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RESOURCES OPTIMIZATION IN CASTING OF SEGMENTS ON BRIDGE CONSTRUCTION

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ABSTRACT

Resources are the most important part of any construction project. Total cost of project is based on resources. For India the construction industry has contributed an estimated ₹ 6708 billion to the national GDP in 2011-12 which is a share of around 8%. This sector is both labour and machine intensive and provides employment to more than 35 million people, which is around 27% population of India. So, optimization of resources plays a vital role in saving of valuable natural resources and cost which is required to generate them. So, in this paper concept of optimization is understood clearly and try to implement it on bridge construction site. The case study is selected as Hyderabad metro project. In this project concreting of precast segment of bridge is considered. The main objective of study is to optimize the resource utilization on concreting activity by applying some operational research techniques such as transportation model, assignment model, EOQ etc. The paper also discussed the concept of multi agent negotiation used on site. Construction projects are unique in nature because construction activities are varies from project to project. Thus, it is not possible to apply result of optimization from any particular case study to any other construction site but the idea or technique regarding optimization till remains same for other sites.

KEYWORDS: **Resource optimization, operational research techniques, EOQ etc.**.

INTRODUCTION

Construction is the activity where resources are essential at any stage of work. To minimize the cost of construction means to minimize cost of resources required for the construction. So, resources are the most important part of any construction project. In Indian construction sector as labour and equipments available in large quantity, our construction sector is both labour intensive and machinery intensive construction sector. But being available in such a large amount it is not mean to use these resources haphazardly. So, they should be optimized in allocation before construction to generate maximum benefits in minimum cost. Also construction have uncertainties and risks. These factors creates problems to complete the given project in scheduled time and cost. If it is not going to complete in scheduled time and cost then optimization comes in picture to complete project in lesser amount of time and cost than what is to be came earlier. Thus, optimization is defined as,

"It is the best way to allocate the resources depends upon availability and nature of resources, type of construction work to do and in the environmental safety with constraint of time."

The nature of the construction projects is resource driven. But to implement it on the site is really difficult task. So construction manager need to decide optimized process to complete project prior to commencement of the work. For the projects like bridges required huge amount of resources and money. These resources should be use optimally so that no wastage of money occurred. The bridges include bulk concrete work so the concreting is one of the vital activity in bridge construction. Also in bridge construction each resource i.e. men, materials, equipments has their own area to improve their optimum use. These area are studied in this paper.

The Hyderabad metro project is considered as the site. The project consist of erection of elevated metro rail in the Hyderabad city. The contract is DBFOT type contract. L & T construction company is the contractor for the project and project cost is around 16375 crore. The metro project is consist of construction of viaducts. The network of these viaduct spread all over the city. It is quiet impossible to implement the cast in situ approach on such huge work. So,

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the contractor decided to go with precast unit in the casting yard and provide them on site as per requirement. This research paper consider the concreting activity in casting yard and try to optimize it using simple operational research models and some concept of construction management. As the optimization is the process based approach it is important to understand process first and then we able to apply different optimization models on project. The project is the vital project to reduce the traffic problem and increase the faster transportation in the city. It consist of 72 km rail route network in the city without affecting the road traffic. Only 2 metre width of the road is occupied at centre of the road where piers of viaducts are erected.

There are 2 casting yard for precasting of segments. One of them is in working at Uppal from where data is collected. The casting yard at Uppal have 2 ready mix concrete plant. In the casting yard there are 3 bays. Each bay is having 3 line moulds for construction. In that two mould are long line mould and one is short line mould. Mostly in viaduct a span of 11 segment is required which is having length 33 metre and at some time required less no of segment when there is lesser span length. There are 11 segments in one span. These segments are of 4 types i.e. S1, S2, S3, and S4. Following table shows the concrete requirements for each segment. In practise these quantity are not come exactly same as that shows in table. But these value gives the guess of concrete use per segment.

