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The Quantitative Use of Heavy Equipment for Excavataion And Embankment Work Items in Road Improvement Project

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ABSTRACT

The delovment in Indonesia lately is developing very rapidly, especially in the field of construction. Starting from the construction of buildings, roads, brodges, to the construction of dams. Most of the construction uses heavy equipment. Heavy equipment is an important factor in construction project, the purpose of using heavy equipment is to make it easier to do work so that bthe expected results can be achieved easily in a relatively short time. The scope of this writing is only limited to excavataion and embankment wotk related to the use of heavy euipment *Excavator*, *Dump Truck*, *Motor Grader*, *Three Wheel Roller*. The results of the analysis found an alternative 1 value of rental cost and the number of tools 1 unit excavator excavation, 2 units of heap Excavato, 4 units Dump truck, 1 unit of Motor Grader, 1 unit of Three Wheel Roller with a total rental fee of Rp. 1.452.952.528,36 and work time of 541,99 hours.

Key words: heavy equipment, productivity, cost and time.

1. INTRODUCTION

The Development in Indonesia lately is developing very rapidly, especially in the field of construction. Starting from the construction of buildings, roads, bridges, to the construction of dams. Most of the construction is using heavy equipment. Heavy equipment is an important factor in construction projects, the purpose of using heavy equipment is to make it easier to do work so that the expected results can be achieved more easily in a relatively shorter time.

Development activities are not instant activities, but activities that have to go through a series of processes in which there are many things that must be well understood and completed with mature scales. The series of activities in construction are sequential and interrelated. Beginning with the emergence of a need (*need*), thought the possibility and feasibility (*feasibility study*), formulating an initial design (*preminary design*), making a clear and detailed design (*development and detail design*), carrying out administrative preparations to carry out construction work because when using heavy equipment to be easier and faster when compared with manual equipment. But the uses of weight less precise as not in accordance with the conditions and the field situation affected performance and results. The conditions when the weather is good can make it easier for the machine to work. Losses such as failure to achieve the predetermined range and the low production achieved by heavy equipment are a few examples when using heavy equipment that is not appropriate to the conditions. Not only for the working conditions, poor terrain conditions also affect the cycle time of the heavy equipment which affected productivity. The distance that traveled also affect for the results of work; if the distance is too far it taken a long time to complete. An alternative distance can be done by finding a closer dump. The closer distance makes the time taken faster, this also affect the overall rental price of the heavy equipment.

Quantitative analysis of the use of heavy equipment is a method of calculation to know the amount of production of each heavy equipment. By knowing the productivity of each machine for excavation work which *Excavators* , *Dump Truck*, for works pile namely *Excavator*, *Dump Truck*, *Motor Grader*, *Three Wheel Roller* further can be to review the manner of combinations and also determines the number of tools used. This is done in order to get optimal employment results. In this case study, it analyzed the heavy equipment that used in excavation and embankment work on Road Improvement works projects. so as to achieve the level of effectiveness of work it is necessary to plan carefully and thoroughly .

The purpose of this research are to know the duration of the total generated from each machine and to know of fee required in accordance with the implementation of the work of each machine.

2. RESEARCH METHOD

The research method used arrangement the way of conducting research in order to find answers to problems.

2.1 Subject of the Research

The subject used as an example case in this study was the work project for Connecting Roads in Ciruas-Lebak wangi-Pontang-Tirtayasa Sub city.

2.2 Object of the Research

The Objects of this research is to apply generated total time duration of each machine and to know the costs required in accordance with the implementation of the work of each heavy equipment project road Improvement.

2.3 Data Collection

The research consisted of primary data and secondary data. Primary data were obtained directly in the field from project documents and archives, with interviews parties in the project. Primary data in the form of project documents are:

1. Type of tool used
2. Tool working hours
3. Price list of basic units of labor and equipment
4. Cost Budget Plan
5. Project data taken from contract documents

2.4 Nature and Type of Soil

Materials that exist in nature are generally not homogeneous, but are mixed materials. Materials also vary from porous to solid materials. With such varied conditions, when choosing heavy equipment to be used in the automatic construction project, the types of material in the field and the material to be used are things that need attention.

In connection with the use of heavy equipment, the land worked experienced changes in volume and usefulness. Changes in these materials, then in stating the volume it is necessary to state the intended soil conditions, that can affect the volume of soil found in the earthmoving business, are:

1. To Circumstances original (*Bank Material* = BM)
   The original condition is the condition of the land before work is done or still in accordance with the size of nature, used as a basis for calculating the amount of removal.
2. Loose state (*Loose Material* = LM)
   Detached state is the condition of the land after the work is done, for example, land that can be in front of the dozer blade, on a dump truck, in a bucket and so on.
3. State of Compact (*Compacted Material*)
   Solid state is the state of the soil after being stockpiled and compacted. The volume of land after compaction is held, may be greater or smaller than the volume in the original state this depends on the compaction effort.
   As an illustration of the development factors for soil types can be seen in the following table.

