International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 3Issue 4 ǁ April 2014 ǁ PP.34-41

Equipment Maintenance: An Effective Aspect Of Enhancing Construction Project Profitability

[1,]Tsado, Theophilus Yisa , [2,]Theophilus Yisa Tsado
[1,2,]Civil Engineering Department, School of Engineering and Engineering Technology, Federal University of Technology, P.M.B. 55, Minna, Niger State, Nigeria

ABSTRACT : *Construction equipment plays great significant role in construction industry, costs as high as 36% of the total construction project expense, however, the equipment maintenance has not been given appropriate attention and this contribute to about 40% of total construction project cost overrun. The objective of this research is to ensure that construction practitioners realize and adhere to proper equipment maintenance strategy as effective aspect of construction project profitability. The study appraised this objective through the use of Investigatory Survey Research Approach (ISRA) method. Five (5) different critical, but closely related integral strategies of effective construction equipment management were identified. A total number of sixty-five (65) well structured questionnaires were administered to eight different construction companies with identity of A, B, C, D, E, F, G and H to collect quantitative and qualitative data on how equipment maintenance has been handled in some randomly selected construction companies located in Abuja, Minna and their environs. The case study areas were selected because of their hub-heavy construction projects activities. Fifty-seven (57) which represents 87.7% of the total questionnaires were retrieved and analyzed. The data collected was subjected to frequency analysis method. The study revealed that 51.5% of the construction companies assessed do not attach high priority to equipment maintenance and this contributed greatly to construction project cost overrun resulting from equipment breakdown. Reliability of construction equipment greatly depends on the maintenance. It is recommended that construction practitioners afford the opportunity of equipment maintenance strategy as part of construction project management. This will help reduce expenses, probability of unexpected failure, optimize utilization and minimize equipment downtime, which will in return increase the overall construction projects profitability.*

KEYWORDS: *Construction project, equipment, maintenance, profitability, reliability, cost overrun*

I. INTRODUCTION

Construction project is different from other projects because it required intensive amount of capital resources to be accomplished amongst which are time, manpower, money and machines (Chitkara, 2009). The basic operations involved in the construction of any project are excavation, digging of small or large quantities of earth and moving them to fairly long distances, placement, compacting, leveling, dozing, grading, hauling, etc. All the machines that are usually used to carry out these construction operations are referred to as construction equipment. In most cases, they are called heavy equipment especially in road construction (Tatum *et al.,* 2006). In 2011, Cucu stated that construction business relies primarily on high utilization of equipment to carry out most of their projects, like construction of highway and other sophisticated structures. Equipment is thus one of the key factors for improving contractor's capability in performing their work more effectively and efficiently. Through the utilization of equipment, an extensive volume of work can be completed in a shorter period of time or within the project schedule. However, in managing construction equipment, contractors are invariably plagued with several difficulties such as huge capital investments in the requisition phase, which usually constitutes a major financial burden to them (Anderson, 1992; Murdock, 2000). Procurement of major construction equipment not only costs as high as 36% of the total construction project expense but also causes a high delivery time uncertainty, which may disrupt the construction schedule (Agbo, 1993; Douglas *et al*., 2006; Moubray, 2010). Richardson (1987) and. Tatum *et al.* (2006) found that proper use of appropriate equipment contributes to economy, quality, safety, speed and timely completion of the project. It is not always desirable or possible for the contractor to own each and every type of construction equipment required for the project. Considering the various aspect of the utility of particular equipment, the contractor has to economically justify whether to purchase the equipment or to hire it. The amount invested in the purchase of equipment should be recovered during the useful period of such equipment. This can only be realized if the equipment is always kept under good working condition by applying effective maintenance strategies. Construction practitioners must continuously

evaluate equipment records in order to determine what actions are needed for their functionality Anderson, 1992; Douglas, 1975; Moubray, 2010).