TABLE- 1

SEGMENTWISE CONCRETE QUANTITY

Sr.No.	Segment type	Concrete requirement
1)	S1	12 Cu.m
2)	S2	15 Cu.m.
3)	S3	12 Cu.m.
4)	S4	12 Cu.m

In one span there are two S1, two S2, two S3 and 5 S4 segments. So for casting of one span requires around 147 cu.m. if concrete required exactly equal to table quantities. Concrete of M45 grade is used. Also for one complete bay about 102 labour are required.

METHODOLOGY ADOPTED

The resources required on site for casting are divided in following 3 heads.

A. Materials,
B. Manpower,
C. Equipments.

There are certain factors which are going to affect the cost and time required on site. As these factors affects cost and time they ultimately affect the optimization of resources required. These factors are listed as below

A. Materials

The function of cost minimization of materials is bound in the constraint of price inflation in the market and material consumption pattern on the construction site. This cost minimization function deals with following factors.

1) Material cost,
2) Material management on site,
3) Material taxes,
4) Material carrying cost,
5) Material testing cost,
6) Material stacking cost,
7) Discount available on bulk purchase,
8) Material consumption practices,
9) Price inflation in market.

Now in above list apart from 1, 2, 4, 6, 7, and 8 other are not significantly used for optimization as these are factor that are not avoidable. As contractor don't control on these factor they are not going to minimize by optimization. Only thing is that planning manager properly planned for these cost and there should not be extra cost due to faulty procedure to be executed the work.

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Factor considered while optimization

Material cost

Material cost includes the raw material cost for the material, process cost, manufacturing machinery cost. These cost are decided by manufacturer. These cost vary by the different process adopted for the production of same material. Now to optimize this cost the cheap manufacturing process should be selected without reducing quality required for the material.

Material management on site

Good material management system lead to less material wastage. Also proper communication between suppliers and consumers maintain quality of the work. The material manager should consider above aspect in mind for good management. On metro site multi agent negotiation system is used which is explained in analysis part.

Material stacking cost, material carrying cost and discount available on a bulk purchase

For large construction site many time material is required in bulk amount. So for such large order the supplier offer some discount. Now for optimization it is essential to know how much order should be placed by contractor to get material in lowest cost. Economic ordered quantity (EOQ) technique is used in this part. This study work gives details regarding cement bags ordering quantity for metro project.

Material consumption practices

On construction site labours often proceed with the casual approach for performing the work. This approach may lead to wastage of money and resources. During the work planning manager should monitor process of work execution to reduce such losses. Also along with labour sometime construction process isn't good enough to reduce the losses. At this time also planning manager try to reduce the wastage by modifying the process.

B. Manpower

The cost requirement for the manpower depends on several factors explained below. These factors affect cost requirement directly or indirectly.

1) Skill level of workers,
2) Number of labour allocated to work,
3) Wages of worker,
4) Inflation,
5) Medical expenses of workers,
6) Number of accident occurred on the site,
7) Basic amenities provided to workers.

From the above factor contractor not able to do cost minimization in 3 to 7 as these factors are not decided by him because some of the factors are affected by external factors and some are not avoidable. For the first 2 factor contractor have opportunity to deal with cost minimization. Developing of multiskilled workforce and use of assignment model to decide the allocation of labour helps to reduce cost in future work.

Skill level of workers

Many time it is seen that contractor utilises same gang of labour for particular work and he has to replace labour gang when another work is started. Multiskilling is the method by which contractor able to train labours for more than one work and able to utilise them on site instead of shifting them to other site. By this method different skills in labours are also able to develop. On Hyderabad metro site the L & T Company build different gangs of labour for different works. These gangs are firstly trained by company and then these gangs are used on site. These labour gangs becomes assets for the company as they are well trained.

Number of labour allotted to work

On construction site many time contractor faulty allocation of labour to site may lead to extra time required for completion of project. Also at some time work is going to complete in required time but some labour remain idle during work which is also wrong. So, to know how much quantity of labour exactly required for particular job is calculated by assignment model. On the metro site labour gangs are used to execute the work. In this study 4 labour gangs are considered which are doing concreting work on site on 4 types of segment i.e. S1, S2, S3 and S4. From result we easily identify which gang of labour allotted to segments so that time required is minimum.

