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LITERATURE REVIEW ON HAULING EQUIPMENT PRODUCTIVITY USING CYCLE TIME CALCULATION

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Abstract -*The construction industry is one of the largest industries in the world. The need for mechanization arises due to the magnitude & complexity of the project. Proper use of appropriate equipment contributes to economy, quality, safety, speed and timely completion of the project. Hence construction equipments play an important role in any construction process. Hauling equipments are used for moving material from one location to another. Productivity of equipment reflects in the whole project performance. Estimating actual productivity is hence an essential element in calculating the time and cost required to complete construction work. Productivity of hauling equipment can be estimated by measuring the cycle time. It is the period required to complete one cycle of an operation or a function from start to finish. Cycle time is used in differentiating the total duration of a process from its run time. In this paper, a literature review was conducted in order to identify the most significant factors that affect the cycle time of hauling equipment and hence the productivity*

Key Words: Cost, Cycle time, Hauling equipment, Productivity, Time, etc

1. INTRODUCTION

Hauling or transport equipments are used to move materials from one location to another. Types of hauling equipment used in construction activities include cranes, bulldozers, excavators, loaders, shovels, tractors and trucks. Productivity is the most important factors affecting the overall performance of any construction project. Productivity measurement at construction site level enables the companies to monitor their performance. The selection of the appropriate type and size of construction equipment often affects the cost, time and effort and thus the job-site productivity of a project. It is therefore important for site managers and construction planners to be familiar with the characteristics of the major types of equipment commonly used in construction. Equipment productivity depends upon availability of raw material, power, skill of workers, machine layout etc.

1.1 Literatures on Factors Affecting Hauling Equipment Productivity

Salem A et.al. (2017) investigated the factors affecting productivity of hauling equipment using fuzzy set theory. A questionnaire has been distributed over eighty (80) construction specialists whom are involved in earthmoving and highway construction projects. The responses are analyzed using fuzzy set theory and are then ranked based on score calculated using the developed defuzzification method. Influencing factors are excessive loads , snowy road , age of equipment , muddy road , bad road conditions , engine tuning / maintenance ,power of machine ,operator skills , tire pressure , road with up or down hills , cold weather , loosely soil road , wind resistance, frequent short trips ,wheel slippage and excessive torque .

Mundane Sagar R and Prof. Khare Pranay R. (2015) conducted comparative study on factors affecting productivity and cycle time of different excavators and their bucket size. The objective of the work is to provide an analytical approach for identifying causes of productivity loss, evaluating their effects, evaluating their performance and to understand how the machine is used and how different modes of use relate to its productivity and reliability. The production performance ratio compares the actual productivity against the estimated productivity to demonstrate the amount of loss of productivity and, thus, judge the level of productivity. Measurement of a cycle time is to determine equipment performance and operator efficiency. Factors considered were angle of swing, operator skill, bucket capacity, cycle time recorded, cycle time recorded (theoretical), actual site production/hr, theoretical production/hr, production performance ratio. The production performance ratio observed was relatively low which indicates poor production per hour. It is recommended that high production rates can be obtained by giving proper training to the operator.

Arka Ghosh et.al (2018) investigated the factors influencing productivity of concreting equipment in Indian construction projects. The purpose of this paper was to identify various factors that affect productivity of concreting equipment in construction projects, especially in developing countries such as India. A questionnaire survey was conducted among experienced professionals (managers and site engineers) across the Indian construction industry. Five key factors identified include improper maintenance, unskilled operator, poor planning, inefficient operator and lack of coordination among different crews. The major findings also indicate that engineers and managers share a general perception of the factors affecting equipment productivity.

Priyanka Methe et.al (2018) identified the factors influencing equipment productivity in construction projects. This study was made to discover the productivity and factors influencing the output of the construction tools. Responses collected through survey study from 20 organizations related with the construction of buildings have been examined using theoretical tool like relative importance index (RII) method. Group I: operators/ human factors include lack of ability of operator, lack of experience, disloyalty, personal problems and lack of training. Group II: resource/ equipment factors include delay in placing the equipment, two or more groups sharing an equipment, equipment breakdown, lack of proper maintenance and spares not available. Group III: technological factors include rework, compatibility and steady among contract records, condition of haul road, excess travel/ lifting and obstacle on site. Group IV: management factors include lack of supervision, improbable planning and expectation of labour execution, communication between site administration and operator non -payment of charges/ delay in payment and interfacing of activities .group V: environmental factors include temperature and humidity effects, rain, snow, wind effects and sandstorm and type of soils.

