Fleet Management System For Cost Optimization In Road And Railway Project

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Abstract-*The road construction and the extensions of platforms are the biggest engineering projects continuing and progressing day by day. With the rapid economic development, the construction industry as a pillar of national economy has been booming. Roads and railway platforms are the most important structures as it deals with the major part of the transportation and also requires high endeavour for each of its work packages however most important part then remains as the execution of work and handling of equipments and machineries. The economic construction site is one which handles with economy of equipment thus here the part of concern is to have proper optimization and management of equipment on road and railway platform extension site.*

Keywords*-*Optimization, management of equipment, fleet

I. INTRODUCTION

The management of the heavy equipment is the most complicated task as it is related with the number of diversified conditions which involves each and every area of study starting from the purchase to end use of the equipment. Equipment managers are often called upon to make typical economic decisions involving the machines in their use. This paper includes study of output efficiency and thus the optimization of the construction equipments along with the concerning areas like acquisitions, maintenance, depreciations, operating cost.

Large contractors have been steadily increasing their investment in construction equipments to satisfy their need in response to increased construction volume is recent years. The technical advancement of earthmoving equipments during the 20th century includes many improvements in key parts of machines making the machine mechanically more efficient. Hence major large construction operations and mega projects uses large number of various construction equipments. This groups of equipments collectively forms a Fleet.

The fleet operations have become complex due to large number of manufacturers, various capacities and size of equipment available which makes the equipment selection a crucial task.

The scope of this work is limited to equipment optimization and benefit analysis at the site through equipment production rate analysis. The case selected for the study is a road construction and platform extension project where considerable amount of earthwork is involved.

II. OBJECTIVE OF STUDY

Optimization in resource planning and management is one of the most important factors for competitiveness and profitability in today's construction era. The objective of this research is to study the output efficiency of the equipment and thus the optimization of the construction equipment through equipment production rate analysis along with the various cost factors concerning with the equipments.

III. METHODOLOGY

1. Study the site layout and site condition
2. Study the current equipment utilization at the site
3. Study the actual composition of fleet at construction site
4. Study the actual performance of the fleet on site
5. Calculating the theoretical fleet performance
6. Compare actual and theoretical fleet performance
7. Cost benefit analysis

3.1 Equipment Productivity Analysis

Production of each equipment involved in the fleet is manipulated as actual and theoretical using various parameters like distance, number of trips, capacity, cycle time, etc. Using various mathematical formulae. The unit of measurement for the production is always quantity of material excavated or moved on hourly basis i.e. cum/hr.

1. The basic production formula for a hoe used as an excavator is :

Hoe (Excavation) Production

$$= \frac{3600\text{sec x Q xF}}{\text{T}} \text{X} \frac{\text{E}}{60 - \text{min hour}} \text{X} \frac{1}{\text{Volume correction}}$$

Where,

Q = heaped bucket capacity in m3

F = bucket fill factors for hoe buckets

t = cycle time in second

E = efficiency in minutes per hour

Volume correction = $\frac{1}{1+swell\ factor}$

2. Tipper/Dumper/Hauler output

$=\frac{V\ x\ 60}{T}$

Where,

V = tipper body volume

T = tipper cycle time

Parameters: Following are the important parameters required for the productivity calculations;

Capacity

The capacity of each equipment is denoted in m3 measure such as the bucket capacity in excavator or body capacity in case of dumper. This is found out by standard dimension of each equipment given by the manufacturing company. The equipments are generally filled at its heaped capacity and not at its struck volume. The struck capacity is that volume actually enclosed by the bucket, while for the heaped capacity an angle of repose is considered. According to standard conditions angle of repose 2:1 slope is considered.

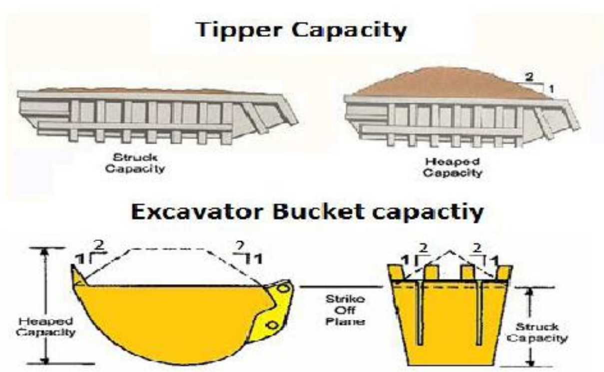

Figure 1: Struck and Heaped Capacity of Volumetric measure

Efficiency

Efficiency factor is the job efficiency of the operator. It is calculated as number of operating minutes per hour divided by 60 min. Job efficiency for each type of machine operator is calculated by taking mean of the daily machine working time divided by actual working time. The daily machine working time is taken from the timesheets being maintained by the site accountant.

Illustrative calculation:

In the timesheet monthly total is 154.14.

Site working for the month= 27 days.

Avg. Daily working = 154.14/ 27 = 6.70 = 6:42 hrs.

Daily efficiency out of 8hrs.working day = 6.7 8 = 0.83.

