Time And Motion Study For Road Construction Equipment

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Abstract:
Productivity and efficiency in any construction are always a challenge. Due to various factors, the efficiency of men and machines gets reduced, hampering productivity. This study highlights the benefits of time and motion research in the construction sector. Time and motion analysis and work sampling have been used to measure the productivity of various construction activities. The paper discusses its application to the multiple phases of road construction, such as excavation, compaction and grading. Employing lean construction concepts is expected to help increase productivity and reduce risks. The past researchers focused on construction equipment selection, acquisition, operation, maintenance and disposal or replacement. The method used in time and motion study is to identify problems, choose the appropriate activity, plan the move, record the information by proper technique, analyse activity factors to develop an economical way, measure work and standard time, define the newly efficient manner and maintain the new standard. In this research work, the stopwatch method is used to determine the respective operation of construction activity of excavation for subgrade construction by physical observation. The results are auspicious, and hence the management of the construction industry needs to consider the application of time and motion study not only from the point of view of enhancing efficiency. By improving the effectiveness of utilising equipment, the extensive volume of work can be completed within a shorter period and, more importantly, within the project schedule. Equipment is thus one of the critical factors for improving contractors' capabilities in performing their work more effectively and efficiently.
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1. Introduction

Time and motion study (also referred to as motion and time study, the terms are used interchangeably) is the scientific study of the conservation of human efforts in the search for the most efficient method of doing a task with optimum output. A fascination with the word "efficiency" began in the late 19th and early 20th centuries when it was considered one of the most important concepts. A passion for "efficiency" started in the late 19th and early 20th centuries when it was considered one of the most important concepts. Time and motion studies of construction activities are processed to find the time required to complete the task. Fedrick W. Taylor developed a time study in about 1880. He is the first to use a stopwatch to study and measure work content to define "a fair day's work". Frank B. Gilbreth developed the motion study, and his wife, Lillian, created and redefined motion study in 1909.

Time study started in the 1880s as a means of wage-rate setting by Frederick W. Taylor, regarded as the "father of scientific management." It consists of various procedures for determining the time required for tasks involving some human activity under certain standard measurement conditions. Motion study was developed by Frank B. Gilbreth and Lillian M. Gilbreth and consists of a wide variety of procedures for the description, systematic analysis, and means of improving work methods. It isn't easy to separate these two aspects. Therefore, the combined term usually refers to all three phases of the activity: method determination, time appraisal, and material development for applying these data. Frank and Lillian also broadened scientific management by including the human element, therefore using psychology to gain the cooperation of employees.

The construction industry significantly contributes to the national economy, employing many people in any nation. In the past few years, the Indian construction sector has been spreading its wings regarding investment. Construction is a business sector that relies primarily on the high utilisation of construction equipment. Equipment is thus one of the critical factors for improving capabilities in performing work more effectively and efficiently. To function in any project smoothly, an engineer must have detailed knowledge about the equipment available and direct it on a particular task. The construction industry ultimately relies on four primary resources: men, materials, machinery and money, i.e., 4M's. Among those men is the exuberant resource, which plays a vital role in every stage of construction. The effective use of this resource enhances performance and productivity. In many nations, labour cost comprises 30-50% of project cost, which reflects its influence on economic success. As construction is a labour-effective industry, it can be firmly stated that efficiency in construction productivity is mainly dependent on labour-power, i.e., human effort and performance. The level of productivity, overall time parameters, cost and profits of a project depend on the labour and machines. The project's progress depends on how fast the work is carried out. Hence, selecting the equipment is necessary considering all aspects of site working conditions. So, it is essential to make the proper planning & management of equipment available to use it effectively at the minimum possible cost and with maximum output productivity.

Despite developing various methods to improve the construction process's efficiency and effectiveness, it still needs to be improved due to multiple factors. To achieve high quality in the ion industry and enhance the performance, feasibility and suitability of construction projects, project, Productivity is the most frequently used performance indicator to measure a construction project's success of its importance and flexibility. Proper planning, selection, procurement, installation, operation, maintenance and equipment replacement policy plays a vital role in equipment management for the successful completion of the project. With the growing use of machinery, it has become necessary for construction engineers to be thoroughly familiar with the Construction application and upkeep of the wide range of modern equipment.