Mudumbai Krishnaswamy Parthasarathy et.al (2017) conducted a critical review on factors affecting manpower and equipment productivity in tall building construction projects. The construction of tall buildings in developing countries is undertaken as a combination of manpower and equipment to economize costs. This research aims at studying the factors affecting productivity of manpower and equipment at the micro level for the basic activities of construction for tall building projects. The factors have been further grouped and combined as sections. Responses collected through questionnaire survey from 109 personnel associated with the construction of 72 tall buildings in different geographies of India have been analyzed using theoretical tools like frequency index, spearman's rank correlation coefficient, and factor analysis. Factors identified include lack of skill of operator, lack of support staff, lack of proper maintenance, improper planning of work, non-availability of materials, interfacing of activities, improper access and egress, excess travel/lifting, extreme weather conditions, lack of support equipment, on-availability of fuel, spares not available, lead time, delay in installing the equipment, two or more gangs sharing an equipment, equipment breakdown, substandard spares etc. Three important factors affecting equipment productivity are improper planning of work, lack of skill of operator and equipment breakdown.

Sachin Pindoria et.al (2017) conducted a critical review of identification of factors affecting the productivity of construction equipment. The study involved the general information about the productivity of construction equipment. For the study 17 factors were identified from the literature survey. They are: company policy, site ground condition, company project forecast, commercial consideration, procurement method, work night shift, site congestion, obstacle on site, project specialization, dependence on out sourcing, shifting responsibility to external party, progress plan, dependent on other equipment, previous experience, labor availability, heavy traffic, strong winds.

1.2 Literatures on Hauling Equipment Productivity Estimation

Ali Montaser et.al (2011) estimated the productivity of earthmoving operations using spatial technologies. This paper presents an automated methodology for calculating productivity of earthmoving operations in near real-time. The developed methodology utilizes global positioning system (GPS) and goggle earth to extract the data needed to estimate productivity of the tracked operation. A GPS device is mounted on one of the hauling units to capture the spatial data along hauling roads considered for the project. 79 cycle times were then used to model the uncertainty associated with the operation. This was carried out by data fitting and computer simulation. The data fitting was carried out using a commercially available software system to generate the probability distribution used in the simulation software “Extend”. The simulation was utilized in optimizing the production of excavator with that of the hauling units. An example project was considered to compare the results obtained using the developed methodology and those actually recorded on a building construction job site in the west end of Montreal. This study showed that the results of the simulation analysis of the probabilistic model are close to actual conditions and indicate that the methodology can be useful in tracking and control of earthmoving operations.

Hoang Nguyen et.al (2014) conducted a study for determination of shovel -truck productivities in open -pit mines. Productivity is dependent both on the number of trucks in use and the number to trips they make per shift. Cycle time depends on time to complete one cycle of operation consisting of loading time, hauling time, dumping time, and time of back to the load point. This cycle time also continually changes as the face advances, since both hauling and return times will increase.

Rashidi A et.al (2014) conducted a study on productivity estimation of bulldozers using generalized linear mixed models. This paper proposes a generalized linear mixed model as a powerful tool to estimate the productivity of Komatsu D-155A1 bulldozers that are commonly used in many earthmoving job sites in different countries. The data for the numerical analysis are collected from actual productivity measurements of 65 bulldozers. The outputs of the proposed model are compared with the results obtained by using a standard linear regression model.

Ashish Singla et.al (2016) studied on the cost and productivity analysis of equipments for flexible pavement. A case study was conducted to evaluate per hour productivity of excavator, loader, backhoe loader, grader, paver, hot mix plant , soil compactor, tipper truck and tandem roller used in various projects in Punjab and Chandigarh for construction of flexible pavement with appropriate methods. Collection of data related to calculation of productivity of equipments, such as hauling speed of tipper, hoe capacity of excavator etc, was made by observing equipments on Patiala road construction project. All the methods and procedures are adopted from the book named "Construction Planning, Equipment and Methods"- by R.L Peurifoy, The Mc Graw Hill Companies Inc, and Edition 7. Results for per hour productivity of equipments working at an efficiency of 50/60 minutes are compared with pre-estimated values by the contractors of the various projects and came out to be considerable.

Seung C. Ok and Sunil K. Sinha (2007) estimated the construction equipment productivity using artificial neural network model. This study develops and compares two methods for estimating construction productivity of dozer operations (the transformed regression analysis, and a non-linear analysis using neural network model).The hypothesis of this study is that the proposed neural networks model may improve productivity estimation models because of the neural network's inherent ability to capture non-linearity and the complexity of the changeable environment of each construction project. The comparison of results suggests that the non-linear artificial neural network (ANN) has the potential to improve the equipment productivity estimation model.

2. HAULING EQUIPMENT PRODUCTIVITY USING CYCLE TIME CALCULATION

A key element with which construction industries should be concerned is with respect to cost and efficiency of equipment operation. A reduction in operational time can result in dramatic improvements in both cost and efficiency. Cycle time is the period required to complete one cycle of an operation or to complete a function, job, or task from start to finish. Cycle time is used in differentiating total duration of a process from its run time. Unfortunately, cycle time problems are sometimes difficult to analyze: there are many factors related to this parameter. Time studies are conducted in order to determine the value of cycle time. Time study may be defined as" the art of observing and recording the time required to do each detailed element of an industrial activity/operation

David J. Edwards et.al (2007) generated a model for calculating excavator productivity and output costs. Hydraulic excavator cycle time and associated unit costs of excavation for given input estimating data, for machines operating in the UK construction industry, are predicted. Using multiple regression analysis, three variables are identified as accurate predictors of cycle time: machine weight, digging depth and machine swing angle. The paper concludes with a spreadsheet model for calculating excavation costs (m3 and cost per h) which is able to deal with any combination of the three independent cycle time predictor variables and other estimator's input data.

