

# Evaluating Excavation Equipment Productivity Constant for Construction Project

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**ABSTRACT:** A considerable body of literature has been dedicated to research studies on construction equipment. Many topics were discussed and analyzed and various conclusions have been reported. Construction projects suffer various problems and complex factors such as cost, duration, quality and safety. Construction sector is diverse as it contains contractors, consultants, designers, owners, and others. The aim of this Project is to achieve equipment productivity at a construction project. Many studies have been conducted before but still there is deeper need of understanding the improvement of productivity. The main outcome from the literature is that there is no standard definition of productivity. So to achieve the productivity the maintenance should be given to that of equipment and this maintenance should be are of different types according to the working condition, budget, cost etc. factors. This study includes different factors which affects the productivity of the equipment. The factors which affect the performance of equipment include job, maintenance, working days, fuels/energy, expenses on repair/maintenance From the given study we have find out different factors which affects the selection of equipment and maintenance of equipment for giving the better output i.e., nothing but improving productivity. The project includes the specifications of the excavation equipment and the working capacity. The daily working hours of equipment on site and the cost estimation of particular equipment used. To achieve these objectives a methodology is adopted towards improving productivity are; Understanding the need of productivity improvement, General types of productivity, Identification of critical success factors and their effective implementation in Maintaining productivity.

**KEYWORDS:** Construction equipment Productivity, Productivity Loss, Productivity Measurement, Improvement Techniques.

## I. INTRODUCTION

### 1.1 Introduction

Construction people have to improve their productivity in order to survive in the highly competitive environment of the industry. Hence, productivity has been generating significant interest in both the construction industry and academia. Construction industry is considered as an industry that contributes significantly to the growth of the economics of the country. Construction is borne out of politico-socio-economic consideration and hence, they have an immeasurable influence on construction technology and management of project effectively and efficiently. Construction, in fact, is ladder of development. Construction industry sector can be broadly divided into building and construction. The earthmoving and heavy equipment industry has always operated in a very competitive environment. For decades, cost-effectiveness and productivity have been of paramount interest, and great strides have been made in these areas. Since World War II the heavy equipment industry has experienced numerous cycles of good times and bad times. The average period of these business cycles has been six years. The current cycle, which peaked in 1981, has now

# International Journal of Innovative Research in Science, Engineering and Technology

*(A High Impact Factor, Monthly, Peer Reviewed Journal)*

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Vol. 8, Issue 5, May 2019

experienced the steepest decline the industry has seen in 40 years (Broad 1986). Total sales of construction equipment dropped 42% between 1981 and 1983. Although some forward progress has been made in the past two or three years, the 1985 sales volume was probably 25% below 1981 levels in terms of constant dollars. The utilization rate of construction equipment is concerned with identifying the total available time of the onsite equipment for production. The efficient utilization of construction equipment plays an indispensable role on the success of a construction project. It could contribute not only to support the construction equipment management, but manage the project cost. In order to achieve the maximum equipment investment return, it is necessary to collect the utilization information of onsite equipment in a timely and accurate manner. Large scale construction activities like road-making, construction of railroads, canals, irrigation and power dams, development of building sites, airports and harbours are clear indicators of growth of a developing country. The activities of a construction industry have been growing very steadily commensurate with the requirement of power, communication, transportation and agricultural output of a developing nation like India.

## 1.2 Importance of study

The productivity of the construction industry worldwide has been declining over the past 40 years. One approach for improving the situation is using lean construction. Lean construction results from the application of a new form of production management to construction several problems were noticed regarding the construction equipment in Egypt, including hardships in operations and maintenance, and low productivity. Generally, the writers suspected these problems were due to a lack in the ability to operate the construction equipment efficiently. The productivity is considered in this study as a measurement dimension that sufficiently describes an operator's performance. The productivity in this context represents the volume of earth produced per operator-hour, and the number of work cycles performed per operator-minute. To judge the level of performance, the actual productivity must be compared against a desired productivity (estimated). The performance ability ratio (PAR) is given as the ratio of the estimated productivity to the current productivity. A PAR value close to 1 indicates that the current productivity is relatively good, while a PAR value far greater than 1 indicates a poor productivity.

