Time - Cost Optimisation in Road Construction Case Study – Nashik Sinnar Highway

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***Abstract*—In the construction project, time and cost are the most important factors to be considered in the planning of every project. The aim is to finish the projects on time, within budget and to achieve other project objectives. Time loss is costly and it creates problem which are related with costs. It increases cost with increasing in time of particular activity. Due to this the total budget of the project gets collapsed.so Time-cost optimization is essential for construction projects. The objective of time-cost optimization is to determine the optimum project duration corresponding to the minimum total cost.**

Keywords- Optimisation, Roadconstruction, Time, Cost, Profit, Fleet Management.

INTRODUCTION :

India has the second largest road network across the world at 4.7 million km. Road transportation has gradually increased over the years with the improvement in connectivity between cities, towns and villages in the country. India is the developing country and in the economy of country, construction industries play a vital role. Time and cost are two main concerns in a construction and they are used for planning a different project such as infrastructure, roads etc. Construction management is defined as the application of management techniques and systems in construction to complete projects on budget, on schedule, safely and according to plans and specifications. The advent of powerful microcomputers, the advances in computer hardware and software and their low costs have led to increased utilization of computers in various areas of construction management such as project management, scheduling, cost eliminating, bid mark-up analysis, accounting, submittal management, equipment management, materials management and field management.

Large contractors have been steadily increasing their investment in construction equipment to satisfy their needs in response to increased construction volume in recent years. The technical advancement of earthmoving equipment 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 a large number of various construction equipment's. The fleet operations have become complex due to large number of manufactures, various capacity and sizes of equipment available which makes the equipment selection the complexity further increases to optimize the size and number construction equipment's in the fleet.

Fleet management consist of conceptual sub –components such as equipment selection and assignment, equipment optimization, maintenance, production monitoring, material and position monitoring etc.

Objectives-

- To study the fleet management process in construction industry.
- To determine cycle time, final cost, profit and other operational parameters of activities such as Earthwork
- To provide a fleet management solution for the road construction projects.

A. Literature Review

A comphresive literature review has been conducted to optimise the time – cost of a constuction project whether in a road or building to pursue the proposed study. The literature review focused on investing, analysing current procedure for erathwork the road constrcution projects.There are various case studies about time – cost optimisation has been studied in the literature review.

B. Methodology

The given detailed Road project is a perfect communication skill for an area which lies on Nashik- Sinnar Highway.

3.1 Detail study and deepinvestigations of the site of the project – detailsof the site, location, maps and overall information is given.

3.2 Study of road procedure – road procedure are studied in details manner. It gives resources which is required for the activity.

3.3 List out of the data which is required for calculation ofobjectives – data collection such as Monthlu progress report(MPR) NTSL agreement, DPR 4 laning are given.

3.4 Study of data collection – study of data collection in detail. It helps to gain information of the site in well manner.

3.5 Selection of plan and profile – after detailed study of data collection, profile is selected.

3.6 Calculations of collected data by mix fleet – calculations of collected data is done by using mix fleet formulas with using various possibilities of vehicles.

3.7 Derive time, cost and related parameters from the calculations using fleet formulas

3.8 Results and discussions – time and cost parameters are given in results chapter in detail manner.

3.9 Conclusion – From results, final conclusion is concluded.

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C. *Case Study*

The practical example is taken from the construction site named 'NASHIK – SINNAR TOLLWAY', which consist of 25.31 km and it runs on BOT basis. The project work falls in Nashik district of Maharashtra.

D. *Data Collection:*

Table 1 : Mobilization of the vehicles and equipment's

Sr. No	Description	Total.
1	Dumper	51
2	Excavator	13
3	Soil Compactor	9
4	Water Tanker	12
5	Grader	6
6	Loader	3
7	Tandem Roller	1
8	PTR Roller	1
9	Transit Mixture	12
10	Dozer	1
11	JCB	5
12	Trailer	1
13	Paver	2
14	Diesel Tanker	2
15	Kerb Machine	1
16	Concrete Pump	1
17	Air Compressor	1
18	Tar boller	1
19	DG Set	26
B. PLANTS		
1	Crusher Plant	1
2	WMM Plant	1
3	RMC Plant	2
4	HM Plant	1
5	Weigh Bridge	1

E. *Analysis and Calculations*

At chainage 198.00 to 199.00 a road length of 1km was to be constructed for which 60000 m^3 earth material was to be hauled and 3 types of three types of trucks are available to the contractor, the details of the trucks are shown in table 1, the material was to be hauled over a distance of 6.5km 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. 2200 per/hour.

