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ASSESSMENT OF FACTORS AFFECTING PRODUCTIVITY OF EXCAVATOR

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Abstract — *Heavy equipments plays major role for completion of construction task timely and successfully. The dependence and need for heavy construction equipment have grown with the size and complexity of construction projects. Today contractors undertake many types of construction activities that require different types, size and groupings of equipment for earthmoving, excavating and lifting. Every construction project includes earthmoving and then excavating operations. Excavators are one of the most commonly used heavy equipments in construction sector. These excavators should give their best performance at job site but in actual condition, they fail to provide desired output. Various factors might be responsible in such cases. This study aims to identify and assess such factors. Total 20 factors were identified and a questionnaire was prepared. Questionnaire and field survey has been carried out in this study by visiting different construction site with ongoing excavation work. The field survey included time-motion study and observation of some field parameters. The collected data from questionnaire survey was analyzed by Relative Importance Index technique and ranking was done. On analysis, it is found that, operator skill is a factor which is found to be most important from both surveys. Apart from this, the effects of other factors is described and concluded in this study.*

Keywords- *Excavating equipment, Productivity, Performance Factors, Construction Equipment, Excavator Performance*

I. INTRODUCTION

Construction Industry is one of the most booming industries in the whole world. This industry is mainly an urban based one which is concerned with preparation as well as construction of real estate properties. Today Indian sub continent is the second fastest-growing economy in the World. The Indian construction industry has been playing a vital role in overall economic development of the country. The construction sector is also the second largest employer in the country following agriculture, employing 18 million people directly and 14 million indirectly. (Dr.Pa.Kaja Mohideen, 2015)

Today contractors undertake many types of construction activities that require different types, size and groupings of equipment for earthmoving, excavating and lifting. The Indian construction equipment industry is a fraction of the global market, whose size is over US$ 75 billion, it has been growing at an average of 30 per cent annually compared to the global growth of 5 per cent. The earthmoving equipment market in India is estimated at about US$ 1.4 billion. The predominant sub-segment in this is excavators, which account for just over half the market (A report by KPMG for IBEF). The dependence and need for heavy construction equipment have grown with the size and complexity of construction projects. The development of automated heavy construction equipment for earthmoving, excavating and lifting occurred in last two centuries. Today, it is assumed that if equipment does not exist to perform a necessary task, it can be designed and built.

II. NEED OF STUDY

Machinery and equipment play a pivotal role in completion of any construction project successfully. The need for mechanization arises due to the reasons such as, magnitude & shortage of skilled and efficient manpower, optimum use of material, manpower and finance, importance of keeping the time schedules, high quality standards, complexity of projects, projects involving large quantities of material handling. Proper use of appropriate equipment contributes to economy, quality, safety, speed and timely completion of the project. Equipment selection is a critical factor in the execution of many construction projects. This is to be much more critical in heavy construction projects where the earthmoving equipment plays a vital role in performing the work (Remon F. Aziz et al. 2015). Numerous factors are involved in fair performance of equipment. Such factor must be identified so as to achieve good command over that equipment. This study aims to study and identify factors influencing performance of excavating equipment.

III. METHODOLOGY

The research methodology consists of two different surveys. One is the questionnaire survey whereas other is a field survey. These surveys were carried out in Amravati and Pune cities from Maharashtra state. Total 32 different sites were visited for this study where excavation work was in progress. The literature review was conducted through books, internet and various international journals to identify various factors that influence performance of excavating equipments.

A. Questionnaire Survey:

Based on the literature review, total 20 factors were selected for this study which affects excavator's performances. Some of the selected factors are equipment related, some are human related and some are site related. These factors are represented in table 3.1 The prepared questionnaire was filled by different authorized persons such as, Engineer, Manager, Site In charge and Supervisor etc. whoever is present on site during excavation execution. The respondents were asked to indicate, based on their local experience and level of importance of each one of the identified factor of performance on five-point Likert scale as; not important, slightly, moderately, very and extremely important. The analysis was then carried out.