2.1 Literatures on Hauling Equipment Productivity Using Cycle Time Calculation

Hoang Nguyen et.al (2014) conducted a study for determination of shovel -truck productivities in open -pit mines. Productivity is dependent both on the number of trucks in use and the number to trips they make per shift. Cycle time depends on time to complete one cycle of operation consisting of loading time, hauling time, dumping time, and time of back to the load point. This cycle time also continually changes as the face advances, since both hauling and return times will increase.

$$\text{Productivity of Truck} = \frac{60 \text{ x Pay load}}{\text{Time Cycle (min)}}$$

This study leads us to the conclusion that the productivity and efficiency of a shovel and truck combination can be achieved by the proper allocation and matching of trucks to a given shovel. This will also reduce losses in the potential productivity. The efficiency of the same shovel-truck system can also be affected by variations material properties of the overburden of the mine. A random increase in the number of trucks, in hopes of increasing the productivity may result in loss in productivity.

Marsudi.M and Shafeek.H (2014) presents a cycle time analysis of a tipping trailer frame in a heavy equipment industry. The cycle time analysis, based on the cycle time data collected by a time study, together with the use of an Arena software simulation, is outlined. From the results of this study, it was found that the manufacturing cycle time was 56 hours, and that resources were under-utilized.

Javier Bonal et.al (2016) conducted a study on productivity improvement through cycle time analysis. A cycle time (CT) reduction methodology has been developed in the Lucent Technology facility (former AT&T) in Madrid. It is based on a comparison of the contribution of each process step in each technology with a target generated by a cycle time model. These targeted cycle times are obtained using capacity data of the machines processing those steps, queuing theory and Theory of Constrains (TOC) principles (buffers to protect bottleneck and low cycle time/inventory everywhere else). Overall Efficiency Equipment (OEE) like analysis is done in the machine groups with major differences between their target cycle time and real values. Comparisons between the current value of the parameters that command their capacity (process times, availability, idles, reworks, etc.) and the engineering standards are done to detect the cause of exceeding their contribution to the cycle time.

Siyuan Song et.al (2017) analyzed the impact variables of dump truck cycle time for heavy excavation construction projects. The objective of this research is to scientifically identify and quantify variables that have a significant impact on the cycle time of a dump truck used for earthwork. Real-time location data collected by GPS devices deployed in an active earthwork moving construction site was analyzed using statistical regression. External data including environmental components and haul road conditions were also collected periodically throughout the study duration. Several statistical analyses including a variance analysis and regression analysis were completed on the dump truck location data. Results indicate that a dump truck's enter idle time, exit idle time, moving speed and driver visibility can significantly impact the dump truck cycle time.
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Emmanuel K. Chanda and Steven Gardiner (2010) conducted a comparative study of truck cycle time prediction methods in open-pit mining. The purpose of this paper is to compare the predictive capability of three methods of truck cycle time estimation in open-pit mining: computer simulation, artificial neural networks (NNs), and multiple regressions (MRs). The aim is to determine the best method. The most common method currently used is computer simulation. Truck cycle times at a large open pit mine are estimated using computer simulation, artificial NNs, and MRs. The estimated cycle times by each method are in turn compared to the actual cycle times recorded by a computerized mine monitoring system at the same mine. The errors associated with each method relative to the actual cycle times are documented and form the basis for comparing the three methods. The paper clearly indicates that computer simulation methods used in predicting truck cycle times in open-pit mining underestimate and overestimate the results for short and long hauls, respectively. It appears that both NN and regression models are superior in their predictive abilities compared to computer simulations.

3. CONCLUSION

Construction equipments play an important role in construction industry. About 30% of overall construction cost accounts for equipment. Hauling equipments are used for construction activities such as earthmoving operation; transportation of cement from plant to site etc. Productivity of hauling equipment depends on the operation time i.e., the cycle time. A reduction in operational time can result in dramatic improvements in both cost and efficiency. Cycle time problems are sometimes difficult to analyze: there are many factors related to this parameter. From the literature survey prominent factors affecting cycle time of hauling equipment were identified. They are

Table -1: List of factors identified from literature reviews

Sl.no	Factors	Sl.no	Factors
1	Hauling time	11	Driver's visibility
2	Hauling distance	12	Previous experience
3	Loading time	13	Planning
4	Dumping time	14	Site and haul road condition
5	Idle time	15	Equipment breakdown
6	Speed	16	Availability of fuel
7	Traffic	17	Spare parts availability
8	Environment	18	Lead time
9	Site management	19	Influence of external party
10	Supervision	20	Labour availability

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