

IT Model to Calculate Required Equipments for Excavation Work in Construction Projects

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Abstract: *Excavation is most commonly used activity in all construction projects. All contracting agencies prefer to use bigger and heavier excavators and dumpers on site to do excavations if quantity of excavation is huge. Estimation of required number of excavators and dumpers for completion of excavation could be rather a tedious process involving repetitive calculation on which professionals spend their valuable time. As the Information Technology is highly involved in construction section there is need to have IT model for estimation of number of excavators and dumpers. The developed model is useful to calculate required equipments within short period of time. The purpose of the developed IT model is to save the time and efforts of the construction professional. The paper discusses about model which can be used on site to estimate numbers of excavators and dumpers required for completion of certain quantity of excavation within the given time. The calculation considers various existing formulas and method to generate the output. This information could certainly be useful in planning equipments on construction project sites. The tool is user friendly where any non IT background person can use it on construction sites.*

Keywords: *Equipments Estimation, Excavation, IT Application, Construction Project*

I. INTRODUCTION

Earth Moving operations are major part of many infrastructure projects. Earth moving operations include excavation, transportation, placement and compaction of earth or soil. Use of equipment to such activities can increase output or productivity and helps to complete task in a shorter time. All such operations can be completed by using equipments like excavators, bulldozers, dumpers, compactors etc.

Excavation is most commonly used activity in all construction projects. All contracting agencies prefer to use bigger and heavier excavators and dumpers on site to do excavations if quantity of excavation is huge. As these equipments are of mega size, they require huge investments. For this reason, their proper management on site is the most important factor. Improper planning and management of these equipments on site causes low production and ultimately increases unit cost of excavation.

Construction equipment planning aims at identifying the construction equipment for executing project tasks, assessing equipment performance capability, forecasting the date wise requirement of numbers and type, type of equipment and finally participating in the selection of equipment to be acquired [1]. Estimation of number of excavators and dumpers is a key element of equipment planning and management on construction project sites. The overall number of equipments required for

excavation is totally depends up on hourly production of equipments. It is well known fact that hourly production of equipments depend on many factors like type of equipment, site conditions, type of soil, geographical condition of plot, working environment etc. generally each manufacturer provides an ideal hourly production capacity of equipment according to equipment specification. But hourly production of equipments is slightly different as compare to ideal hourly production capacity. Thus determining the actual production based up on all above said factors will make considerable help to get correct actual output / hourly productivity of equipments which would, in turn, lead to estimation of correct numbers of equipment on site. The paper discusses about IT model which can be used on site to estimate numbers of excavators and dumpers required for completion of certain quantity of excavation within the given time. The model has been developed by using Visual Basic Application (VBA) which is inbuilt part of Microsoft excel application. This information could certainly be useful in planning equipments on construction project sites.

II. LITERATURE REVIEW

Expert Systems can be defined as computer programs that rely on knowledge and reasoning to perform a difficult task usually perform only by human expert. An expert system is intended to act as human expert who can

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be consulted on range of problems that fall within his or her area of expertise [2].

Alkass S & Harris F (1998) developed an expert system model for the selection of equipment fleet in road construction earthmoving operations by taking resources from field practitioners. The expert system was then developed in four main stages. At the end, the study was concluded by stating that the expert system was developed to minimize and possibly eliminate the deficiency of basic processes and replace it with modern consultation and advice [3].

Haidar et. al. (1999) developed a model for optimizing excavating and haulage operations and the utilization of equipment in opencast mining. Their model was based upon decision expert system, XperRule, for selection of opencast mine equipment [4].

Shapira A & Goldenberg M (2005) developed a model based on an Analytical Hierarchy Process (AHP). The developed model is capable of providing users with results to compare with different alternatives based on several criteria for selection of equipment based on highest score [5].

C Kirmanli and S.G. developed an expert system which selects the optimum hydraulic excavator truck configuration such that unit production cost is minimized and technical constraints such as geological, geotechnical and mining constraints are satisfied. The above said expert system was developed within kappaPc shell and supports object oriented technology for ms windows environment [2].

Siemon Smith developed a regression model by using which actual productivity of a single loader can be easily calculated. The model is based upon data obtained from UK highway construction projects. This model can then be used to assist in the estimation of earth moving productivity would, in turn, help to estimate number of construction equipments [6].

Neil Neldil and John Mayfield created a spreadsheet application in order to facilitate economical selection of size, model and number of scrapers from list of available equipments for the job under consideration. The application made up of seven spreadsheets and a user interface to solicit all data entries specific to a project. Once the user enters required data, system compares the production rates, the time required for the job, determines the estimated unit cost for each scraper in the database and recommends the most economical selection [7].

Serji Amirakhanian and Nancy J Baker developed a system for selection of earth moving equipments by using rule based expert system i.e. (VP expert). The system with 930 rules interprets information concerning a particular project's soil condition, operator performance and required earth moving operations. The system was tested using requirements for an actual project by three contractors [8].