Table 3.1: Identified Factors Influencing Performance of Excavating Equipment

Sr. No.	Factors
1	Measuring Productivity of Excavator
2	Proper Site Investigation
3	Proper Selection of Equipment
4	Repairs and Maintenance of Equipment
5	Experience of Contractor
6	Presence of Site Engineer
7	Type of Equipment
8	Proper Handling of Equipment
9	Sufficient Knowledge about Machine
10	Condition at Site
11	Type of Soil
12	Condition of Equipment
13	Operator's Skill
14	Bucket Capacity
15	Bucket Teeth
16	Cycle Time
17	Angle of Swing
18	Height of Cut
19	Availability of Hauling Unit
20	Capacity of Hauling Unit

Relative Importance Index:

The data collected in the questionnaire was analyzed by Relative Importance Index (RII) method to determine relative importance of factors influencing performance of excavating equipment. The RII was used to rank those different factors which made it possible to cross compare the relative importance of those factors.

The formula to calculate relative importance index is as follows,

$$R.I.I. = \frac{\sum W}{A\ X\ N}$$

Where,

RII = Relative Importance Index

W = Weightage given to each factor by respondent ranging from 1 to 5.

A = Highest Weight (i.e. 5)

N = Total number of respondents

B. Field Survey:

This study was conducted at 32 job site with total 32 piece of back hoe excavating equipment individually. The actual job operating condition which might affect the productivity were identified and recorded accurately for each individual piece of equipment in the study. These operating conditions include Type of Soil, Bucket Capacity, Operator's Skill, Angle of Swing, Depth of Cut, Condition of Equipment and Capacity of Hauling Unit.

Time-Motion Studies were conducted for piece of excavating equipment. These are the operating piece of equipment that was encountered on site visit. The total cycle time including time for its element was recorded with stopwatch. Several cycle times were measured on site and average value of them was considered for calculation. The productivity for each of equipment was then estimated. Formula to find out the productivity of a hydraulic excavator as given by Peurifoy and Schexnayder (2008) is expressed by the following relationship:

$$Hoe\ (excavation)\ Production\ (Cum./Hr.) = \frac{3600\ X\ Q\ X\ F}{t}\ X\ \frac{E}{60-\text{min}\ hour}\ X\ \frac{1}{volume\ \ correction}$$

Where,

Q = Heaped bucket capacity in cubic meter

F = bucket fill factor for hoe buckets

t = cycle time in seconds

E = efficiency in minutes per hour

Volume Correction = for loose volume to bank volume, $\frac{1}{1+swell\ \ factor}$

IV. RESULTS AND DISCUSSIONS

In this study, total 32 sites were visited among which, 72% sites were from Pune and 28% sites were from Amravati. Total 32 questionnaires were filled and collected from respondents. The most commonly used excavator was found to be JCB which was found on 35% of construction sites. Whereas 22% were L&T Komatsu, 19% were Tata Hitachi, 9% were Volvo and remaining 15% were others.

4.1 Results of Questionnaire Survey

The data collected from questionnaire survey was analyzed by using Relative Importance Index. Different professionals have given their respective responses on the basis of their own experience and opinions. Table 4.1 represents R.I.I. and Ranking given to those selected factors.

Table 4.1: R.I.I. and Ranking of Identified Factors Influencing Performance of Excavating Equipment

Sr. No.	Factors	R.I.I.	Rank
1	Measuring Productivity of Excavator	0.600	20
2	Proper Site Investigation	0.713	14
3	Proper Selection of Equipment	0.825	9
4	Repairs and Maintenance of Equipment	0.856	6
5	Experience of Contractor	0.694	19
6	Presence of Site Engineer	0.788	11
7	Type of Equipment	0.725	13
8	Proper Handling of Equipment	0.863	5
9	Sufficient Knowledge about Machine	0.838	8

10	Condition at Site	0.700	17
11	Type of Soil	0.894	3
12	Condition of Equipment	0.706	16
13	Operator's Skill	0.963	1
14	Bucket Capacity	0.888	4
15	Bucket Teeth	0.919	2
16	Cycle Time	0.763	12
17	Angle of Swing	0.694	18
18	Height of Cut	0.706	15
19	Availability of Hauling Unit	0.850	7
20	Capacity of Hauling Unit	0.800	10

The factor Operator's Skill has been ranked highest i.e. first with RII of 0.96. Most of the respondents have given importance to operator's skills as working of equipments is mainly based on its operator. More the operator is effective; more is the output from equipment. After that, Bucket Teeth, Type of Soil, Bucket capacity and Proper Handling of Equipments found to be more important parameters respectively. Measuring Productivity of Equipment has been ranked at last position i.e. twentieth rank as respondents have not given that much importance to this factor.

