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Fleet optimization for time and cost factors in residential building

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ABSTRACT

Construction sectors are one of the widest sectors in the world. In which there is tremendous growth in terms of profit and development. it increases in terms of new inventions, new designs, new equipment, and a new concept in a wide manner. In that road transportation or road construction has a huge scope of work and chances of development of roads to connect cities and villages to each other. Basically roads of the particular area define their development of the area in terms of success, quality area of living, workplaces respectively. road construction is mainly considered as important work for connecting states, cities, and villages for transportation of goods and other things. In the construction sectors, mainly in road constructions, fleet management is one of the most important factors that define total cycle time, total cost, cost index, and total time required for completing the activity and related parameters. Fleet management can be defined by equipment assignment and optimization. Equipment assignment and optimization is the main reason many construction companies choose to implement fleet management systems in the first place. By enabling the scheduling and assignment of all types of equipment from multiple manufacturers as well as shift change management from a central office location, fleet management helps minimize unproductive machine wait time and optimize equipment usage on site.

Keywords: *Fleet Management, Scheduling and assignment, Cycle Time*

1. INTRODUCTION

India's construction industry is the second largest employer in the country. The Construction industry of India is an important indicator of the development that takes place in the country. This industry has contributed an estimated of $131 billion to the national Gross Domestic Product in the Financial year 2011-12 (1). The construction industry is diverse, with only a few major companies that are in the construction activities across segments; and only a some companies are in selected activities; and contractors who are on the lower end carry out the field work on sub-contractor basis. In 2015, there were in excess of 550 construction equipment-manufacturing companies in all of India. The construction sector which is labour - intensive also includes indirect jobs and provides employment 45 million people and above. Large contractors have been steadily increasing their investment in construction equipment to fulfil their work orders and in response to increased construction volume in recent years. The technical advancement of earthmoving equipment during the previous century and in the 21st century includes many improvements ultimately making the machine mechanically more efficient. Hence large construction operations and mega projects use a variety of large equipment.

This group of equipment's collectively forms a Fleet. The fleet operations has become a complex problem due to large number of manufacturers with various capacity and sizes of equipment available which makes the equipment selection a crucial task. Equipment selection is succeeded by optimization in number of equipment's in fleet. Moreover, large and highly competitive markets for infrastructure projects especially BOT type of contract, enforces the contractors to complete the project as early as possible to start regaining the investments. This demands a continued improvement in the performance of construction equipment's. Therefore, to overcome these challenges there is a need to apply management techniques and systems in managing the fleet to overcome these constraints and complete the project on time. Construction Equipment fleet management addresses only the problem of managing fleets of various construction equipment's maintenance problems and include dumpers, excavators, scrapers, graders, pavers, rollers, cranes, HMA plant, RMC plant, transit mixers, etc. The use of Equipment fleet management increases the productivity and efficiency of overall site and increases the bottom line through a proper equipment selection & optimization, production monitoring, tracking of equipment's, maintenance schedule, etc. Use of various sophisticated tools & techniques can also be used for the same such as telematics, GPS, information transmission systems & various other software's can be used.

2. OBJECTIVES

- To study the Fleet Management Process in Construction Projects.
- To determine Cycle time, Production Rate and other operational Parameters of activities such as, Earthwork and RMC (Ready Mix Concrete) for RCC
- To provide a fleet management solution for the Earthwork and RMC activity.