Fill Factor

According to the type of material being handled, fill factor corrections are applied. Fill factors account for the void spaces between individual material particles of particular type of material when it is loaded into an excavator bucket. Materials such as sand, gravel, or loose earth should easily fill the bucket to capacity with a minimum void space. At the other extreme are the bulky-shaped rock particles. If all the particles are of the same general size, void spaces can be significant especially with large size pieces. Fill factor are the percentage that, when multiplied by heaped capacity, adjust the volume by accounting for how the specific material will load into the bucket. Fill factor can also be called as bucket efficiency factor.

Cycle Time

The sum of time required to complete one production cycle is the cycle time for equipment. The cycle time consist of different elements for different equipment's.

Typical cycle time elements for different equipment are as follows:

Excavator:

1. Excavate/load bucket
2. Swing with load
3. Dump load
4. Return swing

Hauler:

1. Load
2. Haul
3. Dump
4. Return

The cycle time for the equipment's involved in the operation are taken by the mean value of the actual observations taken.

Fleet Concept

To accomplish a task, machines usually work together and are supported by auxiliary machines. To accomplish a loading, hauling and compaction task would involve an excavator, several haul units, and auxiliary machines to distribute the material on the embankment and achieve compaction.

Such groups of equipment are referred to as equipment fleet/spread. An excavator and a fleet of trucks can be thought of a linked system, one link of which will control the fleet production. If spreading and compaction of the hauled material is required a two linked system is created. Because the systems are linked, the capabilities of individual components of the fleet must be compatible in terms of overall production i.e. the compaction equipment used on a project must have production capability matched to that of excavation, hauling, and spreading equipment.

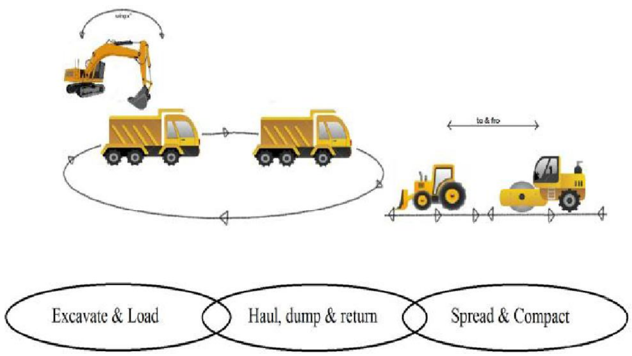

Figure 2: Three link earthwork system

The number of machines and specific types of machines in a fleet will vary with the proposed task. The production capacity of the total system is dictated by the lesser of the production capacities of individual systems.

Equipment Economics

The economics of any equipment in a company is associated with equipment ownership and operation. Ownership expense is the cumulative result of those cash flows the company experiences whether or not the machine is productively employed on a project. Operating cost is the sum of those expenses an owner experiences by working a machine on a project. Equipment cost is often one of a contractor's largest expense categories. The only reason for purchasing equipment is to perform work that will generate a profit for the company. Expense associated with the productive machine work is often associated with ownership and operating (O&O) cost. O&O cost is expressed in Rupees per machine operating hour. Most of information required for ownership and operating is available in the company's accounting records.

Ownership Cost

The cash outflow the firm experiences in acquiring ownership of a machine is the purchase expense. It is the equivalent cost of the machine for the current year considering time and a specific rate of interest and taxes and the insurance premium. It is a cost related to finance and accounting exclusively, and does not include the wrenches and consumables necessary to keep the machine operating. Annualized purchase expense is the required equivalent cost for the amount paid whiles the purchase of equipment. Annualized purchase expense can be calculated using uniform series capital recovery factor.

A (ownership) = $P\frac{i \: x \: (1+i)^n}{(1+i)^n-1})$

Where, P =purchase price I =interest rate for capital n = no. of years from purchase.

Operating Cost

Operating cost is the sum of those expenses an owner experiences by working a machine on a project. Typical expenses include:

Fuel Engine oil
Hydraulic oil
Hub greasing
Coolant Filter
Tires
Operator wages

Optimization of Haul Units

The ultimate goal of optimizing a hauling system is to maximize productivity while minimizing total cost. Therefore, it is conceivable that an optimum equipment mix which is based on physical factors alone may not minimize the cost in every location. Thus, cost factors must be considered equally important to engineering fundamentals. The loading time (L) for the considered tipper is taken for the given loading facility. These are then added to the travel time to calculate the instantaneous cycle time (C) i.e. tipper cycle time (load + haul + dump + return) and the optimum number of haul units (N) from the following, respectively: N = $\frac{C}{L}$

Where,
N = optimum number of haul units.
C = Tipper cycle time
L = Tipper loading time
A virtual fleet is designed to find out the actual benefits been incurred using optimization of the equipment.

IV. CASE STUDY

A. Name of Project- Construction of Bituminous road at Talegaon Dhabhade
Cost of Project – 17.5 Cr
Completion Period – 9 Months
B. Name of Project – Utility shifting work in Panvel Yard
Cost of Project – 44.37 Cr
Completion Period – 2yrs

V. RESULT

The total time to complete an earth- moving project is merely the total quantity of earth to be hauled divided by the production rate of the hauling system. Once the total hourly project costs are known, they can be multiplied by the TT to find the total cost to complete the project. That figure can then be divided by the total quantity of material to be moved (M) to arrive at a unit cost for a given size and number of haul units.