## 1.3 objectives of study

1. To study various parts of excavator.
2. To find the productivity of excavation equipment its maintenance and management.
3. To improve equipment productivity with suitable suggestions and recommendation.

## 1.4 Scope of study

The equipment capability to perform an assigned task under a given situation can best be determined from the on-site actual trials or it can be assessed from its past performance records of operation under similar site conditions. The main factors which affect the performance of equipment / plant and for which allowance must be made when estimating output are of two types,

- 1) Factors affecting hourly output
- 2) Factors affecting overall output. More importantly the earthwork is the first activity for any project and other activities are dependent on this. Here the planning managers will have to allocate the resources to complete the particular sector of earthwork in stipulated time. The factors affecting the output of excavators are numerous and such a study can help in identifying the factors and for assuming a realistic production figures. The cost of any project will vary from the purchase of equipment so it is necessary to take a look at it with proper planning.

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Vol. 8, Issue 5, May 2019

## II. CONCEPTUAL BACKGROUND

### 1.1 Earthmoving machinery

Donkeys-transport can work to about few furlongs and work can be attempted with bullock carts with lead up to one mile. The truck transport is faster, except for unloading the material, but becomes more costly on initial and running expenses with the result that on large jobs it pays to go in for modern earthmoving equipment. These modern equipment's are still costlier, but the work can be completed with great pace and efficiently bringing down the total expenses for earthwork. Large initial investment is required for earthmoving machinery which can be economically advantageous only when fully utilized. The unit rate of earth work based on total expenditure falls progressively as the earthmoving equipment utilized for longer period of its life and for job involving large quantities of earth work, spread over life time of equipment machinery would be much cheaper than manual labor. Construction Equipment is not the only subject of mechanical engineers. Civil engineers also need to be acquainted with the subject. Civil engineers always look at the rate of production. He wants production at minimum cost so that he can control the rates of contractors. Mechanical engineers feel that their job is to repair and maintain the equipment. Mechanical engineers are equally responsible for more production at economic cost. A good co-ordination and amicable relations between the two can lead to success.

### 1. Hydraulic Excavators

This is a basic earthmoving machine which can be used for different works with different types of front & back attachments. A basic shovel has the means of propulsion of the machine, of revolving the superstructure around and of operating the head attached to it. Hydraulic excavators are classified by digging motion of the boom and stick to which the bucket is attached. It consists of the following,

1. Basic component providing locomotion and power.
2. Revolving superstructure and mounting. Mounting are of three types,
  - a. Crawler mounted
  - b. Wheel mounted
  - c. Truck mounted
3. Attachments to suit the work in hand.

Basically, the excavator is a big, extremely powerful version of our arm or finger. It has three segments:

1. The boom
2. The stick
3. The bucket

This arrangement is very similar to our arm. Our arm has three segments -- upper arm, forearm and hand. The excavator segments are connected by three joints, comparable to our wrist, elbow and shoulder. The excavator moves in pretty much the same way as your arm. In an excavator, the boom is bent upward to make it easier to dig with obstacles in the way. This design also provides extra space for the bucket when the operator curls it in with a full load.

### 2. Front Shovel

In case the digging motion of the bucket is upward, the excavator is known as the "Front Shovel". The breakout force is developed by front shovel by crowding material away from the machine. It can be used to excavate at its own level or at levels higher enough for crowding action. It can be used for all sorts of material. The size of the front shovel is determined by the size of the dipper, expressed in cum. Dumpers are needed with this equipment for disposing the excavated material.