2. AIM

To perform Time and motion study for road construction equipment and determine their efficiency

3. Objective

1. Determining the time required by a qualified and properly trained person usually working to do a specific task and operation.
2. To improve the work process in terms of time
3. Analysing the existing system under study and identifying the scope of improving the current operation.
4. Identifying the probable measures for field practice to reduce/improve the current activity.

4. Literature Review

Aakash P. Mohane & Harshita P. Ambre concluded that The result indicated that insufficient knowledge of the selection of equipment, equipment downtime, poor equipment maintenance practices, improper determination of timing of replacement, inadequate training of equipment operators, equipment breakdown, ignorance towards the maintenance of equipment, huge capital investment during acquisition, misunderstanding the scope of work carried out, the unit cost of production and equipment suitability for job condition were found to be the significant problems that affect construction equipment planning and management on Nashik city projects during the planning and construction process. As the study revealed, 40% of the respondents use planned preventive maintenance while only 33% perform periodic maintenance; 27% of contractors still go for care after an equipment breakdown, showing negligence towards maintenance activity. 70% of construction companies must keep a maintenance record of the equipment. It is challenging to keep an eye on maintenance cost expenditure result of this company’ s faces loss in profitability. The study concluded that only 20% of the respondent have separate maintenance staff at the company office, which is necessary to minimise maintenance costs. All three pieces of equipment do not deliver the expected output. OEE for Excavator EX 120 is only 39% which shows a lack of productivity and performance. OEE for EX 200 Excavator is 62.34% which is quite acceptable, but it can be improved as the machine offers a rate drop-in performance rate factor.

Anjay Kumar Mishra & Binod Aryal concluded the study and analysis of the existing equipment management system of Construction companies in Nepal. There was an increase of approximately 52% and 96% in equipment utilisation from 2014 to 2015/16, respectively. There was no pre-organized equipment operation schedule except for rainy season equipment deployment. Most of the operators were trained and performed satisfactory quality work. There were frequent problems scheduling equipment operations during peak hours due to insufficient operators and old equipment. Regarding companies' equipment maintenance practice, it was concluded that, on average, equipment needed maintenance after utilisation of 94 h, with the standard method of 100 h. The calculated result for equipment availability is at the static factory level. Besides the improper management with no pre-schedule, the availability level may lead to the deduction of equipment life. The primary cause of the delay in the equipment maintenance was the delay in receiving spare parts for the breakdown equipment. The routine spare parts like filters, belts, nut bolts, teeth, and cutting edge are readily available. The spare parts that must be imported commonly take 15 to 30 days to deliver. Record management related to equipment operation and maintenance activities could have been better. It took much work for management to make a scientific decision based on records. They have to depend on rules of thumb and assumptions for making decisions. The documents related to the operation and maintenance of pieces of equipment were not kept accordingly, were time-consuming, and data needed to be included.

Santosh Tekkannavar concluded that except for the pre-stage of machine arrangement, which typically takes 45 minutes, the entire activity lasts roughly 68 minutes. The research done on time motion is just one sample. It is necessary to gather more pictures to identify the precise variables of such an activity. The initial stage time can be reduced by making things more straightforward to attain the machinery setup. This research will pave the way for applying the time-motion study to boost productivity. This study is focused on a single sample; however, it can be used as a reference point for a subsequent time-motion analysis of grouted nailing activities to determine the precise variance and causes of the productivity decline. Therefore, the issues can be resolved to boost productivity. The samples can be taken from various stretches and according to the time when the work started. These data can be examined to determine the mean time and reduce deviation from the mean at the root level to speed up the project's progress. If the correct data for soil type soil is made available, it can help schedule the project more reasonably. If there' s a time limit to complete the work, this data can give an appropriate way to help avoid the non-value-added pieces and complete them within the schedule.