4.2 Results of Field Survey

Some factors that are controllable on construction site have been considered in this survey. The data collected from various sites has been analyzed and discussed here. The production of excavators has been calculated for each of site visited considering soil properties with varying bucket sizes. Recorded cycle time through time motion study is considered for calculating actual production whereas, standard cycle time is considered for calculating theoretical production. Varying production of excavating equipment for all sites with respect to different field factors is represented graphically in fig. 4.1.

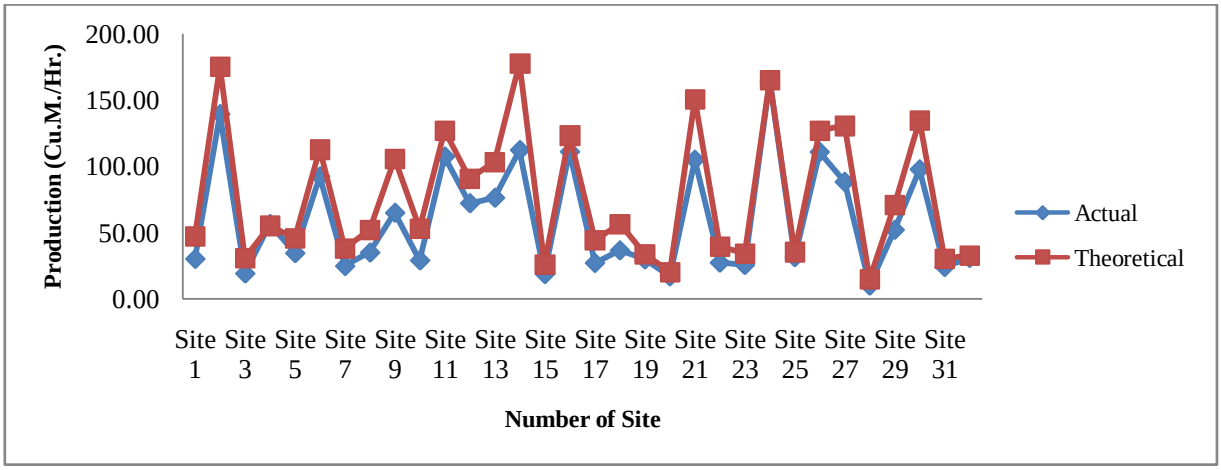

Fig. 4.1: Comparison between Actual and Theoretical Production

Above figure represents comparison between actual and theoretical production of excavators for 32 different sites. From figure, it is clear that, for most of the sites, the actual production is found to be lesser than theoretical production. This means the production occurring there is less than what it should be as per the site conditions and the professionals are getting failure to obtain the output that are planned in initial stage.

The graphs represented bellow from fig. 4.2 to fig. 4.7 shows production of excavators for different field factors from data observed from all sites. In fig. 4.7, on x-axis, 1 indicates Earth Dry, 2 indicates Rock Well Blasted, 3 indicates Rock Poorly Blasted and 4 indicates Wet Clay type of soils.