#### 1.1.1 Method of operation

With a shovel in correct position, near the face of the earth to be excavated, the dipper is lowered to the floor of the pit, with the teeth pointing into the face. A crowding force is applied through the dipper shaft, and at the same time tension is applied to the hoisting line to pull the dipper up the face of the pit. If the depth of the face is just right, considering

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Vol. 8, Issue 5, May 2019

the type of the soil and the size of the dipper, the dipper will be filled as it reaches the top of the face. If the depth of the face, referred to as the depth of the cut, is too shallow, it will not be possible to fill the dipper completely without excessive crowding and hoisting tension, and possibly not at all. This subjects the equipment to excessive strains and reduces the output of the unit. If the depth of the face is greater than is required to fill the dipper when operating under favourable crowd and hoist, it will be necessary to reduce the depth of penetration of the dipper into the face if the full face is to be excavated or to start the excavation above the floor of the pit. The material left near the floor of the pit will be excavated after the upper portion of the face is removed. The general operations of a hydraulically controlled shovel differ from those of a cable-operated shovel primarily in those pistons instead of produce the operating forces of the former by cables.

## 2.2 Backhoe

Backhoes are used primarily to excavate below the surface of the ground on which the machine rests. The downward movement of the bucket is known as the “hoe”. The breakout force is developed by hoe by pulling bucket of the material towards the machine. Backhoes are adept at excavating trenches and pits for basements, and the smaller machines can handle general grading work. Because of their positive bucket control they are superior to drag lies in operating on close range work and loading into haul units. Their dumping operation is however more difficult than that of a front shovel. Hoe cycles are approximately 20 % longer in duration than those of a similar size shovel because the hoisting distance is greater as the boom and stick must be fully extended to dump the bucket. They can dig very hard material. Basically backhoes are used for,

1. For digging trenches, footings or basements.
2. Where excavation is below the ground level
3. Where material to be dug is firm and hard
4. Where excavation must be trimmed closely.
5. Where dumping of disposal material is rather at a short range.

### 2.2.1 Method of operation

Start loading the bucket with the stick in a nearly vertical position. The bucket digs best at this point. The bucket tends to ride out of the material if the bucket is not in the vertical position. Don't swing into ditch walls. Clear bank or ditch walls before attempting to swing. On returning to digging position, step the swing before dropping the attachment in the ditch or excavation. When dumping into truck the boom is always raised simultaneously while extending the dipper arm. If dumping into trucks is attempted without raising the boom, the boom will lower as dipper arm is extended and the dipper may hit the truck and cause damage to the truck and the boom.

When a hoe is used to dig at moderate depths, the output may approach the output of a power shovel of comparable size digging in the same class of material. However, as the depth is increased the output of a hoe will decrease considerably. The most effective digging action occurs when the dipper stick is at right angles to the boom. The greatest output will be obtained if digging is done near the machine, because of the reduced cycle time, and because the material rolls back into the dipper better when the dipper is pulled upward near the machine. Backhoe cycle times are approximately 20% longer in duration than those of a similar size shovel because the hoisting distance is greater as the boom and stick must be fully extended to dump the bucket. Optimum depth of cut for a hoe will depend on the type of material being excavated and bucket size and type. As a rule, the optimum depth of cut for a hoe is usually in the range of 30 to 60% of the machine's maximum digging depth. On many sewer jobs an excavator must lift and swing heavy pipe and manholes and unload material from trucks. In some situations the excavator's lift requirements may be so critical that they determine the size excavator selected. An excavator's lift capacity depends on its weight, centre of gravity, the lift point position and its hydraulic capabilities. Changes in boom, stick and bucket position affect attachment geometry and can drastically change a machines hydraulic lifting capacity.