Dr Krupesh A. Chauhan & Rushabh A. Shah concluded that from the data analysis, Time and Motion study is very useful in identifying the ineffective time and the reasons for that wrong time. It was observed from the data that inadequate time needs to be a more effective part of the plastering work in all the sites. Out of three places, site A and Site B have less time than site C. Out of all three sections of plastering work, ineffective central time was found in lead-time and mixing time. Application time, known as the main part, is less harmful than others. No site is showing no ineffective time, which indicates that there is much need to control that to avoid overruns in the projects. The motion study found that unproductive time is due to three major issues, i.e., Due, Poor Design, Methodologies and Human Resources. If we reduce those factors, we can avoid all the problems and improve the construction work's productivity.

G Vinod Kumar Reddy and K Shyam Chamberlin have concluded that conceptually efficient performance cannot be achieved as per the planned schedule due to unproductive work hours and methods. This research presented real-time case studies of seven working construction sites considering brickwork activity. Various tasks involved in brickwork activity are categorised as mortar works, bricks handling and finishing positions for which a time- motion study is carried out to observe the different time parameters during which some common delays were observed like, Poor site management, Target less work environment, Material shortage, Miscommunications, Issues related to electricity, Equipment breakdown, etc. It had an overall effect on work efficiency and labour productivity. Considering the above-stated problems and upgrading worker efficiency by training as per requirement, along with work sampling, enhances efficiency, reduces the rework, time, and economy and creates a baseline to evaluate the ergonomics side of workers.

Mr Jigar H. Balar, Mr Hiren A. Rathod & Mr Mrushabh Shah concluded that the process could be improved based on the parameters that cause the problems. The combination of the work process and time measurement and the production layout changes will improve the current work process. These modifications are made by eliminating the ed time and reducing the work contents. The comparison between the recent existing new work process improvements successfully achieved the project goals and objectives, which used the processes, production layout, economy in human effort and the reduction of unnecessary fatigue. Further investigation and observations on the field explore the exact reasons for extra time consumption, including inadequate material handling, ineffective method of work, poor planning of inventory, poor layout and utilisation of space. Considering these factors, the activity time can be nearer to the required time.

Prajapati Swetang Prakash Bhai & Prof. Ankit Kumar Somabhai Patel showed that the stopwatch method does physical activity analysis and concluded in research on time and motion studies on the industrial project unnecessary time of operational tasks is an average of 6-12% during the execution of activities. The general factor observed while studying such design and planning procedure of work, Material handling, Precession of work, capacity and productivity of equipment, spacing between two equipment, Lead of operational work, Absence of ideology of work, Frequent breaks, operator’ s proficiency, work permission procedure, internal happiness of worker, Appreciation for the workforce, change in job plan of projects. In the T&M study of industrial construction activity, each factor has a small and more significant impact on a project. It may be positive or negative. The essential operation has more time loss as compared to supportive tasks. It can directly affect our planned schedule and budgeted cost and result in project delay, declining in the S-curve; project cost overrun or an increase in overhead charges.

5. Methodology

This research identifies significant problems in construction equipment planning and management and their effect on construction equipment productivity on the Upgradation and reconstruction of the existing Dharmshala Vighakot road near Border Area RE Park [in Defense Area, road projects. They are investigating the causes and consequences of construction equipment planning and management problems within domestic grade one contractor and equipment. The study sample's determination and the data collection techniques are also described.

6. Case Study

The upgradation and reconstruction of the existing Dharmshala Vighakot road near Border Area RE Park [in Defense Area, Design Ch. 16+266 km to 24+540 km] in Kutch Dist. in the State of Gujarat. This road section is about 8.2km long and is in early construction. Only excavation work from borrowed land and supplying excavated material to the construction site for sub-grade work has been considered to examine the OEE (overall equipment effectiveness) of the Tata Hitachi Ex 200 LC Poclain excavator. The project is in the active stage and is handled by the consultancy. The researcher personally does data collection and record-keeping on the site. OEE of the excavator is carried out concerning equipment utilisation and its management. All the records and data will be maintained in different register formats. A comparative analysis will conclude the most effective and efficient equipment management policy concerning equipment selection and operation.