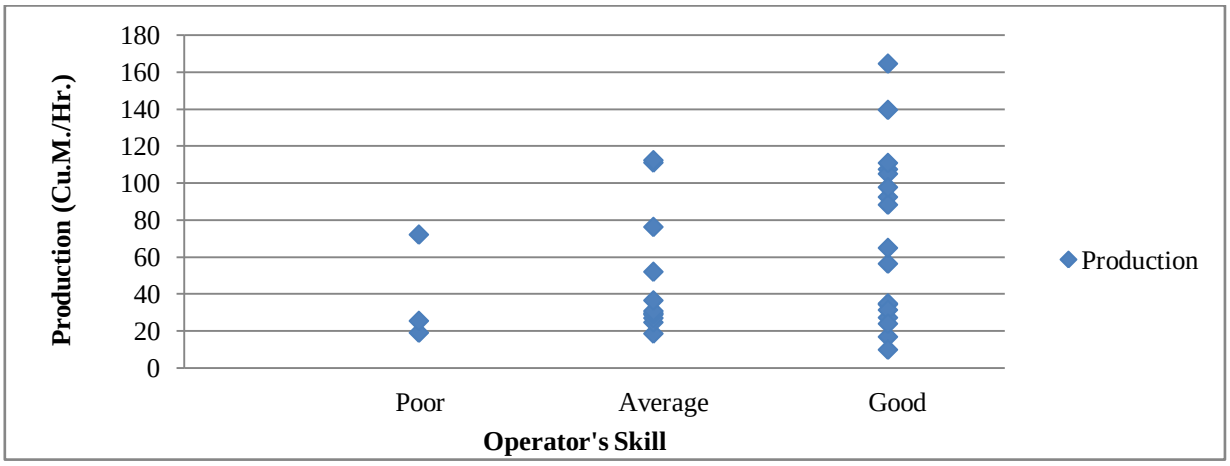

Fig. 4.2: Operator's Skill against Production

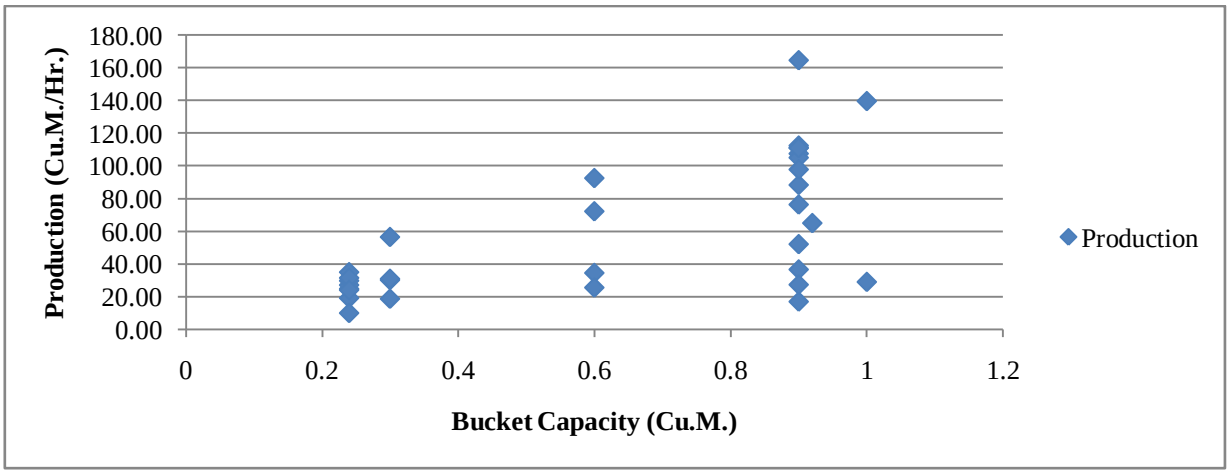

Fig. 4.3: Bucket Capacity against Production

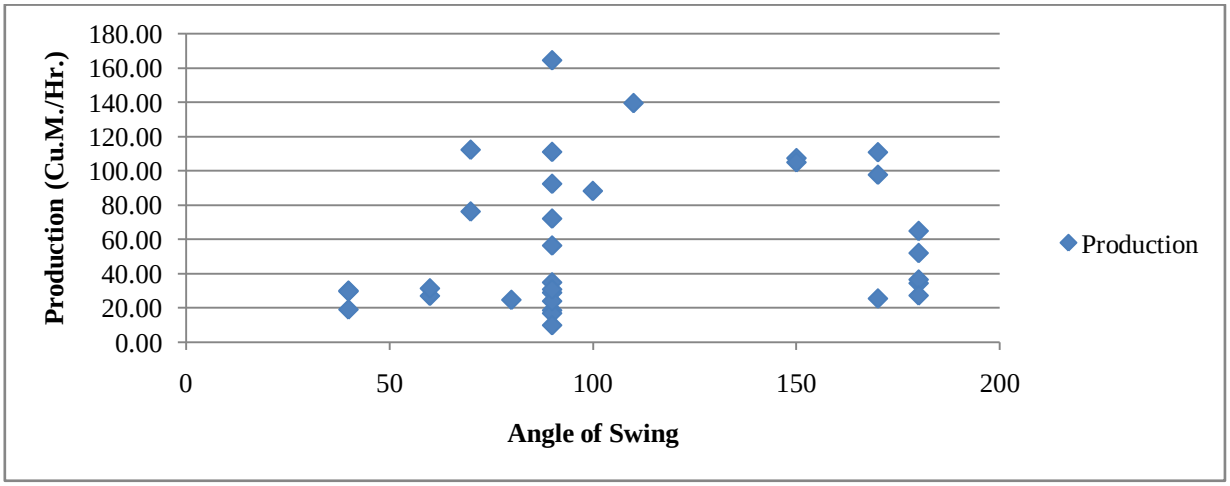

Fig. 4.4: Angle of Swing against Production

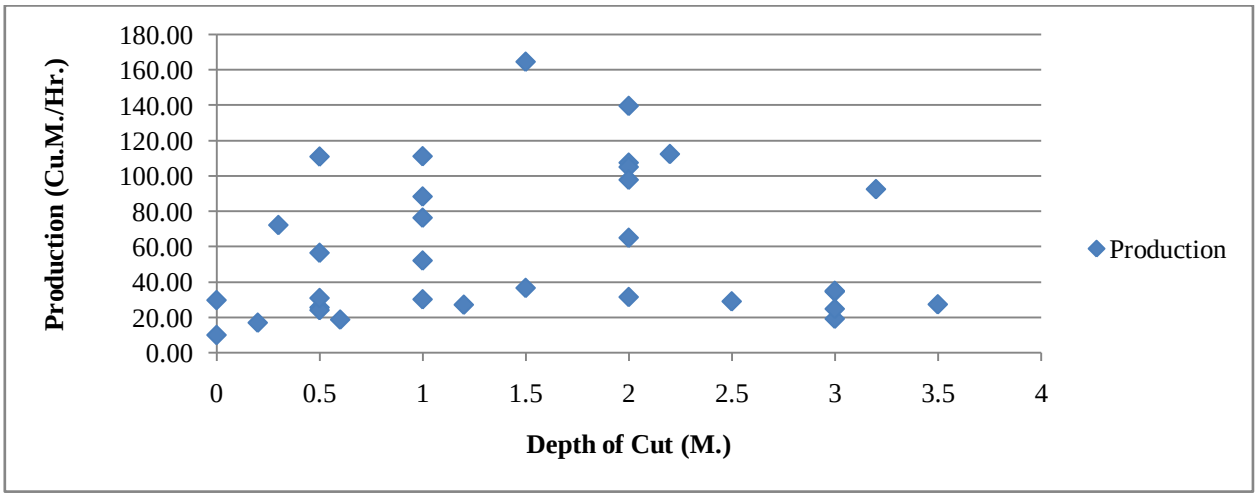

Fig. 4.5: Depth of Cut against Production

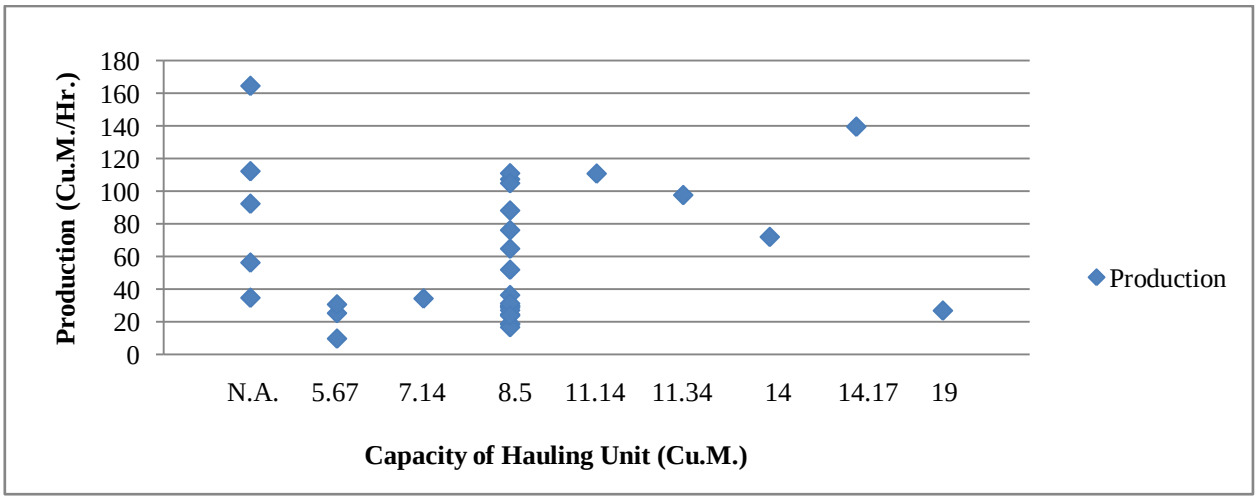

Fig 4.6: Capacity of Hauling Unit against Production

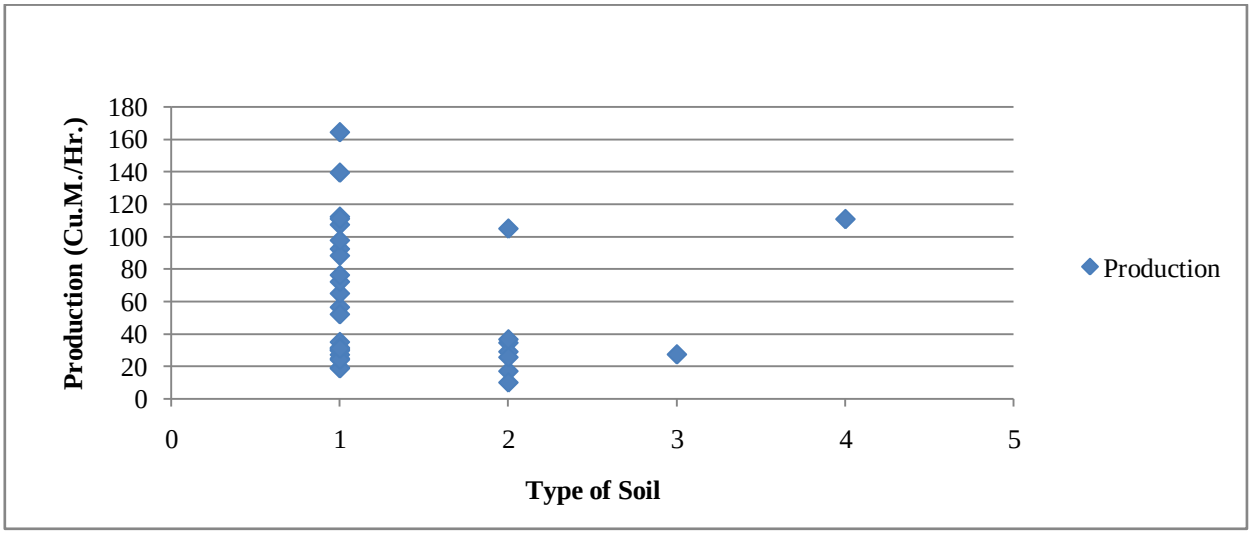

Fig 4.7: Type of Soil against Production

From above graphs, the production found to be maximum for good skilled operator. More bucket capacity provided more material excavation. Availability and capacity of hauling unit plays important role in time saving and increasing efficiency of equipments. Type of soil is an important factor on which performance of excavator depends. Because, soft soil provides easy access for equipment during excavation.

V. CONCLUSIONS

