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Cost and Time Optimization in Fleet Management-Case Study of Sinnar Shirdi Highway

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Abstract: The aim of the study is to show how fleet management can help in saving time and cost by comparing the current onsite equipment to optimised results. The detailed study of fleet of equipment and their related parameters and specifications is important because it helps to determine requirement of equipments for a particular activity. All the cost including labor, maintenance, operating costs, machine capacity were considered to find out the productivity as well as expenses. Based on the site visit and data collection various parameters such as productivity of excavator, production rate, cycle time and other parameters of activities such as earthmoving equipment, hauling of trucks as well as productivity of paver were also calculated. The parameters were obtained for various combinations of different truck sizes as shown in the MS- Excel sheet. For different truck sizes and different combinations we get different cost index.
Keywords: Cost index, fleet management, optimization

I. INTRODUCTION

Fleet operation is the system which uses operation or technology to track and manage different kinds of vehicles similar as buses, weight logistic assignment, luxury motorcars, ambulance assignment, vessels etc. The fleet management system also keeps records of vehicles similar as purchase, reimbursement or parcel information, motorist records, energy information, GPS records and so on. Private builders and trace drivers are also enforcing major systems. numerous of moment's large- scale systems calculate on a line of heavy- duty vehicles and means pavers, excavators, tractors, bulldozers, backhoes, cranes, you name it - each vehicle within the line has a specific use case and serves a unique purpose in support of operations and during a construction design.

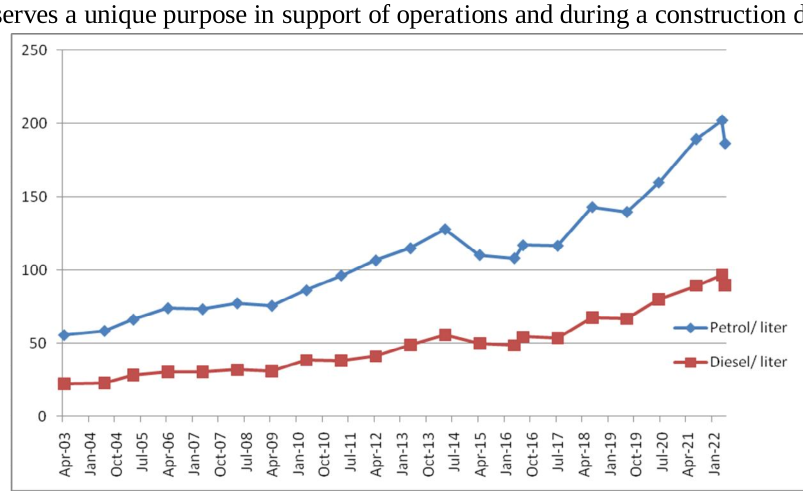

Fig. 1 Price trends of fuel in last 20 years

A. Need of the study

In construction industry construction management is important in operation of equipments as per the operations carried out. Price hike in fuel and energy in last many years has become a reason for need of proper fleet management. The detailed study of machines i.e fleet and their affiliated parameters and specifications is important because it helps to determine demand of equipment for a particular exertion e.g. DBM, earthwork activity. This kind of management not only saves the cost but also helps in optimizing time.

B. Objectives

1) To study fleet management in road construction projects.

2) To do a case study on Sinnar - Shirdi Highway and analyze the data.
3) To determine production rate, cycle time and other parameters of activities such as earthmoving equipment, hauling of trucks, and provide optimum solution to save time and cost.

II. REVIEW OF LITERATURE

Some theoretical and analytical investigations performed in this field are presented in the following literature survey.