Construction firms are often faced with problems related to high rate of equipment failure or breakdown and accident resulting from unskilled operator's abuse. Poor training of equipment operators is often claimed as a major cause of equipment related accidents (John and Herman, 2009; Schenayder *et al.*, 2002).In 1983, Agbo stated that the cost of equipment repair, fixed and variable operating cost wasted during the equipment downtime and a myriad of consequential costs that reverberate and surge through the construction business are enormous. The only way to avoid this huge amount of loss that usually lead to accompanies equipment breakdown or failure is to adopt proper equipment maintenance management strategy. This will keep construction equipment fit at all times and allow timely completion of construction project, thereby increasing construction project profitability. Thus, to understand effective construction equipment management, one must also understand effective construction equipment maintenance. The cost and time that exceed the designated budget or schedule on projects are often resulted from poor equipment maintenance practice (Schexnayder and Hancher, 2009). Maintenance should not be viewed as a cost but as an investment that can be linked to the company's future revenue growth (Robert *et al*, 2006) There is need to let construction managers realize that maintenance of construction equipment if properly carryout is a profit center and not an unavoidable evil as some assumed.

Schexnayder and Hancher (2009) found that, equipment maintenance has not been given appropriate attention and this contributes to about 40% of total construction project cost overrun. Hitherto, high rate of construction equipment failure or breakdown due to poor equipment management by construction practitioners which results into unprofitable construction project is worrisome. The objective of this research is thus; to ensure that construction practitioners realize and adhere to proper equipment maintenance strategy as effective aspect of construction project profitability. The study is justified by the huge contribution that effective equipment maintenance make towards the timely execution of construction projects, this being heavily reliant on proper maintenance strategies employed.

II. MATERIALS AND METHODS

The material for the study is the construction equipment use in construction industry, specifically in Abuja, Minna and their environs for their hub-heavy construction projects activities. The data were obtained through the use of Investigatory Survey Research Approach Method (ISRAM) whereby comprehensive literature relevant to the research topic were reviewed, personal interview with the key players, and a well structured questionnaire administered in various construction companies A total number of sixty-five (65) well structured questionnaires were administered to eight different construction companies with identity of A, B, C, D, E, F, G and H to obtain quantitative and qualitative data on how equipment maintenance has been handled in some randomly selected construction companies located in Abuja, Minna and their environs. The case study areas were selected because of their hub-heavy construction projects activities. Fifty-seven (57) which represents 87.7% of the total questionnaires were retrieved and analyzed. Data obtained were subjected to frequency analysis method expressed in percentage as in equation (1):

$$Percentage frequency(\%) = \frac{n}{N} \times 100 \quad (1)$$

Where, n – Number of respondents, and N - Total number of respondents

III. RESULTS AND DISCUSSIONS

3.1 Results

Five (5) different critical, but closely related identified integral strategies of effective construction equipment management were Leadership and Management, Preventive Maintenance, Reliability Improvement, Personnel Training, and Equipment Parts Administration.

Based on these maintenance strategies, a well structured questionnaire was prepared and administered to construction industries in furtherance of search and adherence to these factors by the randomly sample companies.

3.1.1 Leadership and Management

Table 3.1 below shows the grading of the level of importance and value attached to equipment maintenance by the management of the companies assessed.

Table 3.1 Management's Level of Understanding Equipment Maintenance

Company	Frequency								Total frequency	Percentage (%)
	A	B	C	D	E	F	G	H		
Yes	5	9	4	5	9	7	10	5	54	45.4
No	8	5	9	10	4	8	4	9	57	47.8
No response	0	2	0	2	1	0	2	1	8	6.7
Total									119	100

3.1.2 Preventive Maintenance (PM)

Table 3.2 shows the level of priority attached to preventive maintenance by the companies.

Table 3.2 Level of the Companies Preventive Maintenance

Company	Frequency								Total frequency	Percentage (%)
	A	B	C	D	E	F	G	H		
Yes	5	5	6	8	6	7	4	5	46	39.7
No	9	6	7	10	9	8	9	7	65	56.0
No response	0	0	0	1	0	1	3	0	5	4.3
Total									116	100

3.1.3 Reliability Improvement

Table 3.3 presents the level at which the companies value and use the collection and analysis of maintenance work order data to determine where repeated construction equipment problems can be identified, and more permanent corrective actions be developed and implemented.

Table 3.3 Level of Company's Reliability Improvement

Company	Frequency								Total frequency	Percentage (%)
	A	B	C	D	E	F	G	H		
Yes	2	7	3	2	4	4	5	3	30	39.5
No	5	4	5	5	3	4	7	5	38	50
No response	1	2	0	1	1	0	2	1	8	10.5
Total									76	100

3.1.4. Personnel Training

Table 3.4 shows the level of mechanisms put in place by the companies to develop and maintain the necessary skills in individuals to properly care for and operate construction equipment safely.

