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Optimization of the Combination of Heavy Equipment Use in Land-Filling Work in Terms of Time and Cost in the Construction Project of Job Training Center at Ende District of East Nusa Tenggara

Jacky Christian Karmaley[1], Hery Setyobudiarso[2], Subandiyah Azis[3]
[1]Graduate Program in Civil Engineering Majoring Construction Management, National Institute of Technology Malang [Jacky Christian Karmaley], E-mail: jackychristian.jc @ gmail.com
[2]Graduate Program in Civil Engineering Majoring Construction Management, National Institute of Technology Malang [Hery Setyobudiarso], E-mail: hery_sba @ yahoo.com
[3]Graduate Program in Civil Engineering Majoring Construction Management, National Institute of Technology Malang [Subandiyah Azis], E-mail: cup.subandiyah @ ymail.com

Abstract* —The Government of Ende District plans to build a Job Training Center of Ende District on an area of 2.4 hectares. The land must be firstly filled because its surface elevation is below the elevation of the road side surface. The land filling is carried out by using heavy equipment consisting of Excavators, Dump trucks, Bulldozers and Rollers. The objectives of this research are to analyze the combination of heavy equipment types and determine the minimum cost and efficient time for the construction project of land filling work on Job Training Center of Ende District. The research type is quantitative descriptive research using data sources collected based on observation, interview, and documentation methods. The observation method was used to obtain the cycle time of each heavy equipment use and the efficiency of working hours of each heavy equipment use every day. The interview method was used to obtain information for the research objectives by asking questions in face-to-face meeting between the interviewer and the informant. Moreover, the documentation method was used to get pictures or photos in the work location based on the combination of heavy equipment use. The results of the calculation found that the most effective combination based on cost and time analysis is the alternative use of a combination of 4 types of heavy equipment, consisting of 1 Unit of Excavator (12 Days), 2 Units of Dump Truck (5 Days), 2 Units of Bulldozer (1 Day), and 1 Unit of Roller (10 Days) with a total operational cost of IDR 210,679,286 and a work period of 12 days.*

***Keywords*—** *Heavy equipment, operational cost, productivity and combination.*

1. INTRODUCTION

In 2017, the Government Ende District planned to build a Job Training Center of Ende District, which will be built on an area of 2.4 hectares. The Job Training Center is planned to consist of several building masses, including: office buildings, workshops, theory rooms, practice rooms, dormitories, halls, libraries and others, in which they will be used as training facilities and job exchanges for the people of Ende District.

The area of 2.4 hectares of land provided by the Government Ende District is quite strategic because it is located on the Ende-Wolowaru Highway, Moni Village, Kelimutu Sub-District of Ende District. However, the available land also has drawbacks, including that this land is a flood-prone land because the land surface elevation is below the elevation of the road side surface. Thus, the land must be filled at least with the surface height equivalent to the road. For this reason, before planning a building, the Government of Ende District prioritizes land clearing work, i.e. the physical work of land filling with the surface elevation at least equivalent to the road.

According to information obtained from the employees of the Social Work and Transmigration Service of the Ende District Government, the original type of land at the work site is sandy clay. Thus, the land filling work is planned to use C-Class sand and stone that will be compacted on the site. Therefore, this work requires several heavy equipment, including: (1) Komatsu PC 70 excavator, and 200-8M0 PC; (2) Mitsubishi dump trucks with a capacity of 5m^3 and 12m^3; (3) Komatsu Bulldozer D68ESS-12E0; and (4) Vibratory Roller Bomag BW 141 AD-50. [1], [2]

The definition of C-Class sand and stone in this case is material with a non-uniform size composition. Sand and stone are formed due to the accumulation of sand and stone deposited in relatively low areas or valleys. [3] Sand and stone found in some areas generally come from volcanic stones, are andesitic and often mixed with pumice sand. [4] The interesting point about this project that can be used as a material for the thesis study is that the planner consultant does not know the budget provided by the Government of Ende District to complete the land filling work for an area of 2.4 hectares. For this reason, the optimal time and cost analysis plan is required to complete the landfill work.

A. Research Problems

1. What alternative types of heavy equipment are optimal for the project of land filling work on the Job Training Center of Ende District?