1) Lalitesh Sinha and Atul Tripathi (2019) have shown in this paper that Time and cost are the main ideal to be bandied in the present optimization study using inheritable Algorithm (GA) for trace design. For scheduling of design has been used which gives the correct and accurate schedule of the design while GA optimization solver in MATLAB are used to optimize time and cost of the design. The Performance of the solvers substantially depends upon the parameters of GA which are used according to target and factual duration of design. The present case study shows that GA can be applied in establishing an optimal cost-time balance for trace systems. By considering incitement and penalty costs into the consideration, the cost- time relationship would come more dependent and complex on data. Still, GAs show better results in working this type of problem in small and huge construction systems.
2) The purpose of this paper of Adam Redmer (2020) is to develop an original model and a result procedure for working concertedly three main strategic line operation problems (line composition, relief and make- or- buy), taking into account interdependencies between them. The presented CSFMP result system (the model and the result procedure) allows for defining the line operation strategy in transportation and non transportation companies and institutions exploiting small and large lines of vehicles. The strategy results in the reduction of the total costs of transportation and the enhancement of a specialized and a profitable condition of a line.
3) Saeed Karshena and Foad Farid (June 1989) studied that Loaders and exchanges are frequently used in channel systems. In major earth- moving operations, careful selection of the number of machines used and the size of the outfit can produce substantial savings in both time and cost presently, the only system available for determining the optimum size- number combination for payload is comparison of all possible druthers. This is a tedious and time- consuming task, especially if a large volume of soil must be hauled, taking several lading units. In this study, optimal multiloader- truck lines are delved, and perceptivity of the product cost to the crucial variables is anatomized. The cost- capacity and capacity-power connections for exchanges and payload are delved by using published outfit specifications and cost data.
4) C.B. Tatum, Michael Vorster, Mac G. Klingler, Boyd C. Paulson Jr. (2006) studied the specialized advancement of earthmoving outfit during the 20th century that includes numerous advancements in crucial corridor of machines. This paper uses five systems that make up earthmoving outfit (apply, traction, structure, power train, and control and information) to assay this specialized advancement. The analysis of each system includes its purpose and operation, specialized limitations and crucial technologies, and a report of major advancements. The findings are the benefits of using the five systems for analysis of specialized change, the sequence and timing of crucial specialized advances in each system, the abecedarian technologies that fostered these advances, and the integration of systems into balanced outfit designs. This increased understanding from this analysis results in significant counteraccusations and applicability for civil contrivers working on intertwined brigades, contractors opting styles and planning operations, outfit suppliers developing new machines, construction preceptors tutoring the specialized basics of outfit, and experimenters developing advanced modelling and simulation tools.

III. METHODOLOGY

At present case it has been observed that there was unplanned management of the equipments. The data was obtained from Monthly Progress reports as well as site study from engineers and workers on the site. Study of equipment as well as site visit was done to analyse the data and a model was developed by using Saeed Karshena truck loader and R.L Peurifoys construction planning and methods. The model was used for calculations on M.S excel.

IV. RESULTS ANALYSIS AND DISCUSSIONS

In the current case the hot mix plant is located at Pimpalwadi which can produce about 160 tons per hour. Chainage is 29.00 to 30.00 and the distance between actual site and hot mix plant was about 9 km to and fro. The project was requiring a paving individual 12.5 m lane of 1 km and 115mm thickness having a density of 2.45 tonnes/cum. The maximum speed of paver is about 15m per minute. Efficiency of Asphalt paver is 0.8 and density of 2453 kg/sq.m-m.

Operational cost of paver is Rs. 8000 per hour and total cost of various associated labors is Rs. 3500 per day. In the case study the trucks are variable in sizes as they are rented for the whole duration of project. As there are various costs associated with the equipments, there is a need to select best equipment mix best fleet that will improve the productivity and satisfy the constraints of the project.

Table 1. Data collection for DBM fleet

Sr. No.	Description	Unit	Quantity
1	Capacity of Hot Mix Plant	TPH	160
2	Efficiency factor of HMP	-	0.9
3	Paving length	km	1
4	Width of road	m	12.5
5	Paving thickness	mm	55
6	Distance between site and HMP to and fro	km	9
7	Density of asphalt concrete	kg/m^3	2453
8	Operational cost of HMP (including diesel)	Rs./hr	8000
9	Paved density to be achieved	kg/m^2	1300
10	Delay estimates for paver	min/cycle	1.5
11	Efficiency factor of paver	-	0.8
12	Average slope	-	0.85
13	Swell factor	-	0.9
14	Max. velocity of paver	mtr/min	15
15	Gradient	-	0.3
16	Delay for dump trucks	min	4.5
17	Max. speed of tamper bar screed paver	kmph	15
18	Operational cost of paver (including diesel)	Rs./hr	5000
19	Operational cost of driver of paver (including lunch)	Rs./day	3900
20	Total daily working hours	hrs	8
21	Total working shifts	-	2
22	Delay cycle elements for dumper	min	5.5
23	Rolling resistance	-	3
24	Max. velocity of dumper	-	40
25	Plant capacity	tonnes/min	2.67
26	Labor cost of dumper driver (including lunch)	-	650
27	Capacity of Hot Mix Plant	m^3/hr	65.23
28	HMP Operator cost	Rs./day	650
29	Quantity per m	m^3	0.6875
30	Quantity	tonnes	1.6864
31	Basic Diesel cost	Rs./lit	96.00
32	Quantity required for paving 1km	m^3	687.5

Calculations

Step 1) Productivity of Hot mix Plant = 160 TPH

Productivity = 160 / 60 = 2.67 tonnes per minute

Productivity of plant in cum/hr = 160 x 1000 / density of asphalt = 65.23 m^3/hr

Step 2) Material to be paved per m:-

Volume of material paved per m = width of road x thickness of one layer of dbm for road x length to be paved = 0.6875 m^3

Volume of material to be paved per meter length in tones per meter = 687.5 x 2453 / 1000 = 1.6864 tonnes/m

Step 3) Productivity of Paver in (cum/hr)

Productivity of Paver = 495 m^3/ hour

Productivity of plant is less than productivity of the paver, so we will consider 1 number of paver for the operations.