Table 1: Developmental Factors

Type of soil	Swell (% BM)
Sand	5-10
Surface Soil (soil cap)	10-25
Ordinary Land	20 - 45
Clay	30-60
Stone	50 - 60

Source: Rochmanhadi,1992

In addition to the state of the bag, keep in mind the factors of soil that can affect the productivity of heavy equipment, including:

1. Material weight
   Material weight is the weight of the soil in its original state or released at a certain volume (ton/m^3). The weight of this material was having an effect on the volume transported/driven by pull.
2. Violence
   Harder soil more difficult to do by a tool, so that the hardness of this soil affects the productivity of the tool.
3. Connections / connectivity
   The ability to bind to each other among the soil grains themselves, this property affects the tool, for example the influence on the *overflow*/ overflow factor.
4. Form
   The shape is the material referred to here base on the small grain size there to be a cavity that is of a small size too, like wise on large butyl sized soil there made a large cavity as well.

The method needed to assist in calculating the capacity of heavy equipment is the method of data collection. The data collection methods that can be used are as follows:

1. Retrieval of data in a direct manner to the implementing contractor, the supervisor of the project oversight concerned.
2. Data processing, with the intention of what data is needed, including:
   1) Equipment rental costs: Equipment rental costs obtained from implementing contractors, contractors implementers, consultants, supervisors and equipment rental party be rat are available.
   2) Volume of work: The volume of work for excavation and pile work in accordance with project implementation data**.**

2.5 The Excavation Work

The excavation of works include: handling, properly accounting fantasy or a buildup of soil or rock or other material from the surrounding streets that the need for the completion of this work. This work is generally required for the construction of drains and gutters , for the formation of excavations or foundation pipes, sewers, disposal or other structures, for the disposal of un used material and topsoil, for slope stabilization work and disposal of avalanche material, for the excavation construction materials and disposal of the remaining excavated materials, for stripping and discharging of pavement materials, and generally for the formation of profiles and sections in accordance with these specifications. Excavation work can be in the form of:

1. Ordinary game
   The excavation usually covers up all excavations which are not classified as quarry, structural excavation, *borrow excavation.*
2. Stone scrap
   Rock excavation includes excavation of chunks of rock with a volume of 1 cubic meter or more and all stones or other materials according to the Work Directors are impractical to dig without the use of air pressure equipment or drilling and blasting.
3. Structural excavation

The structure includes excavation in all types of soil. Any excavation identified as ordinary excavation or excavation of rock cannot be added to the excavated structure. Limited structure excavation for excavation of bridge foundation floor, concrete retaining wall, and other load-bearing structures. Structural excavation works include: backfilling with materials, disposal of unused mineral materials, all drainage, pumping, storage, deposition, and support, construction of workplaces or *cofferdam* and demolition.

2.6 Dumping Work

This work includes the procurement, transportation, overlay and compaction of land or grained material approved for piling, for backfilling of excavated pipes or structures and for general embankment required to form the dimensions of the embankment according to lines, slopes and elevation of cross sections in is required or approved.

The pile material used consists of:

1. Material of landfill from excavated with good quality
2. Between the back rest and the embankment there should not be a direct *joint* but must be puritanical (cut *off).*
3. The soil embankment material meets the elevation of embankments / cliffs that are landslides, impermeable to water, and the quantity should meet the following restrictions:
   1) Material does not contain organic or soluble substances.
   2) Material that used to be commonplace last long.

The Heap can be:

1. Regular lead
   Heaps that are classified as ordinary heaps must consist of soil excavation or rock quarry which is approved by the Employment Director as qualified materials.
2. Hoarding of choices
   This heap may only be classified as an "optional heap" if it is used at a location or for the purpose of which the selected heap has been determined or agreed in writing by the Job Directors. Piles which are classified as optional piles consist of soil or stone material that meets all the above conditions for ordinary piles and must additionally have certain characteristics depending on the intended use. The weighing material that used when compaction is saturated or inevitable flooding must be sand or gravel or other clean grained material with a maximum Plasticity Index of 6%.
3. Pile hand above the swamp
   The choice of pile material on swamps should be sand or gravel or other clean grained material with a Maximum Plasticity Index of 6% (results of laboratory tests).