The accurate estimation and selection of equipments has intrigued many researchers for many years yet there is no robust model for calculation of number of excavators and dumper required on construction sites. Although from last few years investigations has been

done on this topic but majority of the studies published in the literature focus mainly on optimization of equipment selection on construction project sites based upon different factors. Also the presented models are proposed for only specific types of construction works due to the many factors which are affecting selection. Majority of research has been conducted in developed countries, but as such no work has been done with respect to Indian context. The model presented in the paper is being developed to calculate only number of excavators and dumpers required to complete given quantity of excavation work within the given time. Thus determining the correct number of excavation equipment by the above said calculator will make considerable help for planning of construction equipments.

III. METHODOLOGY

Estimation of number of excavators and dumpers can be done by using certain stages. Each stage utilizes certain inputs and parameters. Following paragraph explains the method used for the estimation of excavators and dumpers.

Rate of production (i.e. rate of excavation) needs to be determined by using formula (1).

$$\begin{aligned} & \text{Rate of Production} \\ &= \frac{\text{Total Quantity of Excavation}}{\text{Time Required for Excavation}} \end{aligned} \quad (1)$$

Output of an excavator is calculated using formula (2) [9].

$$Q = q \times \frac{3600}{c} \times \text{Efficiency Factor} \quad (2)$$

Where,

$$q = \text{Bucket Capacity} \times \text{Swell Factor} \times \text{Bucket Factor}$$

Bucket Capacity of excavator can be found out by referring technical specification of equipment supplied by manufacturer. Swell factor is the ratio of loose dry weight per unit volume to the bank dry weight per unit volume. It is used in output calculation formula to calculate output of excavator considering original volume of earth. The type of soil and its swell factor is provided in the IT model for selection for user [10]. Bucket factor is mainly used to convert theoretical bucket capacity of excavator into actual bucket capacity. Bucket factor generally varies from 0.4 to 1 and depends upon height of excavation, nature of soil, efficiency of operator. The term efficiency factor is used to account for actual productive operations in terms of an average number of minutes per hour that the machine will operate. A 50 minutes – hour average would yield 0.83 (50 / 60) efficiency factor. The 50 minute – hour is a reasonable starting point if no company and / or equipment specific data are available [10]. The efficiency factor depends upon type of soil, depth of excavation, environmental condition, site conditions, operator skill etc. Cycle time of any equipment is the total time required for an equipment to complete one cycle. Total cycle time for an excavator

should be calculated by using following formula (3).

$$c = \text{Excavation Time} + \text{Swing Time} + \text{Dumping Time} \quad (3)$$

After determining output of one excavator IT model calculates no of excavators by using following formula (4).

$$\text{Number of Excavators required} = \frac{\text{Rate of Production}}{\text{Output of one Excavator}} \quad (4)$$

Once the estimation of excavator is over, IT model calculated no of trucks or dumpers in accordance with output of one excavator and output of one dumper by using formula (5).

$$\text{Number of Dumpers per Excavator} = \frac{\text{Output of one Excavator}}{\text{Output of one Dumper}} \quad (5)$$

IT Model Calculates output of one dumper by using following formulas (6) ~ (9).

$$\begin{aligned} \text{Output of Dumper} &= (\text{Total volume of soil which dumper can carry in a trip}) \\ &\times (\text{Number of trips which dumper can complete in a hour}) \end{aligned} \quad (6)$$

$$\text{Volume of Soil Dumper can carry in a trip} = \frac{(\text{Dumper Capacity} \times \text{Load Factor})}{\text{Density of Soil}} \quad (7)$$

$$\text{Number of Trips which Dumper completes in a hour} = \frac{60}{\text{Cycle Time of Dumper}} \quad (8)$$

$$\begin{aligned} \text{Cycle Time of Dumper} &= \text{Dumping Time} \\ &+ \text{Travelling Time with load} \\ &+ \text{Returning Time without load} \\ &+ \text{Spotting and Waiting Time} \\ &+ \text{Turning Time} \\ &+ \text{Dumping Time} \end{aligned} \quad (9)$$

IV. IT MODEL FOR CALCULATION

IT model starts with the screen shown in Fig 1. In order to determine the number of excavators required user is required to select type of excavator, make and model of equipment and bucket capacity as shown in Fig 1 and Fig 2. In order to determine the number of dumpers required per excavator user is required to select type of excavator, make and model of equipment and bucket capacity as shown in Fig 3. If user is using equipments about which information is not listed, then user can go directly to next screens which is as shown in Fig 4 and Fig 5 allow to