Table 2: Details of available Dumpers (Trucks)

Sr 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+Maintainance cost (Rs/day)	3200	3500	4000
7	Operational Cost (Rs/km)	7.85	11	13.75

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.

Table3: Percentage of heaped buckets (courtesy of caterpillar manual)

Sr. 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

1.Estimated peak cycle time
2. loader cycle time

Table 4 – cycle elements recorded for excavator

Sr. 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

3.Bucket Capacity 1.125 m^3.
4.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 =
$$\frac{60\ mins}{cycle\ time} * \frac{Efficiency}{\frac{60mins}{hr}} * \frac{1}{volume\ correction}$$ …. (Construction Planning by Peurifoy R.L)

$$=\frac{60*1.25*1.05}{0.55} * \frac{55}{60} * \frac{1}{1+0.9} = 72.92 \text{ cum/hr}$$

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.

Table 6 – possibilities of 4 truck dumpers

	A = 10 CUM	B = 14 CUM	C = 18 CUM
CASE	10	14	18
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

Calculation of total cycle time for dump truck =

1) Maximum and minimum number of truck velocities –

For truck C from table S(h) = 18cum

$$Vh= \frac{540x220x0.8}{(50.4(0.3+20x(0.3x20))} = 15.67\ km/hr$$

$$Vr = \frac{540x220x0.8}{18(0.3+20x(0.3x20))} = 40\ \ km/hr$$

2) traveling time =

$$T = \left(\frac{1}{15.67} + \frac{1}{40}\right)x6.5x60 = 34.62 \text{ mins}$$

3) Dumper loading time =

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

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

3) Delay Estimates =

But on site it was found that there was delay in time estimates as follows –

Table 7 – delay in cycle time recorded for dump truck

Sr 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 = 34.62+10.31+4.9 = 49.84 mins

Optimization based on cost Index Number (CIN)= Step 1) Calculating No of Dumpers required for satisfied the operation:

$$N=\frac{(Dumper\ Cycle\ Time)}{loader\ cycle\ time} = \frac{49.84}{10.31} =$$

$$4.833\ dumper = 5\ dumpers$$

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 $=\frac{18*4*60}{49.84}$

= 108.35 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) =

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

= 4*(10.313)- (49.84) =8.59 mins

Thus actual cycle time = 8.59+49.84 = 58.43 min per cycle

And productivity of 4 haul units = $\frac{18x5x60}{58.43}$

=73.93 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 60000cum/hr of the material to be dumped

$$T.T\ = \frac{MXC}{60XNO\ OF\ TRUCKSXSh} = \frac{60000x49.84}{60x4x18}$$

= 692.222hrs of hauling

Considering 16 hours of daily working in 2shifts,Total no. Days of required for dumping work = $\frac{692.222}{16}$= 43.26 days

Step 4) Total Cost=

1) total cost of excavator = Hourly cost X No. of hours of working + labour cost

= (2000 x 692.26) +(500 X 43.26)

= 1544603.50 /-

2) Ownership cost of the dump truck = (4 no's of (18 cum) truck) x total time required in hrs = (4000 x 4) x 43.26

= 692160.00 /-

3) Operational cost of the truck = (no of the trips) x (no of trucks) x (total distance) x (operational cost)+ labour cost

$$= \frac{((0x10+0x14+6x18)\ x\ (6.5)x(13.95)x(60000)}{(0x10+0x14+\ 4x18)} +$$

(500x2x43.26)

= 345516.30 /-

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

=1544603.50 + 692160.00 + 345516.30

= 2582382 /-

Considering 10% independent cost, total cost = 258238.2 /-

Total cost = 2582382 +258238.2 = 2840620 /-

$$\text{Cost index No} = \frac{(total\ cost)}{(total\ quantity} = \frac{2840620}{60000}$$

= 47.34366 (Rs/cum)

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.

RESULTS AND ANALYSIS

For the activities involved in construction of 1.0 km length of road section at chain age of 198.00 km following listed are the no of equipment actually used and optimized no of equipment's to be used

Earthwork fleet –

1.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.