Conditions for the embankment, namely:

1. The final elevation and slope after compaction must be no higher or lower than 2 cm specified.
2. All exposed pile surfaces must be level enough and must have sufficient slope to ensure free flow of surface water.
3. The end embankment slopes should not vary more than 10 cm from the specified profile line.

The stockpile should not be spread in layers with a thickness of more than 20 cm or in layers with a thickness of less than 10 cm.

2.7 Analysis of Determination of Combination Choices

Determining the alternative selection of heavy equipment combined with earth excavation and embankment. This is the measurement scale method. Measurement scale is a set of rules needed to quantify the measurement the data variable.

The Step work analyses in the planning of heavy equipment are:

1. Conduct analysis tool production fallow t by calculating the coefficient of production and calculate the tool on each-each machine.
2. Determine the types of heavy equipment combinations: From the many types of heavy equipment capacities used carried out optimizing the machine so that we get several alternative combinations for the heavy equipment that also used in quarrying and piling work.

Table 2: Total Recapitulations of Heavy Equipment Use

Type and number of tools	Production (m^3 / hour)	Duration (hour)	Rental Price per (hour)	Rental Cost (Rp) (duration x price xj u ml ah tool)
Excavation				
1 *Excavator*	33,57 m^3	136,00	Rp.532,264.27	Rp. 72,387,940.07
4 *Dump Truck*	9,97 m^3	114,00	Rp.329,658.83	Rp. 150.324.425,21
			Results A	Rp. 222.712.365,28
Heap				
2 *Excavators*	33,57 m^3	121,00	Rp.532,264.27	Rp. 128.807.952,19
31 *Dump Truck*	2.10 m^3	125,14	Rp.329.658,83	Rp.1.278.899.471,28
1 *Motor Grader*	87,30 m^3	94,00	Rp.535.580.18	Rp. 50.344.537,28
1 *Three Wheel Roller*	75,00 m^3	108,00	Rp. 67,254.86	Rp. 28.863.525,32
			Results B	Rp.1.486.915.486,07
Amount of A + B			Rp. 1.709.627.851,35	

Source : Analisis Result

3. Calculation of the time of completion of work: In the work of a project the calculation of time is needed because this job must be completed in accordance with the existing contract time. For this reason, heavy equipment analyze carried out which can be combined in excavation and weighing so that it gets faster and more efficient time based on the data obtained.
4. Calculation of operating costs for equipment / rental of equipment: Calculation of rental costs for heavy equipment is very influential, because by knowing the cost of renting a tool we can determine what kind of weight used and can be combined into an alternative excavation work and land heaps.

3. RESULTS AND DISCUSSION ANALYSIS

3.1 The Calculation of Unit Price for Heavy Equipment Rental

From the results of a survey of several companies that provide heavy latency rental in the Banten Province, there are several

price comparisons. So decided to take one company that could not be named by the company in order to maintain competition between other companies. The list of prices obtained is only the hourly rental of equipment for *Excavators, Three Wheel Rollers and Motor Graders which is* different from *Dump Trucks* at a rental price per day. Other needs, namely diesel fuel, are borne by the lessee, for the needs of the operator can be provided by the rental company. Table 2 is a recapitulation of the productivity results of each heavy equipment, the duration of time and the amount of operating costs under optimal conditions adjusted to the conditions in the field. Among others: 1 unit of *Excavate or* excavation with production results per hour 33,57 m^3/hour duration of work required 136,00 hours and operating costs Rp.72,387,940.07,40 units *Dump Truck* excavation with an hourly production output of 9,97 m^3/hour duration of jobs 114,00 hours and operating costs Rp. 150.324.425,21, 2 units *Excavators* pile with production per hour 33,57 m^3 duration of the work required 121,00 hours and operating costs Rp. 128.807.952,19, 31 units of stockpile *dump trucks* with a production yield of 2,10 m^3 per hour per hour duration of work 125,14 hours and operational costs Rp.1.278.899.471,28, 1 unit of *Motor Grader* with an hourly production of 87,30 m^3/hour work duration of 94.00 hours and operational costs of Rp. 50.344.537,28, 1 unit of *Three Wheel Roller* with the production of hourly 75,00 m^3/hour work duration 108,00 hours and operational costs Rp. 28.863.525,32, with a total cost of Rp.1.709.627.851,3 5.

3.2 Calculation of Work Unit Prices

Unit price work costs calculated in an analysis of the unit price of a job, which consists of direct costs (labor, materials and equipment) as well as operational or indirect costs (general or *overhead* costs and profits) as a payment item for a type of work certain, including taxes.