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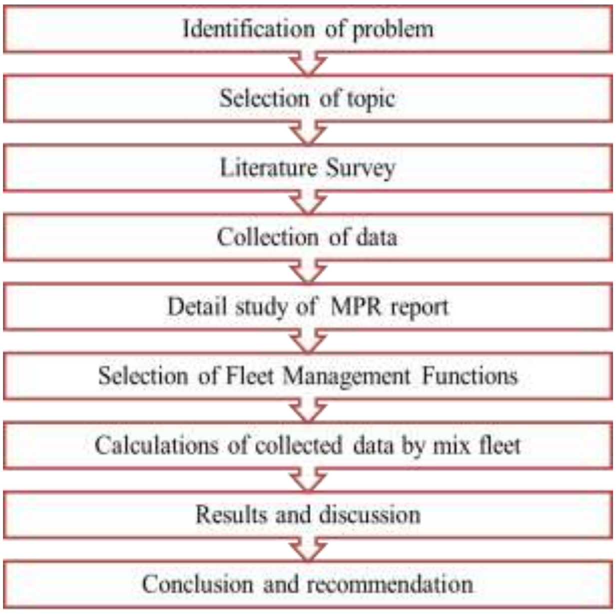
2.1 Literature Review

A compressive literature review has been conducted to optimize the time – cost of a construction project in a building to pursue the proposed study. The literature review focused on investing, analyzing current procedure for earthwork the road construction projects. There are various case studies about time – cost optimization has been studied in the literature review.

2.2 Methodology



3. CASE STUDY

The Building project which is residential and commercial in nature is located near Kusumagraj Pratishthan Gangapur Rd. Nashik. The Architect for the Civil Work project is Mr. Nitin Kute of Origin Architects and the project execution agency is Space+Realty which is a realty firm which has been operating in Nashik for the past 32 years. The project is done for the Client Shri Ramdas Wagh.

The project is a G+3 residential cum commercial building having office on the ground floor and the residence on the above floor. The building is constructed using modern construction techniques and Ready-Mix Concrete is used for all the concreting needs.

The projected cost of the project is around 5 crores and is expected to be completed in the month of July 2018. The project admeasuring around 10000 sq ft is situated on a plot of 980 Sq mt and is situated in a prime locality. The architect for the projects is Brio Architecture who will give consultations to the client on the interior works for the project. The landscape architect for the project are Roots Landscape a firm based out of Pune headed by Mr Umesh Wakeley.

3.1 Data Collection

A. Machinery available at site			
S no.	**Description**	**Total.**	**Remarks**
1	Dumper	3	
2	Excavator	2	
3	Soil Compactor	4	
4	Water Tanker	12	
5	Crawler Excavator	1	
6	Loader	2	
7	Transit Mixer	12	
8	Concrete Pump	1	
9	Air Compressor	1	
10	DG Set	1	
B. PLANTS			
1	RMC Plant	1	
2	Weigh Bridge	1	
C. OTHER			
1	Four Wheeler	4	
2	Motor Cycle	10	
3	Total Station	1	
4	Auto level	2	

3.2 Analysis and Calculation

At present case it has been observed that there was unplanned management of the equipment's. The equipment's were simply allocated based upon their assumed observations, in case of excavation and dumping of earthwork, the equipment's were allocated as 3 number of Dump trucks for 2 excavator were allocated. While on site it was observed the Dump trucks were ineffective and were waiting for certain duration of time during each cycle. Also the dozers were ineffective and lot of time was wasted for completion of the assigned task. Therefore, was a need for proper planning, selection and allocation of the equipment's which result will maximize the productivity and reduce the overall equipment associated cost.

In the above case study depending upon the variability of site conditions the type of excavators are kept same throughout the construction work, but at the same time the trucks are kept variable as they are rented for the whole duration of project. As there are various costs associated with the equipment's, there is a need to select best equipment mix best fleet that will improve the productivity and satisfy the constraints of the project. The analysis starts first determining the productivity of the Excavator by using the by using Peurifoy (1985) model and then the Saeed Karshena (1989) method of determining maximum haul and return velocities, which are further compared with maximum allowable speed to determine the variable time *(V)* and the travel time *(T)* of the trucks.*[Saeed Karshena 1989, 15*].

Where,
Vh = Velocity in Haul Direction (kmph);
Vr = Velocity in Return Direction (kmph);
Vmax = maximum velocity based upon legal speed limit (kmph);
Hp = engine horse power;
e = engine efficiency;
Wf = weight fully loaded (ton);
S = Slope (%); RR = rolling resistance (%) and
We = weight empty (ton).