enter bucket capacity of excavator and payload capacity of dumpers

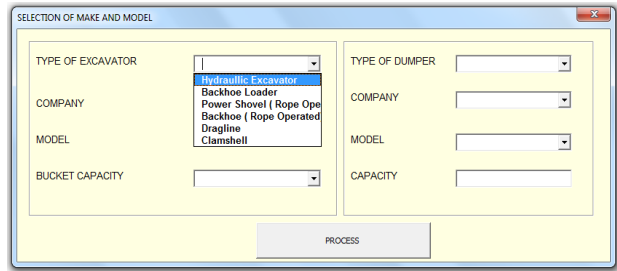


FIGURE I
SELECTION OF MAKE

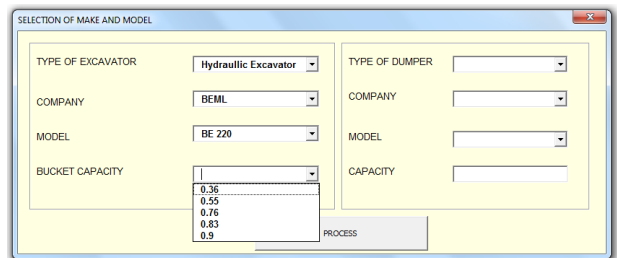


FIGURE II
SELECTION OF MODEL

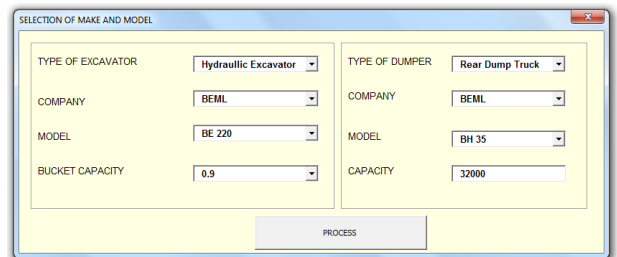


FIGURE III
EXCAVATOR AND DUMPER SELECTION

After the selection of make and model of excavators, user is required to enter values in next screen which is as shown in Fig 4 for total quantity of excavation, total time available, bucket capacity, efficiency factor, and bucket factor. Also user is required to choose the type of soil in which excavation is required to be done. User can select the type of soil from the given list. With the entire details model will calculate the required number of excavators.

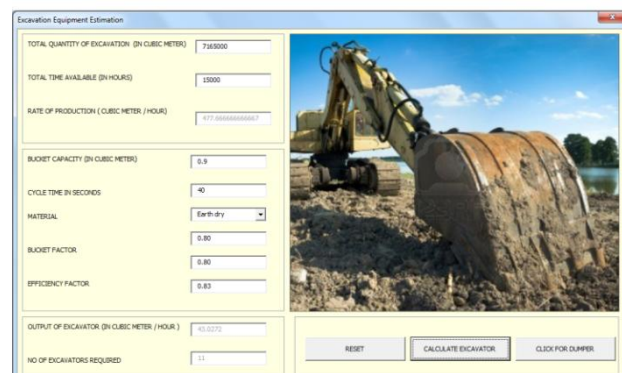


FIGURE IV
EXCAVATION EQUIPMENT ESTIMATION

After the calculation of number of excavators, user is

required to enter values in next screen which is as shown in Fig 2 for loading factor, density of soil, hauling distance, hauling speed with load and without load, efficiency factor for dumper, dumping time, turning time and spotting and waiting time. With the entire details model will calculate the required number of dumpers per excavator and total numbers of dumpers required for completion of excavation operation.

Parameter	Value
CAPACITY OF DUMPER (IN KILOGRAMS)	32000
LOADING FACTOR	0.80
DENSITY OF SOIL (IN KILOGRAM / CUBIC METER)	1960
VOLUME OF SOIL DUMPER CARRIES / ONE TRIP (IN CUBIC METER)	13.061224897959
HAULING DISTANCE (IN KM)	2
HAULING SPEED WITH LOAD (IN KM / HR)	30
HAULING SPEED WITH OUT LOAD (IN KM / HR)	40
LOADING TIME (IN MINUTES)	18.22
DUMPING TIME (IN MINUTES)	1
TURNING TIME (IN MINUTES)	1
SPOTTING AND WAITING (IN MINUTES)	1
EFFICIENCY FACTOR	0.83
CYCLE TIME OF DUMPER (IN MINUTES)	20.22
NO OF DUMPERS REQUIRED PER EXCAVATOR	2
OUT PUT OF DUMPER (IN CUBIC MET / HR)	23.0492196
TOTAL NO OF DUMPERS REQUIRED	22

FIGURE V
CALCULATE DUMPERS

V. CONCLUSION

Excavators and Dumpers are valuable construction equipment for completion of large quantity of excavation on construction projects. Estimation of required number of excavators and dumpers for completion of excavation could be rather a tedious process involving repetitive calculation. An IT model for estimation of number of excavators and dumpers is useful to calculate required equipments within short period of time. The results of this study are to be of major significance to contractors and construction managers. The proposed IT model could be useful if integrated with a database of old projects or historical data. The developed model can also be integrated with manufacturer data for selection of suitable equipment alternative. The proposed model can be used to integrate equipments operational analysis with its economical analysis with the addition of owning and operating cost module which will be useful to do economical analysis. It Saves Time and Effort of the Construction Project Manager.

However overall results showed that accuracy of model depends on different factors like soil type, job site conditions, environmental conditions of site etc. With the changes in these values, the number of excavators and dumpers will also change. For more accurate results the data would always be obtained from actual site and historical data.

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