Thus Total Cost (TC) to complete the project can be described by the following formula:

$$TC = \frac{M \, x \, C \, x \, (Hn+He)}{N \, x \, (Sh) x \, 60}$$

Where,

M = Project Quantity (M3)
C = Tipper corrected cycle time (min)
Hn = Tipper O&O cost
He= Excavator O&O cost
N= Number of Tippers
Sh= Size of Tipper (M3)

Table 1: Practised Fleet Equivalent Value.

Cases	Actual Individual values					Equivalent Values				
Sr. No.	Tipper volume	Lead	Loading time (min)	Cycle time(min)	Nos.	Tipper volume	Lead	Loading time	Cycle time	Nos.
For road project										
1	9.3	300	5.6	18.16	1	12.06	300	8.3	21.17	2
	14.82	300	11	24.18	1					
2	9.3	300	6.2	19.16	1	9.3	300	5.76	19.26	3
	9.3	300	5.6	20.19	1					
	9.3	300	5.5	18.45	1					
3	14.82	300	12.5	22.18	1	14.21333	300	8.7	22.81	3
	9.3	300	6.5	26.12	1					
	9.3	300	7.1	20.15	1					
4	18.52	300	16.2	24.2	1	16.67	300	10.5	22.75	2
	9.3	300	4.8	21.3	1					
For railway platform project-										
A	9.3	120	5.2	19.2	1	9.3	120	5.733	17.65	3
	9.3	120	5.8	17.3	1					
	9.3	120	6.2	16.45	1					
B	9.3	120	6.3	14.2	1	12.6	120	8.255	16.71	2
	14.82	120	10.21	19.22	1					
C	9.3	120	6.4	14.3	1	12.6	120	9.270	18.2	2
	14.82	120	12.14	22.1	1					
D	9.3	120	6.5	18.25	1	9.3	120	6.067	16.58333	3
	9.3	120	6.3	15.2	1					
	9.3	120	5.4	16.3	1					

Table 2: Optimum Number of equivalent in each case

Case	Nos.	Tipper loading time (L)	Tipper cycle time(C)	Optimum Number	Equivalent
For Road project					
1	2	8.3	21.17	2.55	3
2	3	5.76	19.26	3.34	4
3	3	8.7	22.81	2.62	3
4	2	10.5	22.75	2.17	3
For Railway platform project					
A	3	5.73	17.65	3.08	4
B	2	8.255	16.71	2.02	3
C	2	9.27	18	1.96	2
D	3	6.07	16.58	2.73	3

Table 3: Activity cost by actual practiced fleet

Actual Fleet Project Cost							
Case	Equivalent						
	Quantity (Cum)	Tipper cycle time (min)	O&O Tipper cost(Rs./hrs)	O&O excavator cost (Rs./hrs)	No. of Tippers	Size of tippers(m3)	Total cost (Rs.)
For Road project							
1	147.7	21.17	838.80	1075.77	2	12.06	4136.61
2	225.1	19.26	687.24	1075.77	3	9.3	4564.94
3	237.7	22.81	747.83	1075.77	3	14.21	3863.88
4	161.4	22.75	929.23	1075.77	2	16.67	3679.15
For Railway platform project							
A	377.7	17.65	689.96	1075.77	3	9.3	7032.08
B	237.3	16.71	781.59	1075.77	2	12.6	4870.42
C	214.9	18.2	781.09	1075.77	2	12.6	4803.88
D	349.8	16.58	689.92	1075.77	3	9.3	6119.32

Table 4: activity cost by practiced trial fleet

Trial Fleet Cost							
Case	Quantity (Cum)	Tipper cycle time (min)	O&O Tipper cost (Rs./ hrs)	O&O excavator cost(Rs./hrs)	No. of Tippers	Size of tippers(m 3)	Total cost (Rs.)
For Road project							
1	147.7	21.7	838.80	1075.77	3	11.14	3060.23
2	225.1	21.55	687.24	1075.77	4	9.3	3830.78
3	237.7	22.67	747.83	1075.77	3	11.14	4898.88
4	161.4	22.66	929.23	1075.77	3	12.37	3291.42
For Railway platform project							
A	377.7	20.40	689.96	1075.77	4	9.3	6097.29
B	237.3	20.63	781.59	1075.77	3	11.14	4534.75
C	214.9	19.8	781.09	1075.77	2	12.6	5226.20
D	349.8	17.5	689.90	1075.77	3	9.3	6457.58

V. CONCLUSION

The unit rate of excavation i.e. Rs/m3 of excavation is found merely by dividing total cost by quality of work for the particular cases.

Table 5: Comparative Conclusion

Case	Unit Excavation Cost (Rs./m3)	
	Actual Practiced Fleet	Trial Fleet
For Road Project		
	28.01	20.72
	20.28	17.02
	16.26	20.61
	22.80	20.40
For Platform Work		
	18.62	16.14
	20.53	19.11
	22.35	24.32
	17.49	18.46

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