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2. How much is the optimal time and cost for land clearing work in the construction project of land filling work on the Job Training Center of Ende District?

B. Research Objectives

1. Analyzing the optimal use of combination types of heavy equipment in order to achieve productivity in the construction project of land filling work for the Job Training Center of Ende District to run optimally.
2. Analyzing the optimal amount of time and cost for land clearing work in the construction project of land filling work for the Job Training Center of Ende District.

II. Research Method

A. Research Setting

The locations used for the research are:

1. The location of the land collection site is in Wolowaru Sub-District.
2. The distance from collection site to the land site is 11 km.
3. The location for land site is in Moni Village, Kelimutu Sub-District, Ende District.

B. Primary Data

1. Data on area that will become the land site.
2. Data on the thickness of the land.
3. Data on distance between location of collection site and location of land site.
4. Data on Excavator cycle time.
5. Data on Dump Truck travel time.
6. Data on Bulldozer cycle time.
7. Data on Roller cycle time.

C. Secondary Data

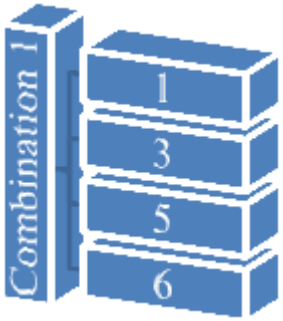
Secondary data are data obtained indirectly. [5] The data were obtained from certain references or literature related to heavy equipment in the construction project of land filling work for the Job Training Center of Ende District which include:

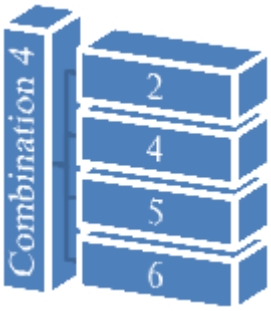
1. Project Technical Specifications
2. Detail Engineering Design
3. Project Implementation Method
4. Heavy Equipment Manual

D. Combination of Heavy Equipment under Research

The combination of heavy equipment under research can be seen in Table 1.

TABLE 1. Combination of Heavy Equipment

No	Heavy Equipment Combination Diagram	Descriptions	Notes
1		1. Excavator Komatsu (PC 70-8) 3. Dump Truck (5m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	1. Excavator Komatsu (PC 70-8) 2. Excavator Komatsu (PC 200-8M0)
2		1. Excavator Komatsu (PC 70-8) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	3. Dump Truck Mitsubishi (5m^3) 4. Dump Truck Mitsubishi (12m^3)

No	Heavy Equipment Combination Diagram	Descriptions	Notes
3		2. Excavator Komatsu (PC 200-8M0) 3. Dump Truck (5m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)
4		2. Excavator Komatsu (PC 200-8M0) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	

Source: being constructed based on Research Method

III. Data Analysis And Discussion

A. Land Filling Volume

The volume of land filling work obtained from the Public Works Department of Ende District can be seen in Table 2.

TABLE 2. Land Filling Volume

Package	:	Land Clearing					
Location	:	Maurole Sub-District					
Work Type	:	Land Filling					
Contract Volume	:		MP				
Mutual Check Volume of 0%	:	32954.24	MP				
NO	NAME	HEIGHT	LENGTH	AREA	CROSS LENGTH	VOLUME	TOTAL VOLUME
		m	m	m2	m	m3	m3
A	Cross 1						
	1	0.95	35.94	34.14	20.00	682.86	1446.78
	2	1.20	31.83	38.20	20.00	763.92	
B	Cross 2						
	1	0.20	1.72	0.34	20.00	6.88	2053.89
	2	0.95	4.07	3.87	20.00	77.33	
	3	1.20	82.07	98.48	20.00	1969.68	
C	Cross 3						
	1	0.20	2.47	0.49	20.00	9.88	2417.78
	2	0.95	5.55	5.27	20.00	105.45	
	3	1.20	43.87	52.64	20.00	1052.88	
	4	1.45	21.53	31.22	20.00	624.37	
	5	1.20	26.05	31.26	20.00	625.20	
D	Cross 4						
	1	0.20	5.71	1.14	20.00	22.84	2746.83
	2	0.95	5.77	5.48	20.00	109.63	
	3	1.20	20.80	24.96	20.00	499.20	
	4	1.45	54.44	78.94	20.00	1578.76	
	5	1.20	22.35	26.82	20.00	536.40	
E	Cross 5						
	1	0.20	4.42	0.88	20.00	17.68	3109.10
	2	0.95	4.11	3.90	20.00	78.09	
	3	1.20	16.01	19.21	20.00	384.24	
	4	1.45	73.85	107.08	20.00	2141.65	
	5	1.20	20.31	24.37	20.00	487.44	
F	Cross 6						
	1	0.95	3.49	3.32	20.00	66.31	3508.10
	2	1.20	21.39	25.67	20.00	513.36	
	3	1.45	94.95	137.68	20.00	2753.55	
	4	1.20	3.74	4.49	20.00	89.76	
	5	0.95	4.48	4.26	20.00	85.12	