Productivity of paver = productivity of plant = 495 m^3/hr

On the site, currently, 6 dumpers are being used for the following cycle of different sizes. We will find the best possible combinations by finding out the cost index of these 6 trucks.

Calculation of total cycle time for dump truck

Step 1) Hauling and return truck velocities for truck C from table =18cum

a) V_h = (k x hp x α) / (W_f) x (R + S)); where,

V_h = hauling velocity of truck (kmph)

k = conversion factor for hp to N-m/s

hp = horsepower of truck

α = mechanical efficiency of engine

W_f = full weight of truck respectively (tons)

R = Rolling resistance

S = grade resistance

Hence,

V_h = 14.54 kmph

b) V_r = (k x hp x α) / (W_e) x (R + S)) = 43.05 kmph but max permissible speed for trucks is 40 kmph so we will consider 40 kmph as return velocity; where,

V_r = return velocity of truck (kmph)

W_e = empty weight of truck (tons)

Step 2) Traveling time = ((1/14.54) + (1/40)) x 4.5 x 60 = 25.3 mins

Step 3) Truck loading time = (Capacity of truck x 60) / (Capacity of plant x efficiency of plant) = 7.5 mins

Step 4) Delay in cycle time for dump truck = 5 mins

Step 5) Total cycle time = 37.85 mins

Step 6) Required number of trucks = Total working hours x 60 / (Cycle time x 2) = 6 trucks

Step 7) Waiting time = ((N x Dumper loading time) - Cycle time) =7.15 mins

Thus, total cycle time = 45.00 mins

Step 8) Total time required for paving 687.5 cum of material = 4.02 hrs of hauling

This can be done in only 1 shift of 8 hours, hence 4.02 / 8 = 0.50 Days

Step 9) Total cost :-

1) Total cost of paver + plant = Hourly cost x No. of hours of working + labor cost = Rs. 54,812.04
2) Ownership cost of the dump truck for the required number of days = Ownership + maintenance cost of 6 number of 18 m^3 truck x total time required in days = Rs. 15,927.74
3) Operational cost of the truck = Number of trips x no. of trucks x total distance x operational cost = (total distance x quantity req. / (truck size x N)) x (N x operational cost of truck per km) + labor cost x no. of shift x days = Rs. 2,711.62
4) Total Cost = 1. + 2. + 3. = Rs. 73,451.40

Considering 10 % independent cost = 7,345.14

Total Cost = Rs. 80,796.54

Cost index = Total Cost / total quantity of earthwork = 80,796.54 / 687.5 = Rs. 117.52 per m^3

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All the parameters are obtained for various combinations of different truck sizes as shown in the below table. For different truck sizes and different combinations we get different cost index for DBM carrying trucks.

Table 2. Cost index and final cost showing actual and optimized results

Case No.	A 10 cum	B 14 cum	C 18 cum	Cycle time	Final cost	Cost index
1	6	0	0	33.08	115,547.54	168.07
2	0	6	0	35.38	93,195.55	135.56
3	0	0	6	37.85	80,796.54	117.52
4	5	1	0	33.46	110,493.26	160.72
5	5	0	1	33.88	106,381.10	154.74
6	1	5	0	35.00	95,995.72	139.63
7	0	5	1	35.79	90,740.68	131.99
8	1	0	5	37.06	84,283.18	122.59
9	0	1	5	37.44	82,555.39	120.08
10	4	1	1	34.26	102,452.56	149.02
11	1	4	1	35.41	93,266.72	135.66
12	1	1	4	36.64	86,114.56	125.26
13	4	2	0	33.85	106,296.16	154.61
14	4	0	2	34.67	99,037.38	144.05
15	2	4	0	34.62	98,882.93	143.83
16	0	4	2	36.21	88,292.97	128.43
17	2	0	4	36.26	88,424.70	128.62
18	0	2	4	37.03	84,221.77	122.50
19	3	3	0	34.23	102,371.69	148.90
20	3	0	3	35.47	93,409.06	135.87
21	0	3	3	36.62	86,051.10	125.17
22	3	1	2	35.05	96,143.98	139.85
23	3	2	1	34.64	98,960.16	143.94
24	1	3	2	35.82	90,809.17	132.09
25	2	3	1	35.03	96,069.85	139.74
26	1	2	3	36.23	88,358.84	128.52
27	2	1	3	35.85	90,877.65	132.19

