# Time and Cost Optimization for a Residential Building Project with an Integrated Project Management Approach

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***Abstract:*** *In construction industry, it is important to have control on time and cost performance of projects to ensure the construction cost is within the budget. For all construction projects, the main objectives are to handover the project within the required time and cost. Resources are the most important part of any construction project and the total cost of project is based on resources. Despite the availability of various control techniques and project control software many construction projects still do not achieve their cost objectives. So, optimization of resources plays a vital role in saving cost as well as time for any particular project. In this paper concept of optimization is understood clearly and implemented on a residential building project. The main objective of the study is to optimize the cost and time of the project by implementing an integration project management system (IPMS) which includes various operational research methods, efficient procurement strategy, value engineering and project management software. The study includes identifying factors affecting the cost and time of a residential building project and further analyzing it for optimizing the overall cost and time of a residential building project by developing IPMS. After performing the analysis on the data collected from on-site observations, authentic documents related to the particular project, meeting various involved stakeholders, interviewing them and making a note of their opinion and expertise, it has been clearly observed through the results that by implementing IPMS can help effectively to control and optimize the cost and time of a residential building project.*

***Keywords:*** **Project Management, Time, Cost, Quality, Optimization models, Operational research, Integration Project Management System (IPMS)**

## 1. Introduction

In construction industry, it is important to have control on time and cost performance of projects to ensure the construction cost is within the budget. For all construction projects, the main objectives are to handover the project within the required time and cost. Each project has its planned budget and schedule. The budget is a measure of the cost that the project will consume in order for the final deliverable to be finished. Employing effective planning in terms of scheduling, budgeting, safety and quality at the early stages of the project is very important. A successful construction project is generally acknowledged to be the one completed on time, within budget, in accordance with the specifications and to stakeholders' satisfaction. One of the most important problems in the construction project is delays. Delays occur in every construction project and the magnitude of these delays varies considerably from project to project. It is therefore essential to define the actual causes of delays in order to minimize and avoid the delays in any construction project. When number of factors affecting construction projects is more, Project Management becomes a necessity on such Construction Projects.

## 2. Need for Study & Literature Review

**Need of the study**

Various problems faced on Construction projects are Unrealistic Planning, Construction Delays, Cost Overruns, Absence of proper communication amongst the employees and stakeholders, Compromised Quality of Work, Improper Inventory Management and Absence of proper management techniques.

There has to be a Single solution to all these problems. Hence there is a need to study and successfully implement 'Project Integration Management' on the construction projects which may result to be a full-proof solution on the problems arising on such projects.

**Literature Review**

From the existing literature reviewed, following points were observed:

Identifying factors and suggesting mitigation measures helps project managers to improve the effectiveness of controlling the projects; Yakubu Adisa Olawale & Ming Sun (2010). Microsoft project software reduces the cost by 6.98 % and the overall duration by 7.71 %; Umesh Kamble and Shashank U. Vanakudari (2018). Implementation of EOQ helps controls the cost of project by 2.84%, improper management of time, cost and manpower; Dipak P. Patil, Pankaj Bhangle et al (2014). Lack of knowledge, inadequate planning for the implementation and the unavailability of qualified expertise is the main problem faced by contractor in optimizing the costs on site; Anuja Rajguru & Parag Mahatme (2016). The transportation model reduces the transportation cost of concrete by 800 Rs., Assignment model helps contractor to complete 1 span of 33-meter length in minimum time and EOQ reduced the cost of cement bags order by 42600 Rs per order; Abhaysinha G. Shelake & Rohit R. Salgude (2015). Implementation of value engineering on a construction project can reduce an overall cost of project by 3.5% of planned budgeted cost; Punam Kokate and Milind Darade (2018).