The analysis is as follows: The required Loose Measure volume is:

$$LM = CM \times 1.25 = 26363.39 \times 1.25 = \mathbf{32954.24\ m^3}$$

So, the volume that is going to be used for the calculation is = **32954.24 m^3**

NO	NAME	HEIGHT	LENGTH	AREA	CROSS LENGTH	VOLUME	TOTAL
		m	m	m2	m	m3	m3
	1	0.95	1.12	1.06	20.00	21.28	3772.19
	2	1.20	30.52	36.62	20.00	732.48	
	3	1.45	95.33	138.23	20.00	2764.57	
	4	1.20	9.01	10.81	20.00	216.24	
	5	0.95	1.98	1.88	20.00	37.62	
H	Cross 8						
	1	0.95	3.57	3.39	20.00	67.83	2538.32
	2	1.20	33.93	40.72	20.00	814.32	
	3	1.45	10.34	14.99	20.00	299.86	
	4	1.20	14.63	17.56	20.00	351.12	
	5	0.95	41.41	39.34	20.00	786.79	
	6	1.20	9.1	10.92	20.00	218.40	
I	Cross 9						
	1	0.95	13.98	13.28	20.00	265.62	1742.75
	2	1.20	34.1	40.92	20.00	818.40	
	3	0.95	34.67	32.94	20.00	658.73	
J	Cross 10						
	1	0.95	81.18	77.12	20.00	1542.42	1542.42
K	Cross 11						
	1	0.95	78.17	74.26	20.00	1485.23	1485.23
TOTAL OF LAND FILLING VOLUME (SOLID) (M3) =							26363.39

Source: Public Works Agency of Ende District

B. Analysis of the Implementation Time

After obtaining the number of heavy equipment requirements in each combination, the analysis of the implementation time of each combination is carried out. The results of the analysis will also produce heavy equipment rental costs and implementation time for each machine from each combination. The following shows an implementation time analysis of various combinations.

C. Analysis of Implementation Time of Alternative Combination I

The analysis data of implementation time used in combination I are:

1. Excavator 0.37 m^3 = 1 unit

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2. Dump Truck 5 m^3 = 4 unit
3. Bulldozer D68ESS = 1 unit
4. Roller BW 141 = 1 unit
5. Working hours per day (S)= 7 hours

a) Working Hours of Excavator 0.37 m^3:

Implementation time (for 1 unit of Excavator)

$$= \frac{V}{SxQ} = \frac{32954.24}{7x369.191}$$

Implementation time (for 1 unit of Excavator) = 13 days

So, for 1 unit of excavator = **13 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

b) Working Hours of Dump Truck 5 m^3:

Implementation time (for 1 unit of Dump Truck)

$$= \frac{V}{SxQ} = \frac{32954.24}{7x84.333}$$

Implementation time (for 1 unit of Dump Truck) = 56 days

So, for 4 units of Dump truck $= \frac{56}{4} =$ **14 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

c) Working Hours of Bulldozer D68ESS:

$$= \frac{V}{SxQ} = \frac{32954.24}{7x7227.852}$$

Implementation time (for 1 unit of Bulldozer) = 1 day

So, for 1 unit of Bulldozer = **1 day**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

d) Working Hours of Roller BW 141 tons:

Implementation time (for 1 unit of Roller)

$$= \frac{V}{SxQ} = \frac{32954.24}{7x459.221}$$

Implementation time (for 1 unit of Roller) = 10 days

So, for 1 unit of Roller = **10 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

D. Analysis of Implementation Time of Alternative Combination II

The analysis data of implementation time used in combination II are:

1. Excavator 0.37 m^3 = 1 unit
2. Dump Truck 12 m^3 = 2 unit
3. Bulldozer D68ESS = 1 unit
4. Roller BW 141 = 1 unit
5. Working hours per day (S)= 7 hours

a) Working Hours of Excavator 0.37 m^3:

Implementation time (for 1 unit of Excavator)

$$= \frac{V}{SxQ} = \frac{32954.24}{7x369.191}$$

Implementation time (for 1 unit of Excavator) = 13 days

So, for 1 unit of excavator = **13 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

b) Working Hours of Dump Truck 12 m^3:

Implementation time (for 1 unit of Dump Truck)

$$= \frac{V}{SxQ} = \frac{32954.24}{7x160.206}$$

Implementation time (for 1 unit of Dump Truck) = 29 days

So, for 2 units of Dump Truck $= \frac{29}{2} =$ **15 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

c) Working Hours of Bulldozer D68ESS:

$$= \frac{V}{SxQ} = \frac{32954.24}{7x7227.852}$$

Implementation time (for 1 unit of Bulldozer) = 1 day

So, for 1 units of Bulldozer = **1 day**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

d) Working Hours of Roller BW 141 tons:

Implementation time (for 1 unit of Roller)

$$= \frac{V}{SxQ} = \frac{32954.24}{7x459.221}$$

Implementation time (for 1 unit of Roller) = 10 days

So, for 1 unit of Roller = **10 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

E. Analysis of Implementation Time of Alternative Combination III

The analysis data of implementation time used in combination II are:

1. Excavator 0.93 m^3 = 1 unit
2. Dump Truck 5 m^3 = 4 unit
3. Bulldozer D68ESS = 1 unit
4. Roller BW 141 = 1 unit
5. Working hours per day (S) = 7 hours

a) Working Hours of Excavator 0.93 m^3:

Implementation time (for 1 unit of Excavator)

$$= \frac{V}{SxQ} = \frac{32954.24}{7x927.967}$$

Implementation time (for 1 unit of Excavator) = 5 days

So, for 1 unit of excavator = **5 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

b) Working Hours of Dump Truck 5 m^3:

Implementation time (for 1 unit of Dump Truck)

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$= \frac{V}{SxQ} = \frac{32954.24}{7x92.073}$

Implementation time (for 1 unit of Dump Truck) $= 51$ days

So, for 4 units of Dump Truck $= \frac{51}{4} =$ **13 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

c) Working Hours of Bulldozer D68ESS:

$= \frac{V}{SxQ} = \frac{32954.24}{7x7227.852}$

Implementation time (for 1 unit of Bulldozer) $= 1$ day
So, for 1 units of Bulldozer $=$ **1 day**
Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

d) Working Hours of Roller BW 141 tons:

Implementation time (for 1 unit of Roller)

$= \frac{V}{SxQ} = \frac{32954.24}{7x459.221}$

Implementation time (for 1 unit of Roller) $= 10$ days
So, for 1 unit of Roller $=$ **10 days**
Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

F. Analysis of Implementation Time of Alternative Combination IV

The analysis data of implementation time used in combination IV are:

1. Excavator 0.93 m^3 = 1 unit
2. Dump Truck 12 m^3 = 2 unit
3. Bulldozer D68ESS = 1 unit
4. Roller BW 141 = 1 unit
5. Working hours per day (S)= 7 hours

a) Working Hours of Excavator 0.93 m^3:

Implementation time (for 1 unit of Excavator)

$= \frac{V}{SxQ} = \frac{32954.24}{7x927.967}$

Implementation time (for 1 unit of Excavator) $= 5$ days
So, for 1 unit of excavator $=$ **5 days**
Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

b) Working Hours of Dump Truck 12 m^3:

Implementation time (for 1 unit of Dump Truck)