7. Overall Equipment Effectiveness

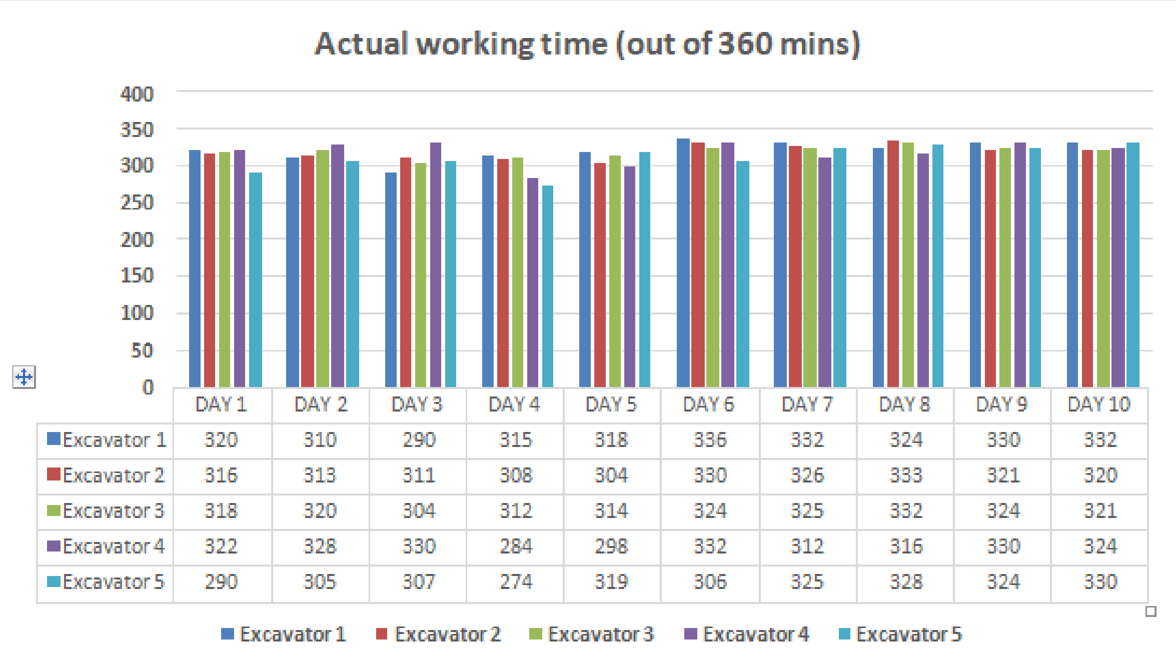
OEE measures the value added to a particular machine’s production time. The demand for increased productivity in the current competitive construction industry led to a need for a performance measurement system for the production process. One such performance measurement tool that measures different production losses and indicates an area of process improvement is the Overall Equipment Effectiveness (OEE) index. It is a tool designed to distinguish factors contributing to productivity losses. Knowing the three fundamental performance rates, Availability Rate (AR), performance Rate (PR) and Quality Rate (QR), will help to compute the overall equipment effectiveness index. These rates indicate the degree to which the required output of hose equipment production losses is stated.

OEE = AR * PR * QR

Where; AR – Availability Rate PR – Performance rate and
QR – Quality Rate

As OEE is based on three parameters, individual calculations are carried out for the availability, performance, and quality rates of the three primary components of the overall equipment effectiveness index, as shown above. Moreover, the OEE index is the product of the three direct component rates. Its value can only be equal to or less than the lowest rate among the three primary component rates. F This result identified the main contributing factors for productivity loss and their order. The most contributing factors are found within the lowest primary component of the OEE index.