S no.	**Item**	**Truck A**	**Truck B**	**Truck C**
1	Capacity(cum)	10	14	18
2	Horsepower(hp)	155	183	220
3	Efficiency	0.80	0.80	0.80
4	Empty Weight (Ton)	15	16.3	18
5	Weight Full (ton)	32.5	40.8	50.4
6	Ownership+Maintenance cost (Rs/day)	3200	3500	4000
7	Operational Cost (Rs/km)	7.85	11	13.75

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The construction site at Pumping St Rd. the earth material to be excavated was around 12500 m^3 and was to be hauled in 3 types of trucks that were available with the contractor, the details of the trucks are shown in table 1, the material was to be hauled over a distance of 3 km to and fro, with average rolling resistance of 3%, average slope 3%, unit weight of material 1750 kg/m^3 and the speed limit of the road as 40 km/hr. For the excavation Tata Hitachi LC200 with a 1.25 m^3 bucket size is going to load the dump trucks. The Equipment ownership + maintenance + operational cost of excavator are Rs. 350 per/hour.

3.3 Production Rate of Excavator

If an excavator is considered as an independent machine, following data is required;
1. Heaped Bucket Load volume.
2. Bucket fill factor based on material being excavated from the Manufacturers Data sheet.

Table Fill factors for excavator buckets (courtesy of Tata Hitachi Manual)

S no.	Material	Fill Factor* (%)
1	Bank Clay; Earth	100-110
2	Rock – Earth mixture	105-115
3	Rock Poorly Blasted	85-100
4	Rock well Blasted	100-110
5	Shale's, Sandstone	85-100

3.4 Estimated peak cycle time

S no.	Cycle Elements	Time
1	Move to stockpile	0.10 min
2	Fill bucket	0.10 min
3	Move to truck and maneuverer to load	0.25 min
4	Dump loaded bucket	0.10 min
5	Total cycle time	0.55 min

Loader cycle time

Bucket Capacity 1.25 m^3.
Swell Factor (The ratio of the weight or volume of loose excavation material to the weight or volume of the same material in place) – 0.90

Production of excavator =

$$\frac{60\ mins}{cycle\ time} * \frac{Efficiency}{\frac{60 mins}{hr}} * \frac{1}{volume\ correction}$$ …. (Construction Planning by Peurifoy R.L)

$$\frac{60 * 1.25 * 1.05}{0.55} * \frac{55}{60} * \frac{1}{1 + 0.8}$$

= *72.92 cum/hr*

Effective bucket capacity = *0.96 cum*

After calculating the productivity of the excavator, we have used mix fleet possibilities to calculate total cycle time and total cost. Following are the possibilities we have considered in the calculations.

CASE	A=10 CUM	B= 14 CUM	C=18 CUM
1	4	0	0
2	0	4	0
3	0	0	4
4	2	1	1
5	1	2	1
6	1	1	2
7	3	1	0
8	1	3	0
9	3	0	1
10	1	0	3
11	0	1	3
12	0	3	1
13	2	2	0
14	2	0	2
15	0	2	2

3.5 Calculation of total cycle time for dump truck=

1) Maximum and minimum truck velocity

For truck C from Table 5.3 = 18cum
Calculating:

1 Hp = 0.06214 ton, hence 220 hp = 13.67 tons

$V_h = \frac{hp x \alpha x k}{(W_t + W_w)(R+S)} \leq V_l \;\; for\ R + S > 0$ …… (Saeed Karshenas, 1989, pg 214)

$$\frac{540x13.67x0.8}{(18 + 50.4)(0.025)}$$

$$= \mathbf{2.158 \frac{m}{s}}\ which\ is\ \mathbf{22.40\ mins}\ for\ 2.9\ km$$

$V_r = \frac{hp x \alpha x k}{W_t (R+S)} \leq V_l \;\; for\ R + S > 0$… (Saeed Karshenas, 1989, pg 214)

$$\frac{540x13.67x0.8}{18(0.025)}$$

$$= \mathbf{8.202 \frac{m}{s}}\ which\ is\ 5.89\ mins\ say\ \mathbf{6\ mins}\ for\ 2.9\ km$$