$= \frac{V}{SxQ} = \frac{32954.24}{7x190.649}$

Implementation time (for 1 unit of Dump Truck) $= 25$ days

So, for 2 units of Dump Truck $= \frac{25}{2} =$ **12 days**

Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

c) Working Hours of Bulldozer D68ESS:

$= \frac{V}{SxQ} = \frac{32954.24}{7x7227.852}$

Implementation time (for 1 unit of Bulldozer) $= 1$ day
So, for 1 units of Bulldozer $=$ **1 day**
Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

d) Working Hours of Roller BW 141 tons:

Implementation time (for 1 unit of Roller)

$= \frac{V}{SxQ} = \frac{32954.24}{7x459.221}$

Implementation time (for 1 unit of Roller) $= 10$ days
So, for 1 unit of Roller $=$ **10 days**
Description:
V = Work Volume
S = Working Hours
Q = Production of Equipment

TABLE 3. Implementation Time for Each Combination

NO	COMBINATION	ESCAVATOR day		DUMP TRUCK day		DOZER day	ROLLER day
		0.37 m3	0.93 m3	5 m3	12 m3	155 Hp	6.9 tons
1	I	13		14		1	10
2	II	13			15	1	10
3	III		5	13		1	10
4	IV		5		12	1	10

G. Cost Analysis

The required initial data to analyze the cost of heavy equipment is the Data of Rental Cost of Heavy Equipment. The data were used as a reference to determine the rental cost of each heavy equipment. Information on the rental cost of heavy equipment was obtained from the Public Works Agency of Ende District and can be seen in Table 4.

TABLE 4. Rental Cost of Heavy Equipment

No.	TYPE OF EQUIPMENT	CODE	HP	CAPACITY (M3)	EQUIPMENT PRICE (IDR)	EQUIPMENT RENTAL PRICE/ HOUR (IDR)	EQUIPMENT RENTAL PRICE/ DAY (IDR) (7 DAYS)	MOBILIZATION & DEMOBILI-ZATION PRICE FOR 1 HEAVY EQUIPMENT (IDR)
1	EXCAVATOR KOMATSU PC70-8	E01	48.5	0.37	1,134,025,275	401,800	2,811,150	12,000,000
2	EXCAVATOR KOMATSU PC200-8M0	E02	138	0.93	1,709,954,081	747,597	5,233,181	12,000,000
3	DUMP TRUCK MITSUBISHI 5 M3	E03	100	5	380,000,000	355,464	2,488,251	500,000
4	DUMP TRUCK MITSUBISHI 12 M3	E04	190	12	390,000,000	574,714	4,022,998	500,000
5	BULLDOZER KOMATSU D68ESS-12E0	E05	155	2.60	2,693,553,988	1,010,838	7,075,865	12,000,000
6	VIBRATORY ROLLERS BOMAG BW 141 AD-	E06	75.3	7.05	1,225,719,207	626,937	4,388,557	12,000,000

Public Works Agency of Ende District

H. Analysis of the Total Rental Cost for Each Combination

After finding the total of needs of each heavy equipment, then it will result the time (working days) of each heavy equipment for each combination and also the equipment rental cost per day of each heavy equipment. After that, the Total Rental Cost for Each Combination can be calculated.

G. Analysis of the Total Rental Cost for Combination I

Cost analysis data used in combination I are:

1. **Excavator PC70-8**

- Rental cost of Excavator PC70-8 per day
  = IDR 2,813,159/day
- The number of the required Excavator PC70-8
  = 1 unit
- Effective working day
  = 13 days
- Mobilization and demobilization costs Excavator PC70-8 (1 unit)
  = IDR 12,000,000

➢ Total Rental Cost of Excavator PC70-8
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 2,813,159 × 13 + IDR 12,000,000) × 1
= IDR 48,571,073

2. Dump Truck 5 m^3

- Rental cost of Dump Truck 5 m^3 per day
  = IDR 2,488,251/day
- The number of the required Dump Truck 5 m^3
  = 4 units
- Effective working day
  = 14 days
- Mobilization and demobilization costs Dump Truck 5 m^3 (1 unit)
  = IDR 500,000

➢ Total Rental Cost of Dump Truck 5 m^3
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 2,488,251 × 14 + IDR 500,000) × 4
= IDR 141,342,033