8. Observation and Results



	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAY 8	DAY 9	DAY 10
Excavator 1	320	310	290	315	318	336	332	324	330	332
Excavator 2	316	313	311	308	304	330	326	333	321	320
Excavator 3	318	320	304	312	314	324	325	332	324	321
Excavator 4	322	328	330	284	298	332	312	316	330	324
Excavator 5	290	305	307	274	319	306	325	328	324	330

Graph 1. Actual working rate

Activity rate Activity rate = $\frac{\text{Available time – Planned downtime * 100}}{\text{Loading time}}$

This rate is essential for the managerial group because, theoretically, the equipment can be utilised 100% of the available time. The project manager must ask why if the activity rate is much less than 100 %. Then, think about reducing the planned downtime. Otherwise, this rate is not a primary component of the OEE index.

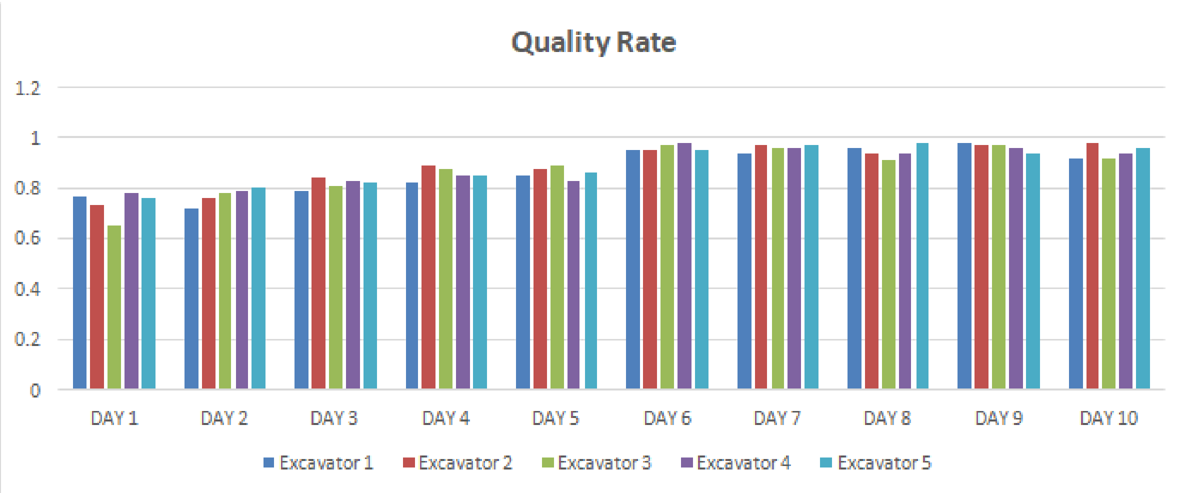
$$\text{Availability/Operativity rate} = \frac{\text{Loading time} - \text{break down losses} * 100}{\text{Loading time}} = \frac{\text{Operating time} * 100}{\text{loading time}}$$

It is a primary component of OEE. Availability accounts for downtime loss at a given production time, including any events that stop planned production. Examples include equipment failure, material shortages, and changeover time (set-up losses). In every productive environment, accessory breakdown during production time is a severe failure to equipment productivity.

Graph 2. Availability rate

$$\text{Quality rate} = \frac{\text{Total executed amount (unit)} - \text{Reworked amount (unit)} *100}{\text{Total executed amount}}$$

This rate reflects the impact of quality loss and start-up yield losses, which accounts for executed amount that does not meet the specification, including activities that require rework.



Graph 3. Quality rate graph

Net operating rate:

Net operating rate = $\frac{\text{Output actual cycle time – Planned downtime * 100}}{\text{Operating time}}$