2) Traveling time =

T = Vh + Vr = 22.40 + 6 = 28.40 mins

3) Dumper loading time =

$$= \frac{dumper\ capacity\ x\ loader\ cycle\ time}{loader\ capacity}$$

$$= \frac{18x0.55}{0.96} = \mathbf{10.313\ mins}$$

4) **Delay Estimates**=
But on site it was found that there was delay in time estimates as follows –

Table Delay in cycle time recorded for dump truck

S no.	Cycle elements	Time
1	Accelerate after load	0.5mins/cycle
2	Decelerate to dump	0.5 mins/cycle
3	Maneuverer and dump	1 mins/cycle
4	Accelerate empty	0.5 mins/cycle
5	Decelerate	0.4 mins/cycle
6	Failure due traffic	2 mins/cycle
7	Total	4.9 mins/cycle

Total cycle time = 28.40+10.31+4.9 = 43.61 *mins*

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Optimisation based on Cost Index Number (CIN) =

Calculating No of Dumpers required to complete the operation:

$$N=\frac{(Dumper\ Cycle\ Time)}{loader\ cycle\ time}$$

$$=\frac{43.61}{10.31}$$

$$= 4.229\ dumper = \mathbf{4\ dumpers}$$

Rounding down will maximize haul unit productivity. In other words, the haul units the haul units will not have to wait to be loaded, but the loader will be idle during a portion of each cycle. Therefore

Productivity of 5 Haul Units $=\frac{18*4*60}{43.61}$

= 99.059 ***cum/hr***

Step 2) Rounding no. of Dumpers required for Operation:

Seems the productivity of loader is not matching with the productivity of the excavator; unit of the hauling have to wait at each cycle. This assumes that there will always be a truck waiting to be loaded as the loader finishes loading the previous truck. For that purpose, we have to calculate waiting time to be loaded (A) =

= (Cycle time) - N*(Dumper Loading Time)

= (43.61) - 4*(10.313)

=***2.36 mins***

Thus actual cycle time (C) = 2.36+43.61 = 45.97 ***min per cycle***

And productivity of 4 haul units = $\frac{18x4x60}{45.97}$= ***93.97 cum/hr***

This is nearly equal to productivity of the loader. Therefore, it checks. When comparing the two possible productions it appears that it is best to round up in this case. Thus four haul units are selected. This decision also makes intuitive sense. No matter how many trucks were added to the system, they could never haul more material than the loader could load. The only way that a higher level of productivity could be achieved in this case is to add another loader.

Step 3) Total Time (T.T) required for completing for the 12500 cum of the material to be dumped

$$T.T\ =\frac{MXC}{60XNO\ OF\ TRUCKSXCapacity\ of\ truck}$$

$$=\frac{12500x45.97}{60x4x18}$$

= 133.015 hrs of hauling

Considering 8 hours of daily working,

Total no. Days of required for dumping work = $\frac{133.015}{8}$

= 16.63 days

Step 4) Total Cost=

1) **Total cost of excavator** = (Hourly cost x No. of hours of working) + (Labour cost per shift x No. of working days)

= (350 x 133.015) +(500 X 16.63)

= Rs. 54870 /-

2) Ownership cost of the dump truck = (4 no's of (18 cum) truck) x (Total time required in days)

= (4000 x 4) x 16.63

= Rs. 2,66,080 /-

3) Operational cost for 1 18 ^{m3} truck = (No of trucks) x (Total distance) x (operational cost) x (No. of Days)

$$=1\ x\ 5.8\ x\ 500\ x\ 16.63$$

= Rs. 48,227 /-

4) Total cost = 1) +2) +3)