We know that 687.5 m^3 of earth material is to be hauled at a distance of 9 km from the site for doing a work of road length of 1 km. As we have found out the cost index for both the cases i.e actual and optimized, we can multiply it by quantity of the DBM and get the result for savings in the DBM hauling.

Table 3. Results showing savings in DBM fleet

Current Cost of machinery usage at site	Rs. 98,960
Optimized Cost of site equipment	Rs. 80,797
Savings in Cost	Rs. 18,164

Similarly, we have analysed the data for Earthwork fleet and the results are as follows -
1,50,000 m^3 of earth material is to be hauled at a distance of 28 km from the site for doing a work of road length of 1.5 km. As we have found out the cost index for both the cases i.e actual and optimized, we can multiply it by quantity of the earth material and get the result for savings in the earthwork hauling.

Table 4. Results showing savings in earthwork fleet

Actual Cost of equipment (dumper trucks)	Rs 1,17,83,598
Optimized Cost of equipment (Dumper trucks)	Rs 1,00,85,781
Savings in Cost	Rs 16,97,818

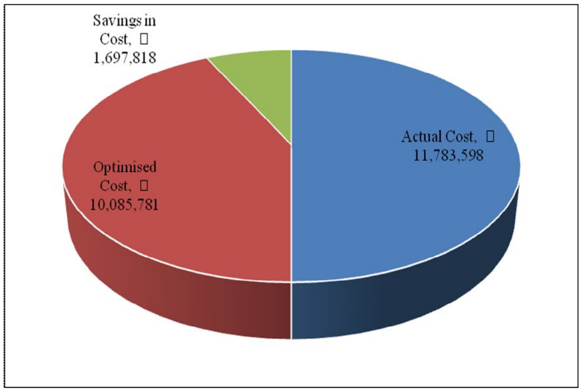

Fig 1. Pie chart showing savings in Earthwork activity

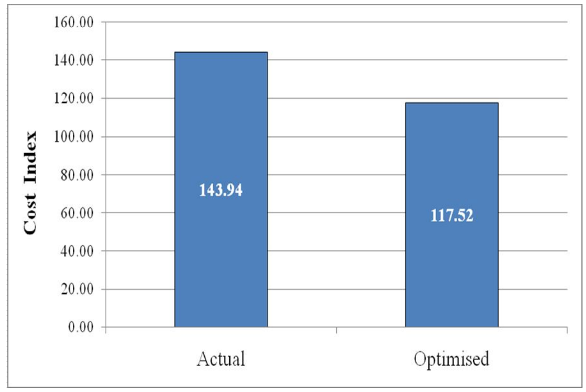

Fig 2. Bar graph of actual cost index vs optimised cost index

V. CONCLUSION

The factual on point line composition is grounded on the assumed thumb rules and no special optimization ways are employed and also the figures of units employed won't with their maximum productivity. From the result and discussion, we conclude that, the mix possibilities of equipments give economical and profitable solution as per site condition. The parameters similar as cycle time, total cost, Cost indicator, total time needed for completing exertion are determined easily. Grounded upon the comparison of values, mentioned in an irregular format, in result chapter are as follows,

1) In earthwork fleet- Actual time required is 118.28 days whereas optimized time is 83 days. Actual cost index is Rs. 78.56 per m^3 and optimized cost index is Rs. 67.24 m^3. So the profitability is Rs. 16,97,818 which is achieved.
2) Paver (DBM) fleet- Actual cost index is 143.94 Rs/cum and optimized cost index is Rs. 117.52 m^3. So the profitability is Rs. 18,164 which is achieved. The parameters such as cycle time, total cost, Cost Index, total time required for completing activity will be changed as per site conditions. The limitation of this study is, only two constructions activities are considered for this case study to analyze the data for actual distance. However, we can change the parameters and easily calculate more profitable options. Distance as well as equipment details can be changed and results can be obtained for any type of truck combinations. The calculations can be implemented for other types of fleet and other hauling material such as Aggregate, GSB, WMM, BC etc. It can be very useful in pre-planning phase of the project and help to save time as well as achieve better economy.

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