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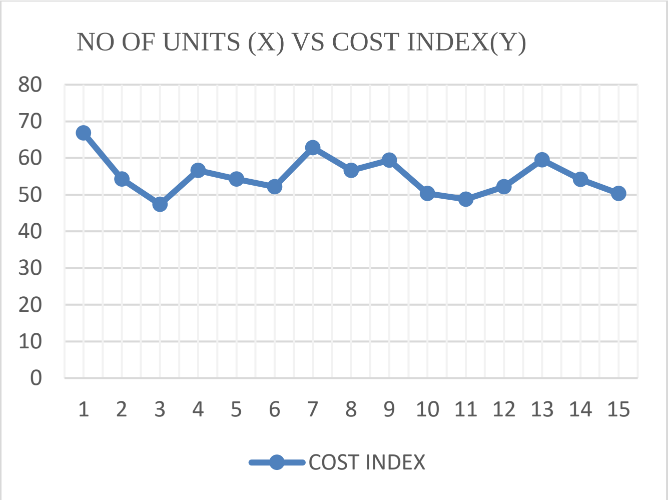
Case	A= 10cum	B=14 cum	C=18 cum	Total cycle time	Total cost	Cost index
1	4	0	0	63.38	4007972	66.79
2	0	4	0	61.68	3255300	54.25
3	0	0	4	58.43	2840620	47.34

Table 6.1 – results of earthwork fleet

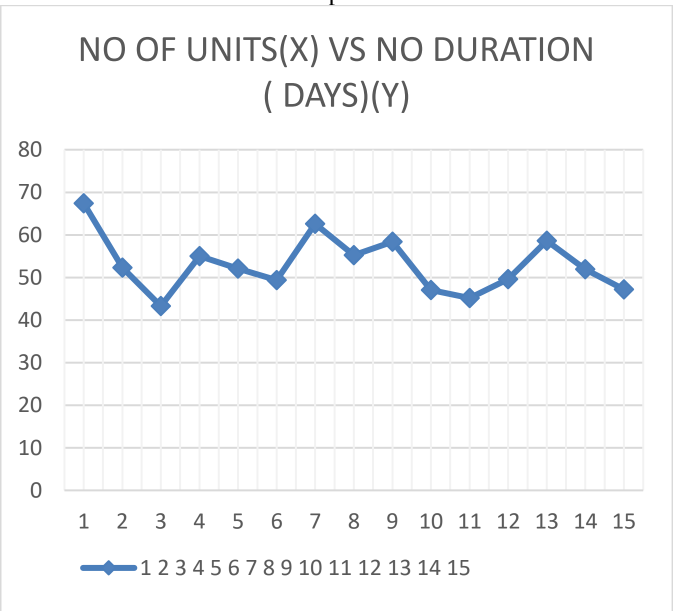
2.From above table we can conclude that, case no 3 in which, 4 nos of 18 cum dump trucks has less total cycle time, total cost and cost index as compared to first 2 cases.
3. on the actual site, 4 nos of 10 cum dumpers were used but 4 nos of 18 cum dumpers is the optimized solution of the earthwork fleet.

Discussion –

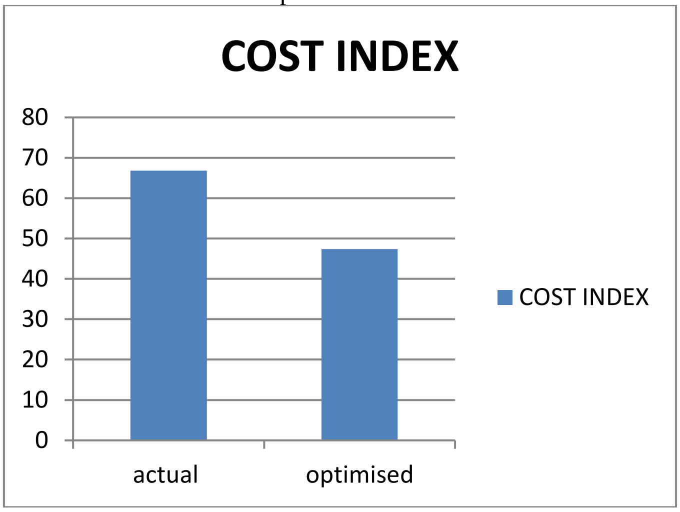
Graph No -1



Graph No-2



Graph No – 3



From graph no 1 and graph no 2 it is observed that,
Case no 3 which consist of 4 nos 18 cum dump trucks proves to be economical.
1.The optimized cost index of case no 3 in which 4 nos of 18 cum dump truck are considered is 47.34 Rs/cum.
2.The optimized duration of case no 3 is 43.26 days (692.21 hr) as compared to case no 1 and case no 2 which is economical and profitable in nature.
3.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,
4.Cost index of actual (4 nos of 10 cum) is 66.79 Rs/cum and cost index of optimised (4 nos of 18 cum) is 47.34 Rs/cum which is relatively achieved.

CONCLUSION-

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.
5. 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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