Table 3.4 Level of Maintenance Skill Development

Company	Frequency								Total frequency	Percentage (%)
	A	B	C	D	E	F	G	H		
Yes	5	10	4	5	4	7	8	5	48	39.3
No	9	4	9	9	10	8	6	11	66	54.1
No response	3	0	0	2	0	1	0	2	8	6.6
Total									122	100

3.1.5. Equipment Parts Administration

Table 3.5 shows the philosophy behind the spare parts inventory, and the mechanisms used by the companies in their purchases as poor equipment parts inventory affects profitability in construction projects.

Table 3.5 Level of Equipment Parts Administration

Company	Frequency								Total frequency	Percentage (%)
	A	B	C	D	E	F	G	H		
Yes	8	10	5	5	4	5	11	5	53	46.1
No	5	4	8	9	9	8	3	11	57	49.6
No response	1	0	1	0	1	1	1	0	5	4.3
Total									115	100

IV. DISCUSSIONS

3.2.1 Leadership and Management (LM)

The maintenance function is often overlooked by management as a competitive factor in the firm's strategy. Most managers regard equipment maintenance as a necessary evil or a service whose sole purpose is to react in emergency situations. The maintenance function should be viewed by management as a resource that can be used strategically to improve productivity and profitability of the project. Leadership and Management help in knowing and measuring the value and importance attached to maintenance by the management at all levels in Construction Company, and also the desire to continually improve business profitability.45.4% of the results as shown in Table 3.1 confirmed that the companies value better equipment maintenance as a way of improving business profitability. There are written goals, objectives and targets for maintenance improvement to increase overall business result. This they achieve by putting in place multi-level leadership committees that work continuously on improving the maintenance state of the company equipment. To get a better maintenance result, there is a very strong awareness that maintenance is a responsibility of everyone in the company, not just the maintenance personnel alone. Furthermore, 47.8% of results show that the companies do not place high priority to equipment maintenance. They do not have the ultimate goal of zero downtime which can only be achieved through improved equipment maintenance. Also, they do not ensure that maintenance System performance is routinely measured and reported for improvement. The results also confirm that the companies assessed do not understand perfectly that the best form of maintenance corrective action is to permanently fix problem but not constantly fixing recurring problems. High emphasis is not being given to equipment maintenance. Maintenance is generally not considered as everyone's responsibility. Most of the companies make sure scheduled preventive maintenance tasks are part of operational planning but they are not being done accordingly. Only few of the companies understand that for equipment to be safe, more effective, give best productivity and higher quality output, they must be well maintained. Therefore, the fact that equipment must be well maintained to get the lowest project execution cost is still not well believed by many of the companies. Preventive type of maintenance is considered more expensive than the reactive. However, 6.7% of the results show that the companies do not understand some of the maintenance strategies.

3.2.2 Preventive Maintenance (PM)

Preventive maintenance is described as maintenance of equipment or systems before fault occurs (BS 3811, 1984). The primary goal of maintenance is to avoid or mitigate the consequences of failure of equipment. This may be by preventing the failure before it actually occurs, which planned maintenance and condition based maintenance help to achieve. It is designed to preserve and restore equipment reliability by replacing worn components before they actually fail. Routine preventive maintenance minimizes downtime, extends equipment life and reduces possible liability. Money is saved on parts, repair and clients are kept happy. Preventive maintenance helps in measuring the level of understanding and commitment attached to preventive maintenance activity by the construction companies.56% of the result obtained as shown in Table 3.2 confirmed that, the companies do not put in place formal periodic equipment cleaning inspection system that identifies potential problems before they become downtime issues and to ensure that equipment PM procedures are current and accurate. The companies also do not ensure that equipment inspections are always carried out exactly as specified and when specified. Hitherto, majority of repair work orders are generated from preventive maintenance inspections. The principle of "Clean to Inspect" should be well understood by those performing PM work. When a breakdown occurs, preventive maintenance procedures should be reviewed and adjusted as required to prevent the problem from reoccurring. Lubrication program should be in place to make sure that equipment are lubricated routinely and with the proper lubricant. To avoid contamination, lubricants and lubrication equipment should be properly stored and maintained. Equipment operating personnel are not being made to know that they have most of the responsibility for preventive maintenance work that is done while equipment is running. There is no ongoing review process involving operators and maintenance personnel to achieve equipment zero downtime. On the other hand, 39.7% of the result shows that the companies do give high priority to preventive equipment maintenance. Most of their repair works are carried out before equipment failure. 4.3% of the result is silent about the topic due to lack of awareness of the preventive maintenance strategy under assessment.