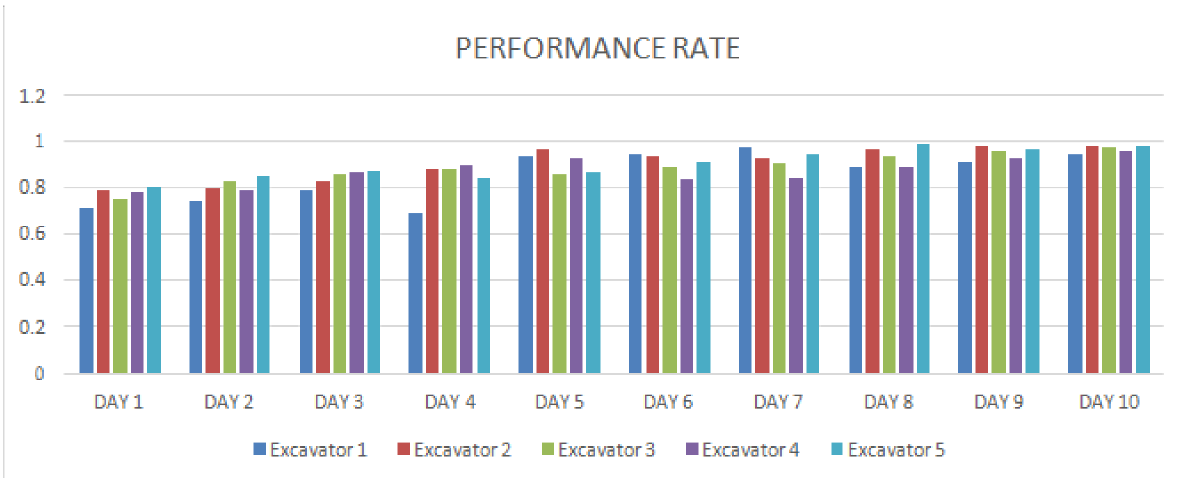
It is also not a direct component of the OEE.

It is not expressed as a percentage or a direct component of OEE but is used to calculate the third component of the OEE index.

Performing rate;

Performing rate = Net operating rate * operating speed coefficient * 100

The performance considers speed loss, which includes any factors that cause the equipment to operate less than the maximum possible operating speed. Examples include machine wear, substandard materials, and operator inefficiency.



