important for achieving the intended returns from the equipment, but this stands out as a challenge to developing countries like Tanzania which are all importers of technology products. When asked about how their maintenance units keep pace with technological changes in CE, about 83% of the interviewees said that their units are unable to keep pace on the grounds that their efforts are thwarted by the wide technological gap between them and the manufacturers. The lack of economic strength and a maintenance culture on the part of the maintenance stakeholders aggravate the problem. Regulators unanimously agreed that technological changes have a negative effect on equipment maintenance in Tanzania as most of the equipment maintainers are unable to keep pace with the advances in technology.

On the failure to meet equipment maintenance completion dates, several situations were cited by different interviewed maintenance personnel as the reasons for the failure. About 23% of the interviewees mentioned the unavailability of spare parts, tools, and necessary material as the reason for the failure while 10% of them attributed it to management, expertise and technology problems. About 7% mentioned economic constraints while 3% said that it was due to the lack of a maintenance culture.

The respondents were asked to rate the influence of external forces (social, cultural, physical and economic) on equipment maintenance using a Likert scale (with 1= highly negative; 2 = negative; 3= zero i.e. no influence; 4 = positive). The results show that the respondents gave a mean rating of 2.3 for the influence of social forces, which is interpreted as negative. The mean rating of 1.8 of the influence of cultural forces was given, which is interpreted as negative influence on the given scale. The mean rating of 2.8 was given for the influence of physical forces and is interpreted as no influence. Lastly, the mean rating of 2 given for the influence of economic forces on equipment maintenance and is interpreted as negative.

Good working conditions on sites play an important role keeping the equipment in a healthy condition. About 75% of the interviewed users were of the opinion that the equipment is not protected from the bad weather of the tropics. On security, 63% of the interviewees confirmed that the equipment is safeguarded. Another crucial factor that affects equipment maintenance negatively is its misuse in terms of overloading it, not using trucks to ferry it between distantly placed points, poor work paths for the equipment and using it in ways in which it was not designed to be used. About 31% of the interviewed users claimed that their units use low bed loader trucks to avoid damage through moving it manually.

Further, it was confessed by 62% of the interviewed users that the site maintenance crew are generally organised by construction staff, which are not properly qualified to do maintenance work on CE, which should therefore be discouraged. Success of equipment maintenance is a function of cooperation, commitment and support from both the users' side and the maintainers' side.

CONCLUSION

The main objective of this research was to establish the factors influencing the effectiveness of maintenance of CE. The results show that CE owners, users and maintainers have a wrong perception regarding the contribution of maintenance to the productivity of CE. They also have a wrong perception regarding the contribution of maintenance to the effectiveness of CE, and they do not see the importance of outsourcing the maintenance of CE. The findings show that the owners, users and maintainers of CE perceive that maintenance has only a minimal effect on productivity, which is why maintenance of CE is given such a low priority. The owners, users and the maintainers of CE also perceive that maintenance has little impact on the efficiency of CE, which again means that maintenance is given low priority and fewer resources. Furthermore, the users of CE do not see the importance of outsourcing maintenance work, which denies companies with relatively unskilled maintenance personnel; the opportunity of using the expertise of OEM trained personnel for maintenance.

Other factors affecting the effectiveness of the maintenance of CE include: the personnel-skill-level requirements for the maintenance work; availability of critical spare parts, tools and material; existence of records on maintenance done on the equipment; the amount of logistical support for maintenance; communication between the maintainers and users of the equipment; lack of built-in features for safety, testing and training in some of the equipment; and the working conditions within which equipment operates.

RECOMMENDATIONS

From the results of this study it is obvious that wrong perception of owners and users regarding the contribution of maintenance to the productivity and effectiveness of CE causes maintenance to be given a low priority. Likewise lack of knowledge regarding the outsourcing of specialised maintenance tasks also contributes to the low priority given to maintenance of CE. Another factor affecting the effectiveness of maintenance is ignorance of the principles of planned maintenance. Therefore, a special maintenance course is recommended for the owners and users of CE, which will clearly depict the relationship between the maintenance and productivity of CE, and also the relationship between maintenance and the effectiveness of CE.