3.2.3 Reliability Improvement (RI)

For many maintenance professionals, there are two burning issues which are always at the forefront of their minds: equipment reliability and cost (Seeley, 1987). Whenever equipment is unavailable, it is not running so it is not playing its part in earning revenue and, even worse, is probably causing increased costs until it is repaired and back into operation. Considering the cost implication, not only that equipment has to be permanently available, it must also be reliable (Maggard and Rhyne, 1992). Often times manpower is reduced to cut costs but this makes it even harder to achieve availability targets and the situation goes from bad to worse. Reliability improvement helps in knowing to what level the construction companies value and use the analysis of maintenance work data to determine where repeated problems can be identified. Through this more permanent corrective action can be developed and implemented to ensure there is improved equipment reliability.50% of the results from Table 3.3 reveal that most work orders are not always completed with all available and relevant actual information (parts procedures man-hours), this does not allow proper analysis for recurring problems. Analysis of repair work orders are not a regular routine task performed with operating teams to avoid breakdowns and greatly improve equipment reliability. Trend information on maintenance downtime and maintenance costs is not being made readily available for each piece of critical construction equipment and that can be routinely referenced to generate maintenance work. Only 39,5% of the results obtained shows that the companies put a formal system to attack equipment problems that involves thoroughly determining the underlying root causes to permanently solve equipment troubles. This means that Maintenance personnel are always available to assist operating teams which shoulder the responsibility of ensuring equipment reliability improvement. On the other hand, 10.5% of the results reveal the companies do not understand how to enhance reliability improvement through equipment maintenance.

3.2.4 Personnel Training

Having maintenance personnel that can maintain the equipment is of great importance. Ensuring that construction equipment operators know as much as possible about equipment maintenance is very important. The only way to ensure this knowledge and skill is readily available through training. When training begins, one must see the result quickly in order to motivate the maintenance personnel receiving the training, and the management who is expecting to see result for the money and time spent on training. This is called 'high impact training' which must embrace some basic principles. 54.1% of the results as in Table 3.4 confirm that the companies assessed do not put in place formal listing of the maintenance training and capability required by operators. There are also no other effective routine mechanisms and materials that are provided to periodically provide Maintenance Training for Operators and Mechanics. Whenever they occasionally receive training, the skills taught to them are not used immediately in their jobs. Whenever equipment develop fault, it is not made compulsory for operators to assist

maintenance personnel with repairs. Maintenance personnel or Senior Operators also are not assisting newer operators in developing preventive maintenance skills. The companies do not understand the importance of effective communication; therefore, there are no committed routine systems to communicate maintenance information between individuals in the organization. Periodically, job descriptions for maintenance and maintenance management personnel are not being reviewed with the employees and also, reviews of skills and skill requirements are not held. There is no periodic "refresher" skill training to ensure that maintenance employees gain new maintenance techniques. There are no standard maintenance procedures that are reviewed and followed for maintenance jobs in most of the companies.
Only 39.3% of the results show that the companies put a well-organized periodic training for their maintenance staff and operators. This also shows that there is a formal listing of the maintenance training and capability required by operators. 6.6% of the result results revealed that the companies do not understand the concept of improving profitability through personnel training.