C. Equipments

The factor that are affects the cost minimization of equipment are listed as below,

1) Cost of equipment,
2) Fuel cost,
3) Selection of equipment(higher efficiency)and
4) Transportation cost.

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From the above list cost of equipment and fuel cost is unavoidable. So these are not considered in optimization.

Transportation cost

The concrete is prepared in 2 ready mix concrete plant and it is transported at the site by concrete transit mixer. The cost required for this transportation may unnecessarily increase if the transit mixer allotted haphazardly to casting location. Transportation model kept minimum cost required for the transit mixer for transporting concrete from ready mix plant to casting yard.

ANALYSIS

A. Material

1. Material management on site.

To minimize cost increment due to faulty management practices the manager should implement good practice on site. Following chart is showing the concept of multi agent negotiation used on Hyderabad metro site. It completely differentiate responsibility of material management by allocating individual person for each function rather than all activities are arranged by same person haphazardly. Here bay incharge plays the role of multi agent. Rather than selecting only one person as casting yard incharge they select respective incharge for particular bays. They communicate precisely in between site engineers, survey incharge and suppliers to reduce the wastage of material on site and bring the exact quantity of material which is required for construction. The bay incharge perform the following functions.

1. Reporting to the casting yard project manager.
2. Interacting with engineer's representatives and internal departments.
3. Daily review of program and progress with the project manager.
4. Responsible for resources allocation.
5. Submission of requirement of materials & other resources for the next week/ month to the supply manager.
6. Responsible for Casting of segments.

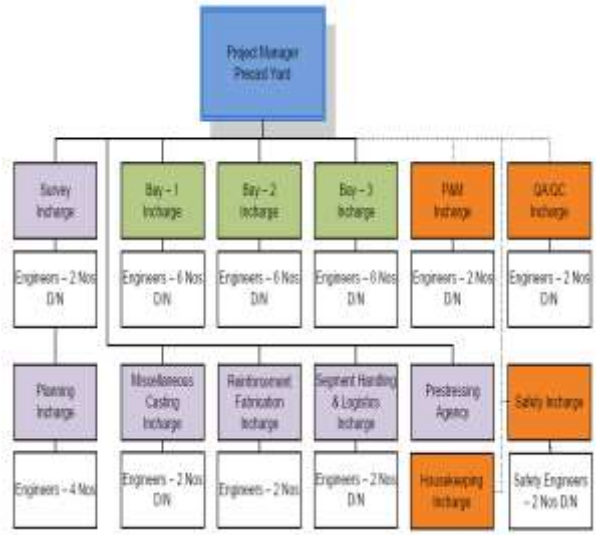

figure 1

Organization chart for one precast yard

2. Material stacking cost, material carrying cost and discount available on bulk purchase

These cost are minimized by EOQ model. The data collected is for month of October 2014. By this data metro site requires 21472 cement bags for the casting of segments. Consider 21500 bags are required with tolerance. Each bag cost Rs. 350. The procurement cost and inventory carrying cost are given by batching plant incharge which are Rs. 35 and 15% of cement bag cost respectively. Also supplier offer discount of Rs. 4 per bag if every single order is at least of 2000 bags. Then in this case to know how much order should be placed for minimum carrying cost and procurement cost. As bay incharge are informed the requirement of cement bags prior to start of work it is possible to use this technique to avoid excess cost for wrong orders.

EOQ formula $= \sqrt{(2.s.Cp)/Cu.i}$

$= \sqrt{2 * 21500 * 35/350 * 0.15}$

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First EOQ without discount = 170 number of bags.
Now there is Rs. 20 discount for every 2000 bags order at one time.
Reduction in material cost = (difference in price per unit)* (monthly requirement)
= 4 * 21500
= Rs. 86000
Decrease in procurement cost per month = (reduction in number of order of month) *(procurement cost per order)
= ((21500/170)-(21500/2000))* 35
= Rs. 4050
Monthly saving due to discount = 86000+4050
= Rs. 90050
Increase in monthly inventory carrying cost =
(Monthly inventory carrying cost for 2000)-
(Monthly inventory carrying cost for 170)
= (0.5*2000*346*0.15)-(0.5*170*350*0.15)
= Rs. 47437

So, inventory carrying cost is quiet less than monthly saving if the discount per cement bags is Rs 4 for order of 2000 bags at one time. So, it is suggested that contractor should go with supplier discount provision.