Every construction project includes earthmoving operations and use of equipments to perform some tasks. Excavators are primary earthmoving equipments used to excavate earth material. The equipment are expected to give their best performance on field but in actual job site, contractors fails to achieve the desired output from excavator. Various factors might be responsible in such cases. This study has focused on such factor to identify and assess them.

On the basis of questionnaire and field survey carried in this study, following salient conclusions can be drawn,

1. Operator's Skill has ranked first with highest R.I.I.. it is found to be most affecting factors on excavators productivity.
2. Bucket teeth, Type of Soil, Bucket Capacity and Proper Handling of Equipment are found to be important factors after Operator's Skill respectively whereas measuring Productivity of Excavator obtained last position by respondents.
3. Angle of swing between 60° to120° provides maximum production to the excavator. Also, cycle time plays important role in productivity of excavator.
4. From analysis of field data collected from 32 sites, productivity of excavator for each site was estimated. The actual production of excavator has been found less than theoretical production for near about 81% percent of visited sites.
5. Operator's Skill is the factor that has got more importance in both questionnaire and field survey as well. Maximum productions are occurred for good skilled operator.
6. Efficiency of excavator plays a vital role in its productivity. It is the working minutes per hour.
7. Availability, capacity and proper position of hauling unit can save cycle time and improve efficiency of equipment increasing its productivity.
8. Considering the field parameters while execution, the owner and mangers can save excavation task from facing problems like delays and extra cost.

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