=54870 + 266080 + 48227

= Rs 369,177/-

Considering 10 % independent cost, total cost = Rs 36,917.77/-

Total cost = 369,177 + 36,917.77 = Rs 4,06,094.77 /-

$$\text{Cost index No} = \frac{(total\ cost)}{(total\ quantity)}$$

$$=\frac{406094.77}{12500}$$

= 32.487 (Rs/cum)

S no.	Actual on site (7 Nos of 8 cum)	Optimised on site (2 Nos of of 4 cum,3 of 6 cum,2 of 8 cum	Profit/ Saving

Similarly, the cycle time, Cost index are obtained for various combinations as shown in MS-excel sheet with various combinations. Therefore, from the above obtained Results Truck C with capacity 18 m^3 proves to be Economical for selected Excavator and next page all calculations are given in detailed manner.

4 no.'s Truck C should be selected to perform the Job. This is nearly equal to productivity of the loader. Therefore, it checks, when comparing the two possible productions it appears that it is best to round up in this case.

In this case it is better to round up, as greater profit is realized. In practice, engineers tend to always round down, as it is easier to add another truck when necessary than to delete one that is not required. The simple logic of this rule speaks for itself. The engineer should never make this decision arbitrarily. Factors such as time, equipment, and labour constraints must be considered before the decision is made. Finally, the experience of the decision maker must ultimately be relied on to determine the most advantageous situation (Purifoy 1975).

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4.RESULTS AND ANALYSIS

For the activities involved in construction of the said building totalling to 120 m3 of concrete used following equipment's are listed equipment actually used and optimised no of equipment's to be used.

1. Earthwork fleet

- In this activity, the mix fleet cases are analysed to calculate cycle time, total cost and cost index. So there are 3 cases in which cost index are relatively less as compared to others.

Table Results of earthwork fleet

Case	A= 10cum	B= 14 cum	C= 18 cum	Total cycle time	Total cost	Cost index
1	4	0	0	27.36	476879.26	38.15
2	0	4	0	32.8	395372.37	31.63
3	0	0	4	45.97	488123.47	39.05

- From above table we can conclude that, case no 2 in which, 4 nos of 14 cum dump trucks has less total cycle time, total cost and cost index as compared to the other 2 cases.

Table Results of Saving/ Profit of Earthwork fleet

S no.	Actual on site (4 Nos of 10 cum)	Optimised on site (4 Nos of 18 cum)	Profit/ Saving
1	476879.26	395372.37	81,506.89

- From above table, the actual and the optimised cost of earthwork fleet is calculated.

2. Transit Mixer and RMC

In this activity, the mix fleet cases are analysed to calculate cycle time, total cost and cost index. So there are 3 cases in which cost index are relatively less as compared to others.

Table Results of TM fleet

Case	A= 4 cum	B= 6 cum	C= 8 cum	Total cycle time	Total cost	Cost index
1	7	0	0	65.50	287785.73	2398.21
2	1	6	0	62.20	251639.20	2096.99
3	2	3	2	73	181451.60	1512.10

- From above table, case 3 in which truck dumps of 8 cum less total cycle time, total cost and cost index as compared to case 1 and case 2.

5. DISCUSSION

5.1 Earthwork fleet

From graph no 1 and graph no 2 it is observed that,

a) Case no 2 which consist of 4 nos 14 cum dump trucks proves to be economical.