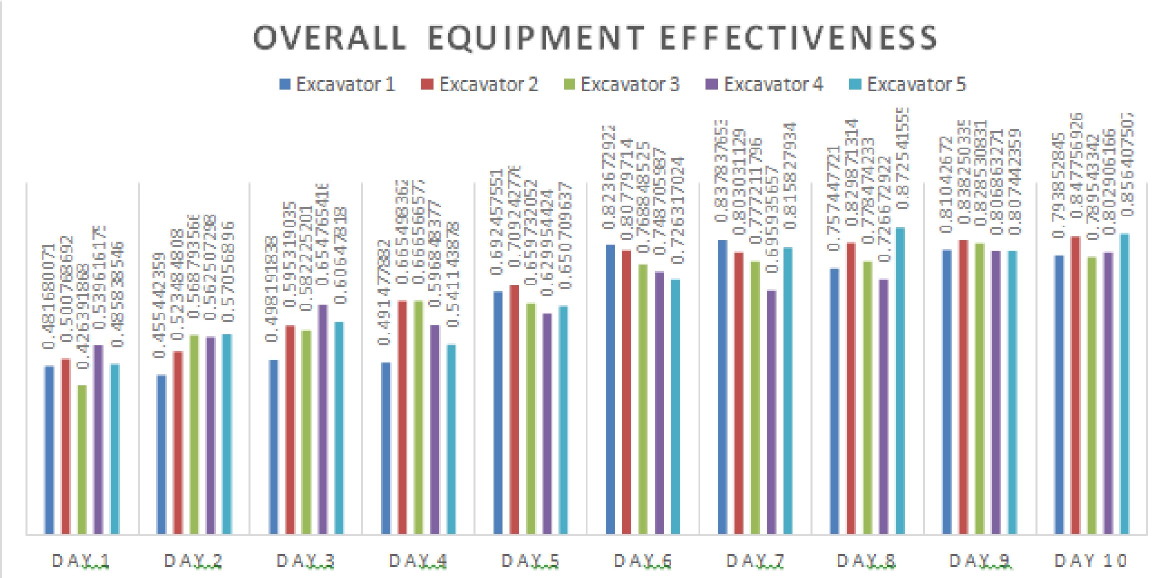
Graph 4. Performance rate graph

Finally,

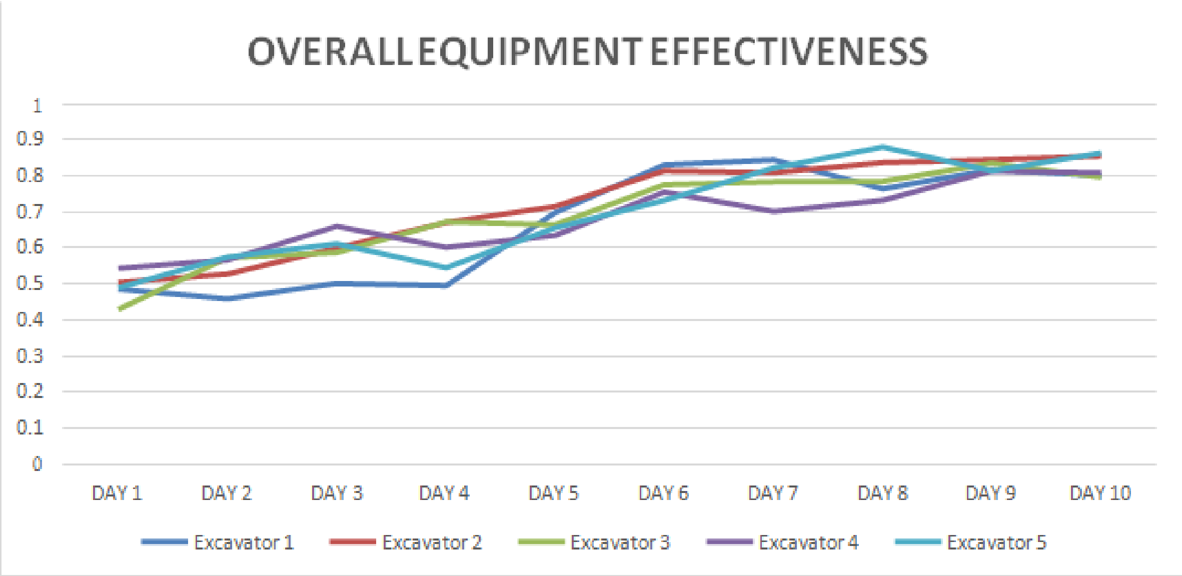
OEE = AR * PR * QR

As OEE is based on three parameters, individual calculations are carried out for the availability, performance, and quality rates of the three primary components of the overall equipment effectiveness index, as shown above. Moreover, the OEE index is the product of the three direct component rates. Its value can only be equal to or less than the lowest rate among the three primary component rates. This result identified the main contributing factors for productivity loss in their order. The most contributing factors are found within the lowest primary component of the OEE index.

This OEE calculation quantifies how well the construction equipment performs relative to its designed capacity when scheduled to execute certain activities. OEE defines a machine's expected performance, measures it, quantifies the extent of equipment productivity and provides less structure for analysis, which leads to improvement. It can be used as a tracking measure to see if progress is to be sustained.