3. Bulldozer D6ESS

- Rental cost of Bulldozer D6ESS per day
  = IDR 7,075,865/day
- The number of the required Bulldozer D6ESS
  = 1 unit
- Effective working day
  = 1 day
- Mobilization and demobilization costs Bulldozer D6ESS (1 unit)
  = IDR 12,000,000

➢ Total Rental Cost of Bulldozer D6ESS
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 7,075,865 × 1 + IDR 12,000,000) × 1
= IDR 19,075,865

4. Roller BW 141 AD-50

- Rental cost of Roller BW141 per day
  = IDR 4,388,557/day
- The number of the required Roller BW141
  = 1 unit
- Effective working day
  = 10 days
- Mobilization and demobilization costs Roller BW141 (1 unit)
  = IDR 12,000,000

➢ Total Rental Cost of Roller BW141
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 4,338,557 × 10 + IDR 12,000,000) × 1
= IDR 55,775,571

Based on the above calculation, the Total Rental Cost of Heavy Equipment for Combination I is:
= excavator rental + dump truck rental + bulldozer rental + roller rental
= IDR 48,571,073 + IDR 141,342,033 + IDR 19,075,865 + IDR 55,775,571
= **IDR 264,874,542**

H. Analysis of the Total Rental Cost for Combination II

Cost analysis data used in combination II are:

1. Excavator PC70-8

- Rental cost of Excavator PC70-8 per day
  = IDR 2,813,159/day
- The number of the required Excavator PC70-8
  = 1 unit
- Effective working day
  = 13 days
- Mobilization and demobilization costs Excavator PC70-8 (1 unit)
  = IDR 12,000,000

➢ Total Rental Cost of Excavator PC70-8
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 2,813,159 × 13 + IDR 12,000,000) × 1
= IDR 48,571,073

2. Dump Truck 12 m^3

- Rental cost of Dump Truck 12 m^3 per day
  = IDR 4,022,998/day
- The number of the required Dump Truck 12 m^3
  = 2 units
- Effective working day
  = 15 days
- Mobilization and demobilization costs Dump Truck 12 m^3 (1 unit)
  = IDR 500,000

➢ Total Rental Cost of Dump Truck 12 m^3
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 4,022,998 × 15 + IDR 500,000) × 2
= IDR 121,689,931

3. Bulldozer D6ESS

- Rental cost of Bulldozer D6ESS per day
  = IDR 7,075,865/day
- The number of the required Bulldozer D6ESS
  = 1 unit
- Effective working day
  = 1 day
- Mobilization and demobilization costs Bulldozer D6ESS (1 unit)
  = IDR 12,000,000

➢ Total Rental Cost of Bulldozer D6ESS

= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 7,075,865 × 1 + IDR 12,000,000) × 1
= IDR 19,075,865

5. **Roller BW 141 AD-50**
   - Rental cost of Roller BW141 per day
     = IDR 4,388,557/day
   - The number of the required Roller BW141
     = 1 unit
   - Effective working day
     = 10 days
   - Mobilization and demobilization costs
     Roller BW141 (1 unit)
     = IDR 12,000,000
   - Total Rental Cost of Roller BW141
     = (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
     = (IDR 4,338,557 × 10 + IDR 12,000,000) × 1
     = IDR 55,775,571

Based on the above calculation, the Total Rental Cost of Heavy Equipment for Combination II is:
= excavator rental + dump truck rental + bulldozer rental + roller rental
= IDR 48,571,073 + IDR 121,689,931 + IDR 19,075,865 + IDR 55,775,571
= **IDR 245,222,441**

I. Analysis of the Total Rental Cost for Combination III

Cost analysis data used in combination III are:

1. **Excavator PC200-8**
   - Rental cost of Excavator PC200-8 per day
     = IDR 5,233,181/day
   - The number of the required Excavator PC200-8
     = 1 unit
   - Effective working day
     = 5 days
   - Mobilization and demobilization costs
     Excavator PC200-8 (1 unit)
     = IDR 12,000,000
   - Total Rental Cost of Excavator PC200-8
     = (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
     = (IDR 5,233,181 × 13 + IDR 12,000,000) × 1
     = IDR 38,165,905
2. **Dump Truck 5 m^3**
   - Rental cost of Dump Truck 5 m^3 per day
     = IDR 2,488,251/day
   - The number of the required Dump Truck 5 m^3
     = 4 units
   - Effective working day
     = 13 days
   - Mobilization and demobilization costs
     Dump Truck 5 m^3 (1 unit)
     = IDR 500,000
   - Total Rental Cost of Dump Truck 5 m^3
     = (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
     = (IDR 2,488,251 × 13 + IDR 500,000) × 4
     = IDR 131,389,030
3. **Bulldozer D6ESS**
   - Rental cost of Bulldozer D6ESS per day
     = IDR 7,075,865/day
   - The number of the required Bulldozer D6ESS
     = 1 unit
   - Effective working day
     = 1 day
   - Mobilization and demobilization costs
     Bulldozer D6ESS (1 unit)
     = IDR 12,000,000
   - Total Rental Cost of Bulldozer D6ESS
     = (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
     = (IDR 7,075,865 × 1 + IDR 12,000,000) × 1
     = IDR 19,075,865
4. **Roller BW 141 AD-50**
   - Rental cost of Roller BW141 per day
     = IDR 4,388,557/day
   - The number of the required Roller BW141
     = 1 unit
   - Effective working day
     = 10 days
   - Mobilization and demobilization costs
     Roller BW141 (1 unit)
     = IDR 12,000,000
   - Total Rental Cost of Roller BW141
     = (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
     = (IDR 4,338,557 × 10 + IDR 12,000,000) × 1
     = IDR 55,775,571

Based on the above calculation, the Total Rental Cost of Heavy Equipment for Combination III is:
= excavator rental + dump truck rental + bulldozer rental + roller rental
= IDR 38,165,905 + IDR 131,389,030 + IDR 19,075,865 + IDR 55,775,571
= **IDR 244,516,372**

J. Analysis of the Total Rental Cost for Combination IV

Cost analysis data used in combination IV are:

1. **Excavator PC200-8**
   - Rental cost of Excavator PC200-8 per day
     = IDR 5,233,181/day
   - The number of the required Excavator PC200-8
     = 1 unit
   - Effective working day
     = 5 days
   - Mobilization and demobilization costs
     Excavator PC200-8 (1 unit)
     = IDR 12,000,000
   - Total Rental Cost of Excavator PC200-8

= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 5,233,181 × 5 + IDR 12,000,000) × 1
= IDR 38,165,905

2. Dump Truck 12 m^3

- Rental cost of Dump Truck 12 m^3 per day
  = IDR 4,022,998/day
- The number of the required Dump Truck 12 m^3
  = 2 units
- Effective working day
  = 12 days
- Mobilization and demobilization costs Dump Truck 12 m^3 (1 unit)
  = IDR 500,000

➢ Total Rental Cost of Dump Truck 12 m^3
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 4,022,998 × 12 + IDR 500,000) × 2
= IDR 97,551,945

3. Bulldozer D6ESS

- Rental cost of Bulldozer D6ESS per day
  = IDR 7,075,865/day
- The number of the required Bulldozer D6ESS
  = 1 unit
- Effective working day
  = 1 day
- Mobilization and demobilization costs Bulldozer D6ESS (1 unit)
  = IDR 12,000,000

➢ Total Rental Cost of Bulldozer D6ESS
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 7,075,865 × 1 + IDR 12,000,000) × 1
= IDR 19,075,865

4. Roller BW 141 AD-50

- Rental cost of Roller BW141 per day
  = IDR 4,388,557/day
- The number of the required Roller BW141
  = 1 unit
- Effective working day
  = 10 days
- Mobilization and demobilization costs Roller BW141 (1 unit)
  = IDR 12,000,000

➢ Total Rental Cost of Roller BW141
= (rental cost per day × working time + mobilization and demobilization costs) × number of equipment
= (IDR 4,338,557 × 10 + IDR 12,000,000) × 1
= IDR 55,775,571

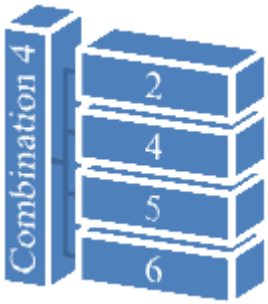
Based on the above calculation, the Total Rental Cost of Heavy Equipment for Combination IV is:
= excavator rental + dump truck rental + bulldozer rental + roller rental
= IDR 38,165,905 + IDR 97,551,945 + IDR 19,075,865 + IDR 55,775,571
= **IDR 210,679,286**

K. Selection of Optimal Alternative Combination

Based on the calculation results, it obtains the calculation results of the Implementation Time and Total Equipment Rental Costs for each combination which can be seen in Table 5.