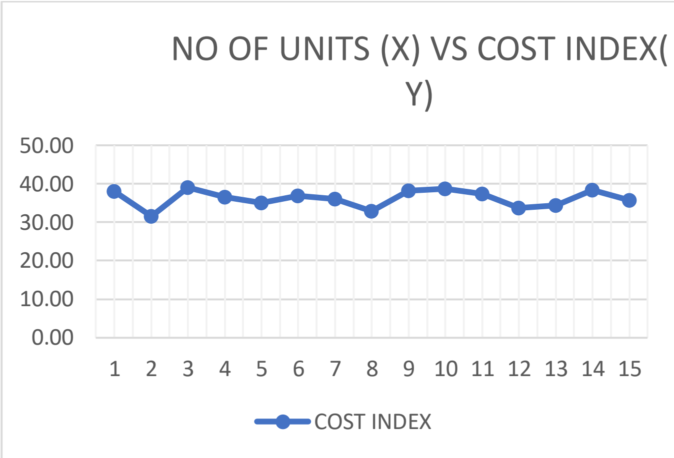
b) The optimised cost index of case no 2 in which 4 nos of 14 cum dump truck are considered is 31.63 Rs/cum.

c) The optimised duration of case no 2 is 6.53 days (104.44 hr) as compared to case no 1 and case no 3 which is economical and profitable in nature.

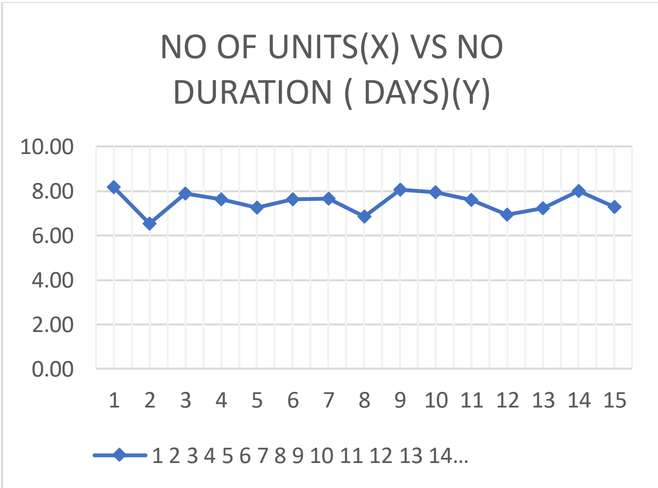
Depending upon availability of dump trucks on site the decision regarding the optimum no of haul units to be selected with the help of above graphs.

From graph no 3 it is observed that,

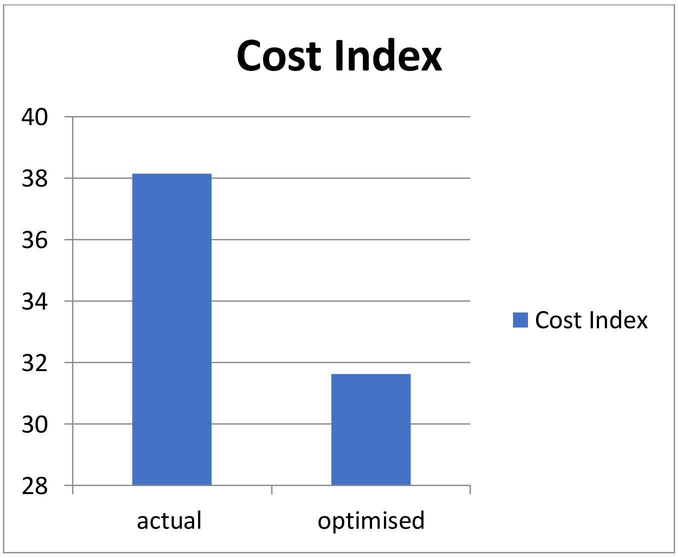
Cost index of actual (4 nos of 10 cum) is 38.15 Rs/cum and cost index of optimised (4 nos of 14 cum) is 31.63 Rs/cum which is relatively achieved.