B. Manpower

1. Number of labour allocated to work,

Manpower is one of the most unpredictable source for construction work. On Hyderabad metro site gangs are used for performing the different works. On casting yard there are many gangs which are doing all concreting activity. Data is the time required for the different gangs to complete concreting activity is calculated. This time used to determine least time requirement using following assignment model. The main aspect of this model is to complete maximum work in minimum time

TABLE- 2
CALCULATED TIME FOR DIFFERENT LABOUR GANGS.

Gang number	S1 segment (in hrs)	S2 segment (in hrs)	S3 segment (in hrs)	S4 segment (in hrs)
A	20	18	23	17
B	21	17	22	18
C	23	17	20	16
D	21	20	24	19

Calculate row minimum value and subtract it from each row element and also after doing this subtraction calculate column minimum value an subtract from each column.
Carry out these iterations still final result become,
Number of rows = Number of columns = Minimum possible number of lines drawn in table which covers all zeros in it.
The table obtained as below,

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TABLE -3
FINAL RESULT OF ASSIGNMENT MODEL

Gang number	S1 segment (in hrs)	S2 segment (in hrs)	S3 segment (in hrs)	S4 segment (in hrs)
A	1	1	2	0*
B	2	0*	1	1
C	5	1	0*	0
D	0*	1	1	0

So, by above table it is clear that if we allotted work as S1 segment to gang D, S2 segment to gang B, S3 segment to gang C and S4 segment to gang D then we get minimum time for completion for respective segment construction work which is shown as below,

TABLE - 4
MINIMUM HOURS REQUIRED FOR CONCRETING FOR ALL SEGMENTS.

Gang number	Segment allotted	Minimum time in hrs
A	S4	17
B	S2	17
C	S3	20
D	S1	21
Total time in hrs		75 hrs

So, by above table it is clear that minimum hrs required for casting S1, S2, S3 and S4 segment is 75 hrs.

C. Equipment

1. *Transportation model*

On Hyderabad metro site there are 3 bay and 2 ready mix plant. Transit mixer of capacity 4 cu.m, 5 cu.m, and 6 cu.m are used to transport the concrete from batching plant to bay. Appendix gives the detail data required for transportation model. The cost coefficient and supply and demand for transportation model are given in appendix. After solving this model by NW corner method the result generated are given as,

Minimum transportation cost = (39*30.5) + (28*34) + (11*36.1) + (55*39.5)

= Rs. 4711.

That means the transportation of concrete from 2 RMC plant to 3 bay should be done by following ways only to obtain minimum cost in transportation. This minimum cost requirement need to allocate concrete to 3 bay as per following chart. However this paper only consider NW corner method but if other methods like least square and MODI methods are used then more optimum allocation will obtained.

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TABLE - 5
RESULT OBTAINED FROM TRANSPORTATION MODEL

RMC plant	Bay 1	Bay 2	Bay 3
1	39 cubic metre	28 cubic metre	-
2	-	11 cubic metre	55 cubic meter

RECOMMENDATIONS

Optimization is the never ending phenomenon and to implement it on project it is essential to update knowledge with the project progress. For such a huge project like metro it is impossible to cover every aspect regarding optimization of resources in single study so future scope of the study is to cover remaining aspects. One can't implement results generated from this study directly to another site because every construction project is unique by it's nature and detail study of project working and optimization is required to implement optimization in project. Also **t**his study deals only with some operational research technique with simple mathematical solutions but this process will going to more effective when software based optimization techniques such as genetic algorithm are going to be implemented on site.

RESULTS AND CONCLUSIONS

From the analysis of various problem it is conclude that construction manager able to save much cost by using simple operational research techniques. Systematic data collection, analysis allows the contractor to avoid all possible extra cost on site. The results of different models are listed as below.