TABLE 5. Calculation Results of Time and Cost

No	Equipment Combination Diagram	Description	Results
1		1. Excavator Komatsu (PC 70-8) 3. Dump Truck (5m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	1. Time : 14 days 2. Cost: IDR 264,874,542
2		1. Excavator Komatsu (PC 70-8) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	1. Time: 15 days 2. Cost: IDR 245,222,441

No	Equipment Combination Diagram	Description	Results
3		2. Excavator Komatsu (PC 200-8M0) 3. Dump Truck (5m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	1. Time: 13 days 2. Cost: IDR 244,516,372
4		2. Excavator Komatsu (PC 200-8M0) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68ESS-12E0) 6. Roller Bomag (BW 141 AD-50)	1. Time: 12 days 2. Cost: IDR 210,679,286

Based on Table 5, we can see that the most efficient combination in terms of completion time and total rental cost of heavy equipment is Combination IV (Four). It explains that the 2.4-hectares land filling work for Job Training Center of Ende District will be more optimal and efficient if it is carried by referring to the following things:

1. Using the following heavy equipment:
   a. Excavator 0.93 m^3 (PC 200) = 1 unit
   b. Dump Truck 12 m^3 = 2 units
   c. Bulldozer 155 Hp (D68ESS) = 1 unit
   d. Roller BW-141 = 1 unit
2. Implementation time = 12 working calendar period
3. Total Rental Cost of Heavy Equipment = **IDR 210,679,286**

Thus, the total cost required to complete the land filling work is **IDR 210,679,286** (two hundred ten million, six hundred seventy-nine thousand, two hundred and eighty-six rupiah).

TABLE 6. Consultant's Calculation Result

No	Name of Heavy Equipment	Time	Cost
1	1. Excavator 2. Dump Truck 3. Bulldozer 4. Roller	13 days	IDR 245,756,500

Source: Planner Consultant

Based on Table 6, we can see the calculation results of planner consultant without knowing how many alternative combinations are considered in which the information of this calculation was obtained via phone call. However, we can exactly observe that the time and costs are greater than those in Combination IV displayed in Table 5. Thus, in this case, it can be concluded that the calculation of alternative combinations of heavy equipment in this thesis is much more optimal than the calculations of the planner consultant.

IV. Conclusions

From the results of the analysis, the following conclusions can be drawn:

1. Based on the results of the analysis on 4 (four) alternative combinations of heavy equipment, the most optimal combination is combination 4 (four), because it is more optimal than 3 (three) other combinations. So, it can be concluded that the productivity and the amount of each heavy equipment required fill the land of 2.4-hectares Job Training Center of Ende District with a total volume of 32954.24 m^3 is more optimal with the following things:
   a. Excavator 0.93m^3 (PC 200) = 927,967m^3/hour = 1 Unit
   b. Dump Truck 12 m^3= 190,649 m^3/hour = 2 Units
   c. Bulldozer D68ESS (155Hp)=7227,852m^3/hour= 1 Unit
   d. Roller BW-141 = 459,221 m^3/ hour = 1 Unit
2. The most optimal implementation time for heavy equipment in completing 2.4 hectares of land filling work for Job Training Center of Ende District is **12 days**, with the following details:
   a. Excavator 0.93 m^3 (PC 200), 1 unit = 5 days
   b. Dump Truck 12 m^3, 2 units = 12 days
   c. Bulldozer D68ESS (155 Hp), 1 unit = 1 day
   d. Roller BW-141, 1 unit = 10 days

   In addition, the most optimal Total Cost Budget for completing 2.4 hectares of land filling work for Job Training Center of Ende District is **IDR 210,679,286** (two hundred ten million, six hundred seventy-nine thousand, two hundred and eighty-six rupiah).

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