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### 2.3 Size of bucket

In measuring the size of the dipper the earth is struck even with the contour of the dipper. This is referred to as the struck volume, as distinguished from the heaped volume, which a dipper may pick up in loose soil. Owing to the swelling of a soil when it is loosened, the bank measure volume of a dipper will be less than the loose volume. It is possible that a dipper may be heaped sufficiently to give a bank-measure volume equal to the rated size of a dipper. However, this condition will not occur except for easy digging soils, under favourable conditions, and the assumption should not be made unless field test indicate is to be correct. If a 3 cu.m. Dipper, excavating a soil whose swell is 25 percent, is able to fill the dipper to its struck volume only, the bank-measure volume will be  $3/1.25 = 2.40$ .

Rated heaped capacities represent a net section bucket volume and must be corrected to average bucket payload based on the characteristic of the material being handled. Fill factors are percentages that, when multiplied by rated heaped capacity, adjust the volume by accounting for how the specific material will load in to the bucket.

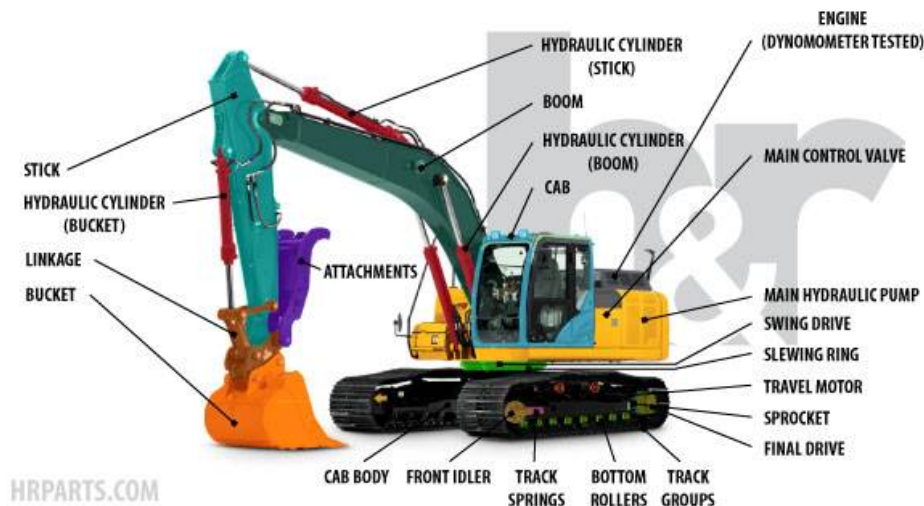


Fig No 02 Different parts of excavator machine

### 2.4 Factors affecting Production of excavator

The actual production of an excavator is affected mainly by the following factors,

- a. Class of material handled
- b. Bucket capacity
- c. Moisture content of materials
- d. Angle of swing
- e. Height / Depth of cut
- f. Horse power of the engine
- g. Operator's skill
- h. Age of excavator

### 2.5 Selection of an Excavator

In selecting an excavator, the two fundamental factors that should be taken in to account are,

- A. The cost per cubic meter of material excavated and
- B. The job conditions under which the excavator will operate

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In estimating the cost per cum, one should consider the following factors,

- a. The size of the job; a job involving a large quantity of material may justify the higher cost of a larger excavator.
- b. The cost of transporting the machine; a large excavator will involve more cost than a small one.
- c. The combined cost of drilling, blasting and excavating; for large excavator, these costs may be less than for a small excavator, as large machine will handle more massive rock than small ones.

The following job conditions should also be considered while selecting the size of excavator,

- a. If the material is hard to excavate, the bucket of the large excavator that exerts higher digging pressure will handle the material more easily.
- b. If blasted rock is to be excavated, the large size bucket will handle larger individual pieces.
- c. The size of available hauling units should be considered in selecting the size of the excavator. The hauling unit capacity should be approximately five times excavator bucket size.