By allowing the multiagent negotiation system on the construction site planning work smoothly and avoid complication in supply and demand. As no time is wasted the project will remain on track.

EOQ helps contractor to place the economically ordered quantity. For the cement bags it comes 170 but as supplier provide much better offer for 2000 bags per order, contractor will go with supplier offer. The saving earned by contractor when contractor goes with supplier offer is Rs. 90,050 per month and extra cost incurred is Rs. 47437

In assignment model the minimum hours required for concreting for different gangs are calculated. The model explain which gang able to complete the concreting activity of particular segment in minimum time. This will help contractor to complete 1 span of 33 metre length in minimum time.

Using transportation model contractor able to save transportation cost of concrete. The minimum transportation cost by NW corner method comes as Rs. 4711 which is less than actual cost required on the site which is Rs. 5000.

APPENDIX

Estimation of cost coefficient in transportation model

Two parameter are considered.

1) Wages of operator

Wages are Rs. 600 per day.

So, the monthly wage is Rs. 18000

But this transportation model the concreting activity of date consider is 2/11/2014 in which 10 number of segments casted in 3 bays and total amount of concreting is 133 cubic meter

Also for concreting 4 transit mixer of capacity 6 cu.m. Are used. So, wage of transit mixer operator per cubic meter is Rs.18.00

2) Fuel cost.

Diesel cost per liter in October Rs. 59

Now distance covered per liter of diesel by transit mixer is taken as 3.5 km.

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Table number 6
Per cubic meter diesel cost calculation from both rmc plant

RMC plant	Bay 1 (39 cu.m)	Bay 2(39 cu.m)	Bay 3(55 cu.m)
Distance from 1	2km	2.5 km	3 km
Distance from 2	2.3 km	2.8 km	3.3 km
Diesel req by 1(lit)	1.1 lit	1.4 lit	1.7 lit
Diesel req by 2(lit)	1.3 lit	1.6 lit	1.9 lit
Cost of diesel for1(Rs)	Rs. 65	Rs. 83	Rs. 100
Cost of diesel for2(Rs)	Rs. 77	Rs. 94	Rs. 112
Per cubic meter cost for 1	Rs.10.8	Rs. 13.8	Rs. 16.6
Per cubic meter cost for 2	Rs. 12.8	Rs. 15.6	Rs.18.6

Oil cost per liter in October is Rs. 250 and about 16 liter are required and need to change after 3000 Km so per km cost is Rs. 1.3

Table number - 7
Per cubic meter oil cost calculation

Oil cost	Bay 1	Bay 2	Bay 3
From 1	Rs 5	Rs. 6.5	Rs. 7.8
From 2	Rs. 6	Rs. 7.2	Rs. 8.6
Cost of oil per cubic m (1)	Rs. 0.8	Rs 1.	Rs 1.3
Cost of oil per cubic m (2)	Rs. 1	Rs. 1.2	Rs 1.4

Coolant cost per liter in October is Rs. 270 and about 23 liter are required and need to change after 4500 Km so per km cost is Rs. 1.38.

Table number 8
Per cubic meter coolent cost calculation

Coolant cost	Bay 1	Bay 2	Bay 3
From 1	Rs. 5.5	Rs. 7.0	Rs. 8.3
From 2	Rs. 6.3	Rs. 7.7	Rs. 9.10

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Cost of coolant per cu.m (1)	RS 0.9	Rs. 1.1	Rs. 1.4
Cost of coolant per cu.m (2)	Rs. 1.05	Rs. 1.3	Rs. 1.5

So, the transporting cost coefficient per cubic meter are as follows,

Table number - 9
Per cubic meter cost coefficent

RMC plant	Bay 1	Bay 2	Bay 3
Plant 1	30.5	34	37.3
Plant 2	32.8	36.1	39.5

Demand and supply chart for transportation model (capacity of both batching plant is 6 cu. m. / hr.)

Table number - 10
Demand and supply per bay

RMC Plant	Bay 1	Bay 2	Bay 3	Supply in cubic meter
Plant 1				67
Plant 2				66
Demand in Cu.m.	39	39	55	133

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