Table 3: Unit Price per Hour

Type of Tool	Production Capacity (m^3/ hour) Q	Tool coefficient m^3 / hour 1 / Q	Equipment rental price Rp / hour	Unit Price per m^3 (Rp) (1 / Q x Rp / hour)
Excavator				
Excavator	33,57	0,0298	Rp.532.264,26	Rp. 15.855,35
Dump *Truck*	9,97	0,1003	Rp.329.658,82	Rp. 33.065,08
Heap				
Excavator	33,57	0,0298	Rp. 32.264,26	Rp. 15.855,35
Dump truck	2,10	0,4762	Rp.329.658.82	Rp.156.980,39
Motor Graders	87,30	0,0115	Rp.535.580,18	Rp. 6.134,94
Three Wheel Roller	75,00	0,0133	Rp.67.254,86	Rp. 3.563,40
		amount		Rp.31.454,52

Source : Analisis Result

The Calculation of the need for labor, materials and equipment to get the unit price of a certain type of work.

The material who used raw materials namely materials. In a particular location or source material *quarry* and is a basic ingredient that has not undergone processing (stone, sand) or material received in the warehouse or *base camp* , which calculated from the source material, after into account the cost of b freight and transportation. The job description on Road Improvement project is soil dug use and *Excavator* on the road side area, *Excavator* totally us loading results excavation and into the *Dump Truck* to throw into a specific area that has been specified. *The dump trucks also transports aggregate B and aggregate* A materials from the *quarry* to the project site. Material in the bed uses *Motor Grader*, the material in the bed is flushed using *Water Tank Truck* (before compacting) and compacted using *Three Wheel Roller*. The following is a description of the calculation of the basic unit price of the tool, the price of the basic unit of material, the price of one of the laborers included in the price of one job.

3.3 The Calculation of Unit Price for Tools per hour

The price of one tool per m 3 can be calculated by multiplying the coefficient of the tool and the rental price of the tool, by the formulation below (Guidelines for Satisfaction Analysis of the Directorate General of Highways in the Department of Public Works).

Table 3 is a recapitulation of the tool unit price per m^3 is based on the production capacity per hour of heavy equipment and heavy equipment rental rates per hour. Among others: Excavator digging with production hour 33,57 m^3/hour with a coefficient of appliance 0,0298 and the unit price appliance Rp.15.855,35 m^3, Dump Truck excavated with the production of hourly 9,97 m^3/hour with a coefficient of 0,1003 tools and the unit price of Rp. 33.065,08, Excavator pile with production result hour 33,57 m^3/hour with a coefficient of appliance 0,0298 and the unit price appliance Rp. 15,855.35 m^3, Dump Truck with heap production 2,10 m^3/hour with the coefficient of tools 0,4762 and the unit price of tools Rp.156.980,39, Motor Grader with the results of the product per hour 87,30 m^3/hour with the coefficient of tools 0,0115 and the unit price of the tool Rp. 6.134,94, Three Wheel Roller with production results per hour 75 m^3/hour with tool coefficient 0,0133 and unit price of tools Rp.3.563,40. With the overall unit price per m^3 Rp. 231.454,52.

3.4 Unit Price for Material per m^3

The safety calculate factor then conducted a survey also speed across at the location of research. Three samples were taken for each hour. From the results of a survey conducted at the location get speed mobile data late on the road section towards Attack-Ciruas and directions ci segment attack with three samples of the type of vehicles are motorcycles, cars and trucks.

Table 4: Base Material Unit Price (Per m^3)

Material Type	Unit Price for Material Per m^3
Class A aggregate	Rp. 194.000,00
Class B aggregate	Rp. 191,000,00
Heap Aggregate B	Rp. 249.900,00

Source : Analisis Result

Table 4 is a base price of units of material per m^3 based on the list price of the basic unit of work materials Office Publict City Serang.

3. 5 Calculation of the Unit Price for Workers

Table 5: Base Wage Unit Prices (Hourly)

No	Description	Unit	Unit price
1	The worker	hour	14.142,86
2	Foreman	hour	21.285,71

Source : Analisis Result

Table 5. is the basic price of the hourly wage unit based on the list of work price in City Serang Public Works Office.

Based on the production capacity per hour and hourly wages. Among others : Excavation foreman with the results of hourly production 33,57 m^3/hour with the coefficient of labor 0,208 and the unit price of hourly labor Rp.4.427,43/hour. Excavated workers with an hourly production of 33,57 m^3/hour with a coefficient of labor 0,834 and the unit price of hourly labor Rp. 11.795,15/hour. Unloaded foreman with the results of hourly production 87,30 m^3/hour with a coefficient of labor 0,08 and the unit price of hourly labor Rp.1.702,85/hour. Heap workers with production results per hour 87,30 m^3/hour with labor coefficients 0,320 and unit price of borrowed workers Rp. 4.527,63/hour.