REFERENCES

- Agoos, A. (2011), "Equipment Executive: Three Decisions for Parts Management", *Construction Equipment Magazine*, Vol. 115, No. 4 pp. 54-55.
- Balozi F. (2006), "Policy strategy and implementation aspects in creating an enabling Environment for the development of construction industry", Paper presented at the CRB Annual Consultative Meeting: - *An Enabling Environment for the development of a Vibrant, Efficient and Sustainable Construction Industry*; 15-16 June, 2006. Dar es Salaam, Tanzania
- Bamber, C.; Sharp, J., and Hides, M., (1999), "Factors affecting successful implementation of total productive maintenance", *Journal of Quality in Maintenance Engineering*, Vol.5 No.3, pp. 162-181
- Banga, T., and Sharma, S., (1983), *Industrial Organisation and Engineering Economics*, Khan Publishers, New Delhi
- Blanchard, B.; Verma, D., and Peterson, E., (1995), *Maintainability: A Key to Effective Serviceability and Maintenance Management*, Wiley-IEEE, New York
- Duffuaa, S.; Raouf, A.; and Campbell, J., (1999), *Planning and Control of Maintenance and Analysis*, John Wiley & Sons, Inc, New York
- Edwards, D.; Harris, F.; and McCaffer, R., (2003), *Management of Off-Highway Plant and Equipment*, Spon Press, UK
- Gransberg, D.; Popescu, C.; and Ryan, R. (2006), *Construction Equipment Management for Engineers, Estimators and Owners*, CRC Press, USA
- Higgins, L., (1988), *Introduction to the Theory and Practice of Maintenance: Maintenance Engineering Handbook, 4th Edition*, McGraw-Hill, Inc., New York.
- Krause, G. (2011), "The Management Challenge: In-House vs. Outsourced Maintenance", *Construction Equipment Magazine*, Vol. 115, No. 4, pp. 30 - 38.
- Lin, J. and Wang, C. (2008), "Exploring maintenance strategies in Chinese products manufacturing companies", *Management research news* Vol.13 No.12
- Malongo, J., (2004), "Performance of Contractors during 2003", *Proceedings of CRB Annual consultative meetings on Globalization: A challenge to the local contractors*, Vol. 2, No.3, pp. 12-25
- Mhegi, B.C. (2007), "An overview of the contractors Registration Board and The contracting industry achievements and Challenges" *Proceedings of the CRB Annual Consultative Meeting: 10 Years of CRB: Empowering Contractors to Meet the Challenges Ahead* 16-18 October, 2007- Dar es Salaam – Tanzania pp. 1-22.
- Mlinga, R.S. (2006), "Procurement aspects in creating an enabling environment for construction industry." *Proceedings of the CRB Annual Consultative Meeting: on An Enabling Environment for the development of a Vibrant, Efficient and Sustainable Construction Industry*; 15-16 June, 2006. Dar es Salaam, Tanzania pp. 78-87
- Ngibwa, C., and Baitan, D., (2004), "Capacity Building in Preparation for Globalization Competition", *Proceedings of CRB Annual consultative meetings on Globalization: A challenge to the local contractors*, Vol.2, No.4, pp. 165-177.

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- Niebel, B., and Freivalds, A., (2003), *Method Standards and Work Design*, McGraw Hill
- Niebel, W., (1994), *Engineering Maintenance Management*, Marcel Dekker, CRC Press.
- Rweyemamu, M.S. (2006), "Construction Plant & Equipment Availability: Problems & Challenges", *Proceedings of the CRB Annual Consultative Meeting: An Enabling Environment for the Development of a Vibrant, Efficient and Sustainable Construction Industry* 15 - 16 June, 2006 - Dar es Salaam – Tanzania pp 42-53
- TRA, (2004), "Tax Regime for Contractors", *Proceedings of CRB Annual consultative meetings on Globalization: A challenge to the local contractors*, Vol.2, No.5, pp.78-91
- Tripathi, P., (2002), *Personnel Management and Industrial Relations*, Sultan Chand and Sons, 23 Daryaganj, New Delhi
- Wireman, T., (1990), *World Class Maintenance Management*, Industrial Press Inc, UK

Web Resources

- ⁱ (<http://ntl.bts.gov/lib/> visited on 10/5/2010)
- ⁱⁱ (<http://www.iqpc.co.uk/binary-data/IQPC> visited on 11/11/2010)
- ⁱⁱⁱ ([http://www.plant-maintenance.com/article visited on 4/1/2010](http://www.plant-maintenance.com/article%20visited%20on%204/1/2010))
- ^{iv} (<http://webstore.ansi.org/ansidocsto> visited on 05/1/2010)
- ^v (<http://www.logisticworld.com> visited on 1/2/2010)
- ^{vi} (<http://www.logisticworld.com> visited on 1/2/2010)
- ^{vii} (<http://www.plant-maintenance.com/article> visited on 4/1/2010)
- ^{viii} (<http://www.open.ac.uk/foi-docs> visited on 31/1/2010)