Graph No: 1



Graph No: 2



Graph No: 3

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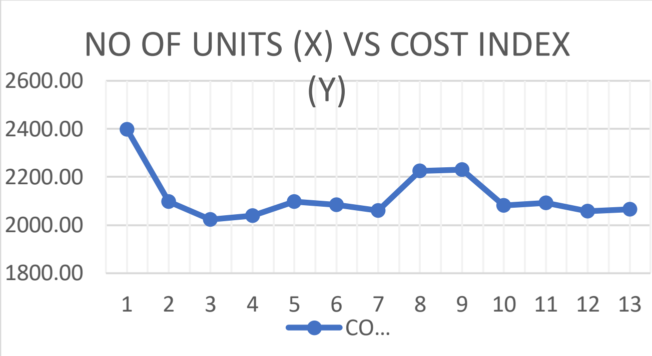
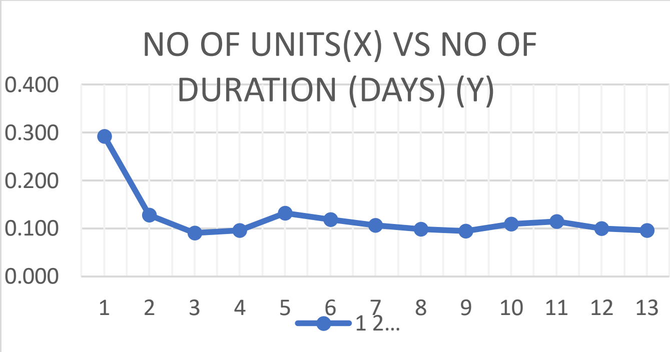
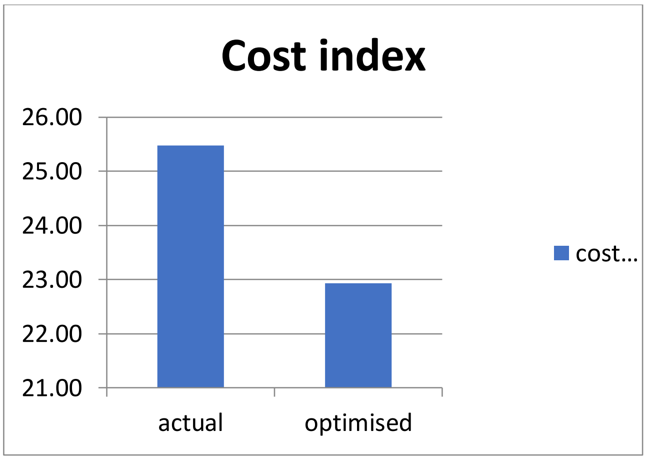
5.2 TM fleet



Graph No: 4



Graph No: 5



Graph No: 6 Cost Index

From graph no 4 and graph no 5 it is observed that

a) Case no 3 which consist of 2 nos of 4 cum, 3 nos of 6 cum and 2 nos of 8 cum TM proves to be economical.
b) The optimised cost index of case no 3 is 1512.10 Rs/cum.
c) The optimised duration of case no 3 is 0.143 days (2.33 hrs) as compared to case no 1 and case no 2 which is economical and profitable in nature.
d) Depending upon availability of TM at RMC plant the decision regarding the optimum no of haul units to be selected with the help of above graphs.

From graph no 6 it is observed that
Cost index of actual (7 nos of 4 cum) is 2398.21 Rs/cum and cost index of optimised (2 of 4cum,3 of 6 cum and 2 of 8cum) is 1512.10 Rs/cum which is relatively achieved.

6. CONCLUSIONS

1. The actual on site fleet composition is based on the assumed thumb rules and no special optimization techniques are employed and also the nos of units utilized will not with their maximum productivity.
2. From the result and discussion, we conclude that, the mix possibilities of equipment's give economical and profitable solution as per site condition.
3. The parameters such as cycle time, total cost, Cost Index, total time required for completing activity are determined clearly.
4. Based upon the comparison of values, which is mentioned in a tabular format, in result chapter as follows,

i) In earthwork fleet,
Actual cost index is 66.79 Rs/cum and optimised cost index is 47.34 Rs/cum
So the profitability is 11,67,352 Rs which is achieved.

ii)TM fleet,
Actual cost index is 2398.21 Rs/cum and optimised cost index is 1512.10 Rs/cum

So the profitability is Rs 106334.13, 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.

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