3.6 The Choosing the Alternative Heavy Equipment

The above tool productivity calculation is the number and condition of the tools used in the Road Improvement Project. In doing 3 alternative experiment with the aim to experiment done with appropriate planned that is timely and cost required to determine in accordance with the implementation of their respective jobs. The following are some alternative calculations that will be analyzed.

A. Alternative I

The result of productivity for each machine, the duration of time and operational costs, among others are : 1 unit *excavator* digging with production per hour 49,09 m^3/hour duration necessary work 93,00 hours and the cost of operating Rp. 49.500.576,67, 4 units of *Dum p* Excavated *trucks* with production results per hour 11,72 m^3/hour duration of work 96,99 hours and operational costs Rp. 127.894.438,61, 2 units *Excavators* pile with production per hour 49,09 m^3 duration work in need 84,00 hours and operating costs Rp. 89.420.396,56, 41 units of *dump trucks* with a production yield of 2,41 m^3 per hour /hour duration of work 82,43 hours and operational costs Rp. 1.114.154.596,35, 1 unit *Motor Grader* with the results production 96 mph, 61 m^3 / hour duration of the work 85,00 hours and the cost of operating Rp.45.524.315,63, 1 unit *Three Wheel Roller* with production per hour 83,00 m^3/hour duration of the work 99,00 hours and operating costs Rp.26.458.231,54, with a total cost of Rp.1.452.952.528,36.

B. Alternative II

Based on the conditions above, the results of the analysis of tool efficiency and tool factors, the cost component are the cost of ownership and rental costs. Alternative II calculated by analyzing two calculations in the Road Improvement Research Project and calculating based on the cost of ownership which includes rental costs or fixed costs and hourly operational costs. In the calculation here, based on the 100% rental price, only the cost of fuel, operator and the exact costs are calculated, below is the calculation of the rental price of heavy equipment with the condition of the equipment rented.

The total operational cost result of each machine, the duration of time and operational costs description. Among others are : 1 unit *excavator* digging with output per hour in 49,09 m^3/hour duration work the required 93,00 hours and operating costs Rp. 27.701.376,65, 40 units of excavated *Dump Truck* with production results per hour 11,72 m^3/hour duration of work 96,99 hours and operating costs Rp.75.849.601,81, 10 unit of heap *Excavator* with hourly production results 49,09 m^3/hour duration of work required 84,00 hours and operational costs Rp. 50.041.196,56, 41 units of *dump trucks* with a production result of 2,33 m^3 per hour /hour duration of work 84,00 hours and operational costs Rp. 673.332.400,93, 1 *Motor Grader* with hourly production results 96,61 m^3 /hour work duration 85,00 hours and operational costs Rp. 28.024.940,63, 1 *Three Wheel Roller* with production results 83,00 m^3/hour duration of work 99,00 hours and operational costs Rp.16.917.106,54.

C. Alternatives III

Based on the conditions in Alternative I and Alternative II there are differences in terms of cost and time. So that Alternative III have compared the productivity of the *Three Wheel Roller* machine with the productivity of the *Vibrio Roller* can conclude that the Productivity differences heavy equipment at work in a heap compaction Road Improvement Project. Among others are : 1 unit *Three Wheel Roller* with hourly production output of 75,00 m^3/hour duration of jobs 108,00 hours and operating costs Rp. 28.863.525,32, 1 unit of Vibrio *Roller* with production results of 112,50 m^3/hour duration of work 72,50 hours and rational operational costs Rp. 25.579.773,50.

5. CONCLUSION

The method done on the project Improvement of Road, get the total time duration generated in accordance with the conditions in the field, namely 698,30 hours with excavation : *Excavator* 136,00 hours, *Dump Truck* 114,00 hours, Heap, aggregate B, aggregate A, heap aggregate road shoulder B: *Excavator* 121,00 hours, *Dump Truck* 125,14 hours, *Motor Grader* 94,00 hours, *Motor Grader* 108,00 hours.

The Costs required in accordance with field conditions are Rp.1.709.627.851,35 with excavation land : 1 unit *Excavator* Rp.72,387,940.07, 4 units of *Dump Truck* Rp.150.324.425,21, stockpile aggregate B, aggregate A shoulder of the road embankment aggregate B : 2 units *Excavator* Rp.128.807.952,19, 31 units of *Dump Truck* Rp.1.278.899.471,28, 1 unit of *Motor Grader* Rp.50.344.537,28, 1 unit of *Three Wheel Roller* Rp.28.863.525,32.

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