3.4.5 Equipment Parts Administration (EPM)

Maintenance material costs are related to the frequency and size of the repairs made to the company's equipment. The total number of parts, in addition to the stores' policies, purchasing policies and overall inventory management policies, contribute to the overall maintenance materials costs. Since little attention is paid to maintenance materials in some construction companies, inventory may be higher than necessary. This increases inventory holding costs and make materials unnecessary expensive.. Good inventory control enables companies to lower the value of the inventory and continue to maintain a service level of at least 95%. This enables the maintenance department to be responsive to the operations group, while increasing the maintenance department's own personal productivity. EPM helps in knowing the philosophy behind the spare parts inventory, and the mechanisms used in the purchase of these parts.46.1% of the results in Table 3.5 confirmed that everybody in the companies understands that lowering the levels of emergency and unplanned maintenance work, allows corresponding lower levels of in-house, spare parts inventory. Therefore, there are guidelines for in-house maintenance spare parts stocking decisions and levels which are well understood by all personnel. There is set objective of spare parts inventory turns per year thereby keeping the stock outs of critical parts at the less than 5% level and also the spare parts usage always captured promptly on work orders or requisitions to keep inventory information accurate. Vendor performance are evaluated annually using system information and spare parts storage well organized, cycle counting of spare parts performed regularly and frequencies of counting parts are based on their ABC classification. The cycle counts have a small (less than five percent) variance against system counts. Maintenance purchasing, a centralized efficient activity driven by inventory and scheduled work order requirements is approximately three times per week. The annual contracts are in effect with major suppliers to reduce the purchasing effort. Emergency Purchasing and Expediting is an infrequent activity in the companies.

However, 49.60% of the results proved that the companies do not attach high priority to spare parts inventory and thereby achieving the project completion at a loss. They do not understand the importance of proper spare parts administration as they are always faced with problem of getting the appropriate parts whenever their equipment fail and some parts need replacement.

V. GENERAL OBSERVATIONS

Table 4. Frequency Summary of Effective Equipment Maintenance Strategies by Companies.

Responses	Effective Equipment Maintenance Management Strategies					Total Frequency	Percentage (%)
	Leadership and Management	Preventive Maintenance	Reliability Improvement	Personnel Training	Equipment Part Administration		
Yes	54	46	30	48	53	231	42.3
No	57	65	36	66	57	281	51.5
No response	8	5	8	8	5	34	6.2
Total	119	116	741	221	155	546	100

It can be observed from Table 4 that only 42.3% of companies attach high priority to construction equipment maintenance, and 51.5% prove otherwise. This means that considerable attention is not given to equipment maintenance by the companies and this usually results into equipment failure or breakdown. Also, 6.2% of the whole results confirm that the companies do not recognize most of the maintenance strategies assessed. This means some construction

companies still largely believe that equipment should be fixed whenever breakdown occurs. The following are the effects of lack of proper equipment maintenance as exhibited by most of the sample companies assessed;

[1] There is high rate of costly downtime which decreases profitability and uptime.
[2] Catastrophic equipment failure is very common.
[3] Unscheduled equipment maintenance is at high rate, most of the repairs are made when equipment are supposed to be working, this affect production.
[4] Spare parts inventories are at the high rate, many parts are purchased just after breakdown occurs.
[5] Equipment performance is not optimized; it does not operate within specifications.
[6] Equipment capacity is drastically reduced.
[7] There are numbers of clients who are dissatisfied because contractors deliver behind schedule as a result of frequent equipment failure.
[8] Overtime needed to make up for lost hours due to broken down or poorly performing equipment is at increase rate.
[9] Equipment safety is not guaranteed since site injuries are often caused by poorly performing equipment.
[10] The ease of operating equipment is greatly affected.
[11] Quality of output is reduced as a result of poor equipment maintenance.
[12] There is low rate of quality control.
[13] Overall maintenance cost is increased as catastrophic failure is common.
[14] Equipment availability is greatly affected.
[15] There is high rate of depreciation of capital investment caused by poor equipment maintenance because well maintained equipment last longer and perform better.

VI. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the fact that 51.5% of the construction companies assessed do not attach high priority to equipment maintenance, the following conclusions can be deduced;

[1] Most of the Construction companies in Nigeria are not making the required profit from their projects because of poor equipment management.
[2] The high rate of construction equipment breakdown in this country is caused by lack of proper equipment maintenance programme.
[3] Many construction companies still practice run to fail system of equipment maintenance (reactive type of equipment maintenance).
[4] The true cost of equipment failure is not well understood by most of the construction managers.

The frequent equipment failure incident in most of our construction industries has the following cost effects:

[1] Operators usually leave their normal duties that make money for duties that cost money.
[2] The project supervisors, purchasers and repairmen usually waste time and spend money addressing frequent equipment stoppage.
[3] Clients do not usually get timely delivery; this attracts the invoking of liability clause.
[4] A rush work-around that put people at high risk is common.
[5] Time and money better used on project building activities is often drawn into the black hole of equipment failure.