### 2.6 Productivity of Excavator

**Theoretical Output calculation for 191.00 and 182.95 working hour for the month of November 2018 & December 2018 for excavator**

1. Size of bucket = 0.9 m
2. Bucket fill factor = 0.625
3. Optimum depth of cut is 30 to 60 % of maximum digging depth. From Above for 0.9 m<sup>3</sup> size bucket hoe maximum digging depth is 5.5 to 8.2 m. Here, Depth of excavation is 2.5 m, which is 30 % to 45 % of maximum depth.
4. Height of swing factor

Average height of excavation = 2.5m

Optimum height = 50% of maximum height

= 6.85 x 0.5

= 3.43 m

Percent Optimum height =  $2.5 \times 100 = 72.89 \%$

#### 5. Cycle element times

Load bucket	-	7 sec
Swing with load	-	5 sec
Dump load	-	4 sec
Return swing	-	4 sec

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Cycle time = 20seconds

6. Efficiency factor, 45- min hour (Assumed)
7. Class of material, hard rock, swell 60%
8. Production rate

$$\begin{aligned}
 &= \frac{(3600 \text{sec} \times Q \times F \times X \times (\text{AS:D}) \times \frac{E}{60} \times \frac{1}{\text{Volume correction}})}{22 \times 60 \times (1 + 0.6)} \\
 &= \frac{3600 \times 1.0 \times 0.625 \times 0.92 \times \frac{45}{60} \times 1}{22 \times 60 \times (1 + 0.6)}
 \end{aligned}$$

=54.68 cum/hr.

### Practical Output Data For 191 Working Hour Of Excavator In The Month Of November 2018

working hours till date (In the month of November before study)

- 8960 hrs

sr. no .	soil type	soil condition	length in M	Breadth in M	Ht/depth of cut in M	Angle of swing	skill of operator	working hours	effective production per Hour	Avg. Qty. per cum.	Output Cum./hr.
1	ST	SS	18.2	5	2.5	90	Good	12.00	10.00	227.50	22.75
2	ST	SS	19.6	5	2.5	90	Good	12.30	10.30	245.00	23.79
3	ST	SS	12.8	5	2.5	90	Good	10.30	6.80	160.00	23.53
4	ST	SS	20	5	2.5	90	Good	10.40	8.40	250.00	29.76
5	ST	SS	21.1	5	2.5	90	Good	10.50	8.40	263.75	31.03
6	ST	SS	21.5	5	2.5	90	Good	10.50	8.50	268.75	31.62
7	ST	SS	21	5	2.5	90	Good	10.50	8.50	262.50	30.88
8	ST	SS	20	5	2.5	90	Good	10.55	8.55	250.00	29.24
9	ST	SS	22.1	5	2.5	90	Good	11.00	9.00	276.25	30.69
10	O	D	20.1	5	2.5	90	Good	12.40	9.90	251.25	25.38
11	ST	SS	22.6	5	2.5	90	Good	11.40	8.90	282.50	31.74
12	ST	SS	18	5	2.5	90	Good	14.40	10.90	225.00	20.64
13	ST	SS	22.1	5	2.5	90	Good	13.55	11.05	276.25	25.00
14	ST	SS	22.8	5	2.5	90	Good	11.60	9.60	285.00	29.69
15	O	D	25.2	5	2.5	90	Good	12.00	9.60	315.00	32.81
16	O	D	26	5	2.5	90	Good	12.30	10.30	325.00	31.55
17	O	D	27.1	5	2.5	90	Good	12.30	10.30	340.00	33.01
18	O	D	27	5	2.5	90	Good	12.45	10.45	337.50	32.30

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19	O	D	27.1	5		90	Good	12.45	10.45	338.75	32.40
20	O	D	26.5	5	2.5	90	Good	13.00	11.00	331.25	30.11
	<b>Total Sum</b>		<b>440.8</b>						<b>190.9</b>	<b>5511.25</b>	<b>577.92</b>
	<b>Average per day</b>		<b>22.04</b>						<b>9.545</b>	<b>275.5625</b>	<b>28.896</b>

- Average Production hour per day    9.55 hours
  
- Average Quantity produced per day    275.56 cum/day
  
- Average output per hour                    28.89 cum/hours
  
- Theoretical output per hour                54.68 cum/hours
  
- Output efficiency of the machine        52.86 %

\* In the working hours, three breaks are scheduled. Two for the tea and one for the lunch.