Graph 5. OEE graph



Graph 6. Improvement in the OEE graph

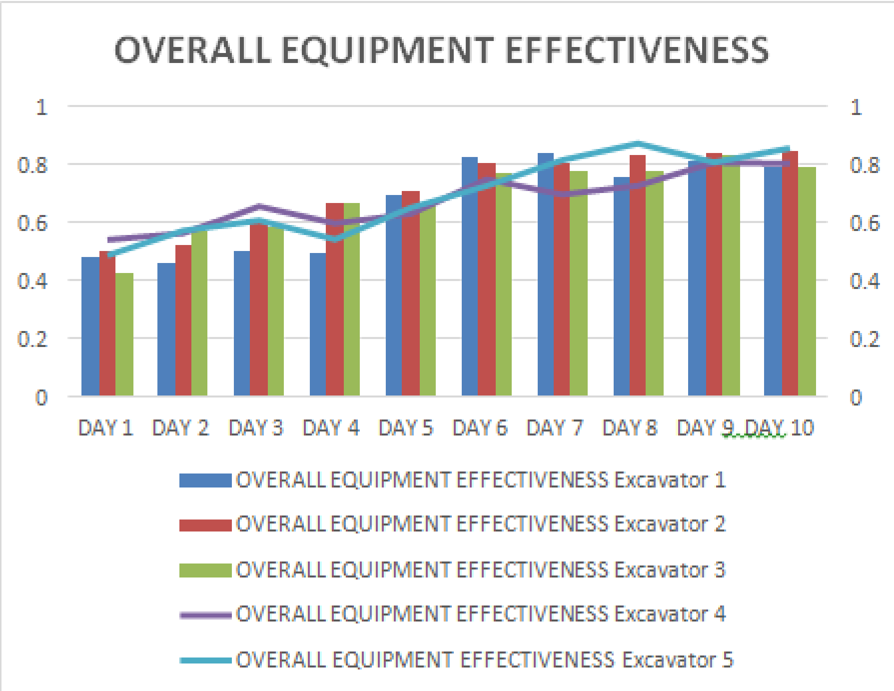
9. Conclusion

The road construction sector is one of the significant absorbers of the country' s budget. In this regard, the allocation of construction equipment consumes about one-third of the total road project cost. According to the study results, most contracting companies use on-site production as a base to estimate operating costs. Others jointly use three methods (historical data from experience, recommendations from equipment manufacturers and onsite production rate). Using onsite production rate as the only base to estimate operating cost is irrelevant to companies that expect reasonable profits. Most of the time, the equipment' s hourly production rate is below standard at construction sites because of different site conditions and management problems.

Also, it is better to do corrective maintenance when necessary to increase the efficiency of the equipment. In addition, unplanned or unscheduled maintenance is essential because equipment can break down suddenly. Therefore, using all maintenance methods to make equipment more productive is better.

These causes of construction equipment planning and management problems negatively affected project performance. Losses in the productivity of equipment, time overrun, cost overrun, and equipment-related accidents are some of the significant impacts of construction equipment planning and management problems. Most results, like loss in productivity of equipment, time overrun, and equipment-related accidents, are reflected in cost overrun.

The performance of equipment effectiveness is evaluated based on actual on-site measurements. This actual onsite construction equipment effectiveness is assessed by overall equipment effectiveness (OEE) indexes. As proved by the case study, the actual on-site performance of equipment could be better due to different management problems. All the analyses show that the OEE of construction equipment ranges from 50% to 60%. This indicates that the equipment productivity rate is almost half its capacity.



Graph 7. OEE Graph

The performance of equipment effectiveness is evaluated based on actual on-site measurements. This actual onsite construction equipment effectiveness is assessed by overall equipment effectiveness (OEE)indexes. OEE analysis concluded a significant flaw in the performance factor of the equipment. All three-piece kits do not deliver the expected output. OEE for Tata Hitachi Ex 200 LC Poclain excavators ranges from 50-60%, which shows a lack of productivity and performance. OEE for Tata Hitachi Ex 200 LC poclain excavators is 50-55% for the first three days, which is acceptable but can be improved as the machine shows a rate drop-in performance rate factor. The overall conclusion of the OEE Analysis shows that all devices were available for more time, but because of a lack of performance, machines showed low productivity. At the same time, quality factors depend upon the equipment operator and the activity's management.

10.Recommendations

After a detailed inspection of construction equipment planning and management issues, their causes and consequences, recommendations can be forwarded to the contractor. This recommendation was meant to ease the planning and management of construction machinery in the Dharmshala Vighakot road construction project. The following recommendations are forwarded to the authorities.

Recommendations at the management level:

1. Should give awareness training for site engineers about equipment planning and management policy and how to manage equipment at the project level.
2. Collect data about the construction equipment's current status and equipment efficiency at the project level.
3. Develop optimisation methods to use available equipment resources effectively and efficiently; Management has to establish a training centre, to train unskilled and semi-skilled operators.

Recommendations for maintenance of equipment:

1. Consider poor maintenance and use of non-original parts as the leading cause of machine failure during use.
2. Wait until the failed machine is completely repaired and ready.
3. Determine equipment’ s economic life based on maintenance and repair costs.
4. Dispose of or replace equipment when it is technologically obsolete.

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