The effect of all these is accumulated loss which would not have happened if well planned preventive maintenance strategies are in place to avoid equipment failures. Companies pay for the loss from their profit which is then reflected in poor financial performance (Boris, 1997).

5.2 Recommendations

Sequel to negative attitude of the construction practitioners on effective equipment maintenance and consequences of it on project profitability, it is recommended that construction practitioners afford the opportunity of equipment maintenance strategy as part of construction project management. This will help reduce expenses, probability of unexpected failure, optimize utilization and minimize equipment downtime, which will in return increase the overall construction projects profitability. In the same vein, the overall productivity of equipment maintenance personnel should also be increased using the following vital tools:

[1] Planning of jobs in advance.
[2] Scheduling of jobs and coordination of schedules with operations.
[3] Proper coordination of availability of tools, rental equipment etc.

[4] Proper arrangement for equipment parts.
[5] Reduction of emergency work below the 50% emergency level by adequate preventive maintenance.

REFERENCES

[1] Agbo, O.T. (1993). Variations in Building Contract: The Nigeria Perspective. *The Quantity Surveyor Journal of Nigerian Institute of Quantity Surveyors*, Vol.116, 24
[2] Anderson, J.M. (1992). Managing Equipment in Construction, Proceedings of the institute of Civil Engineering, London, UK, 127-132.
[3] Boris, S. (1997). Total Productive Maintenance, First Edition, McGraw Hill, New York, 447-448.
[4] British Standards (BS) 3811. (1984). Glossary of Maintenance Management, British Standards Institute, London, UK
[5] Chitkara, K.K. (2009). Construction Project Management. Planning, Scheduling and Controlling. Seventh Edition, Tata McGraw-Hill, New Delhi, India
[6] Cucu, C. (2011). Modern Management Method for Equipment Maintenance. Third Edition, John Walley, USA.
[7] Douglas, D. G., Calin, P., Richard, C. R. (2006). Construction Equipment Management for Engineers, Estimator, and Owners, Pecrc press, New Delhi, 678-782.
[8] Douglas, J. (1975). Construction Equipment Policy, Mc-Graw Hill New York, 119-206
[9] John, M. N. and Herman, S. (2009). Maintenance Management, Sixth Edition, Peter Thomas, Sydney
[10] Murdock, I.J. (2000). Maintenance Engineering Handbook, McGraw Hill, New York, pp 23-25
[11] Moubray, J. (2010). Equipment Maintenance Management. Second Edition, Mike Steve, India
[12] Maggard, B. and Rhyne, D.M. (1992). "Total Productive Maintenance: A Timely Integration of Production and Maintenance", *Production and Inventory Management Journal*, *Vol 2*, pp. 11-15
[13] Richardson, F. (1987). Optimum Productivity of Construction Equipments, *Journal of Construction Management*, 6, pp.3-34.
[14] Richardson, F., David, L., Robert, N., Sydney, U. (2010). Construction Management in Practice, Second Edition, Joseph Hill, Russia
[15] Robert, l., Peurifoy, P.E., Clifford, J., Schexnayder, P.E., Avaial Shapira. (2006). Construction Planning, Equipment and Methods, International Edition, Seventh Edition, McGraw-Hill, New York.
[16] Peurifoy, G. and Schexnayder, S. (2002). Construction Planning, Equipment and Methods, Sixth Edition, McGrew Hill, pp-2-20.
[17] Schexnayder, P.E.and Hancher, F. (2009). The True Cost of Equipment Failure. Third Edition, Netta Hook, Germany.
[18] Schexnayder, P.E., Clifford, J., Scort, A. D. (2002). Future of Construction Equipment, *Journal of Construction Engineering and Management, ASCE*, 128(4), pp. 279-286.
[19] Seeley, I.H. (1987). Engineering Equipment Maintenance, The Macmillan Press, London, U.K, pp. 234-237
[20] Wikipedia the free encyclopedia /ttp//en.wikipedia.org/wiki/Construction Equipment. Retrieved on 12/04/2012
[21] William, R.H. (2011). History of Construction Equipment. *Journal of Construction Engineering and Management.* 137(10), pp.14-18
[22] Tatum, C.B., Gren, G. H., Fett, H. (2006). Construction Equipment and their Uses, *Journal of Construction and Engineering Management*, pp.132-137.