The timing for the breaks are;

I <sup>st</sup> Tea break	=	30 min.
II <sup>nd</sup> Lunch break	=	1 hrs
III <sup>rd</sup> Tea break	=	30 min.
Total		
	=	2 hrs

\* \* At all times where the difference between the working hours and the effective production hour is more than two hours, the equipment is in breakdown condition.



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## Some Productivity improvement techniques

1. **Arrangement of skilled staff for operation and maintenance:** To get optimum output from any equipment, it is essential to handle the equipment by a skilled staff. The skilled staff includes the operator, the mechanic etc. The working hours of any equipment depends upon the maintenance period & the rest period of the engine. If the equipment is working in shifts i.e. first, second, third, the operator shall be separate for each shift.
2. **Establishment Of Service And Repair Facilities:** Selection of equipment needs careful thought to ensure efficient and effective performance. Though the actual selection would depend on factors like type of work and its magnitude, location etc. The equipment requires regular maintenance during the work. Every equipment has its own unique features. This requires skilled mechanic, store of spare parts, lubricants etc.
3. **Maintenance of spare parts inventory:** This is a job, which needs the exact balance between availability of spares and low inventory cost. On one hand it should provide proper assurance for availability of desired spare parts in proper time and quantity. And on other hand should not result in excessive stocking or blocking up of capital. Proper planning is very essential to get the best result.
4. **Decision regarding number of shifts per operation:** The shifts depends on the volume of the work to be done in the specified time limit, availability of skilled operators working conditions, location of site, environment etc. The decision of number of shifts shall be taken by the project engineer by considering the above factors.

## III. CONCLUSION

1. Construction is a constantly evolving industry, heavily affected by the rapid evolution of technology which makes situations change dramatically from one day to the other. People involved in constructions have diverse opinions on the subject of productivity measurement, mostly because the term “productivity” is not easily defined and understood. Furthermore, causes of productivity loss are not always predictable and easy to track. It usually requires much effort to define those causes and much more effort to adequately face them. Research also showed that there is a difference in the way of productivity measurement between large and small-independent firms which do not frequently measure or record productivity of their projects, and thus have difficulties in improving performance.

2. output of crawler mounted excavator depends upon the cycle time i.e, the time taken by the equipment to complete one full cycle of operation and this cycle time changes accordingly to the different machine and job conditions. output efficiency of machine is approximately 52.86% and theoretical output per hour is 54.68 cum/hr. Moreover, the majority of techniques/ tools used for measuring productivity have key limitations, something that should alert industry participants before deciding the selection of a specific tool. Some of those participants should be key people working for developers and manufacturers of software and hardware used for productivity measurement and analysis, mostly because they can reveal the conceptual background behind the development of a measurement tool and the industry's needs and wills for such tools. Many studies have been conducted before but still there is deeper need of understanding the improvement of productivity. The main outcome from the literature is that there is no standard definition of productivity. So to achieve the productivity the maintenance should be given to that of equipment and this maintenance should be are of different types according to the working condition, budget, cost etc. factors. This study includes different factors which affects the productivity of the equipment. The factors which affect the performance of equipment include job, maintenance, working days, fuels/energy, expenses on repair/maintenance From the given study we have find out different factors which affects the selection of equipment and maintenance of equipment for giving the better output i.e., nothing but improving productivity. The project includes the specifications of the excavation equipment and the working capacity. The daily working hours of equipment on site and the cost estimation of particular equipment used. To achieve these objectives a methodology is adopted towards improving productivity are;

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Vol. 8, Issue 5, May 2019

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