## 3. Research Objectives

The main objectives of the study are:

- To identify various factors affecting the overall cost and time of a residential building.
- To rank the identified factors and to identify the issues related with resources at site for time and cost overrun.
- To optimize the cost and time by using project management software, procurement strategy and value engineering technique.
- To optimize the cost and time by applying various operational research techniques such as EOQ model, Assignment model and Transportation model

## 4. Research Methodology

To achieve the objectives of the project following methodology was adopted as shown in figure 1:


**Figure 1. Research Methodology**

**Data collection**

The data was collected from a residential building project located at Virar, Mumbai that comprised of construction of 4 towers namely A, B, C and D; with each tower of 14 storeys. The data collected from the site is as follows:

a. BOQ of buildings
b. Material procurement details
c. Budgeted versus actual cost reports
d. Reconciliation reports
e. MOM with the contractor and within the staff
f. Detailed schedule with baseline and tracking
g. Personal interviews with questionnaire using google forms

**Issues related to the factors at site**

- Non-utilization of professional construction management techniques or software for planning and scheduling.
- Non-effective procurement strategy adopted at site.
- Over budgeted cost for various materials and methods in construction.
- Shortage in gypsum bags for finishing activities at site against the total monthly requirement.
- Non-productivity of labors for casting of slabs and poor equipment productivity for delivering RMC at site.

**Relative Importance Index (RII)**

RII = ΣW / (A*N)

Where, W = Total weighting given to each factor by the respondents (1 to 5)

A = Highest weight

N = Total number of respondents.

Higher the value of RII, more important is the factor.

**Table 1. RII for the factors**

| Sr. No | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RII | 0.76 | 0.88 | 0.86 | 0.6 | 0.9 | 0.8 | 0.78 | 0.74 | 0.56 | 0.72 | 0.68 | 0.66 | 0.64 | 0.54 |
| RANK | 6 | 2 | 3 | 12 | 1 | 4 | 5 | 7 | 13 | 8 | 9 | 10 | 11 | 14 |

**Table 2. Factors affecting time and cost with ranks**

| Sr. no | Factors | Rank |
|---|---|---|
| 1 | Scope change | 6 |
| 2 | Inappropriate and inadequate procurement and faulty contractual management system | 2 |
| 3 | Changes in materials types and specifications during construction | 3 |
| 4 | Errors committed due to lack of experience | 12 |
| 5 | Non utilization of professional construction management | 1 |
| 6 | Slow delivery and shortage in construction materials | 4 |
| 7 | Poor labour productivity or poor equipment productivity | 5 |
| 8 | Complexity of project | 7 |
| 9 | Accidents during construction | 13 |
| 10 | Difficulty of coordination between various parties working on the project. | 8 |
| 11 | Design changes by owner or his agent during construction | 9 |
| 12 | Slowness of the owner decision making process | 10 |
| 13 | Delays in contractor's payment by owner | 11 |
| 14 | Weather effect | 14 |

# 5. Data Analysis

**5.1. Microsoft Project** - Utilization of professional construction management software:
After collecting the drawings and preparing list of activities and duration required, next scheduling of the activities in the MS-Project Software was done.

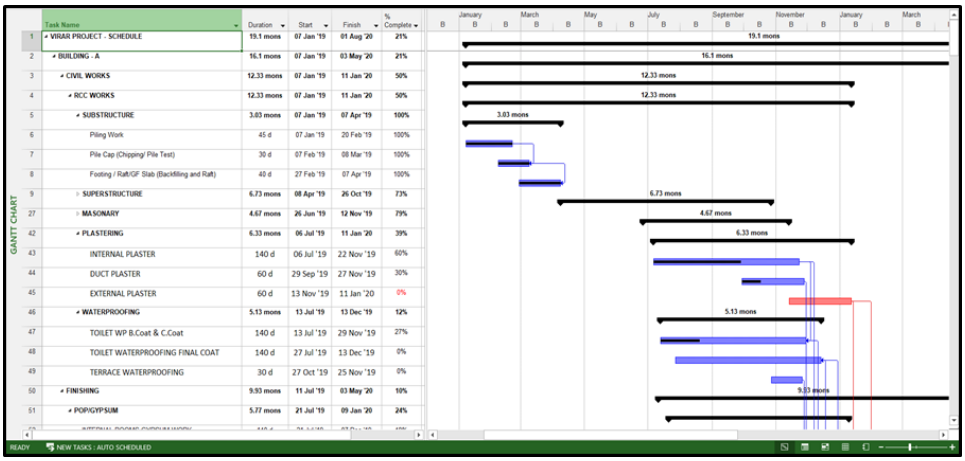


**Figure 2. Scheduled activities**

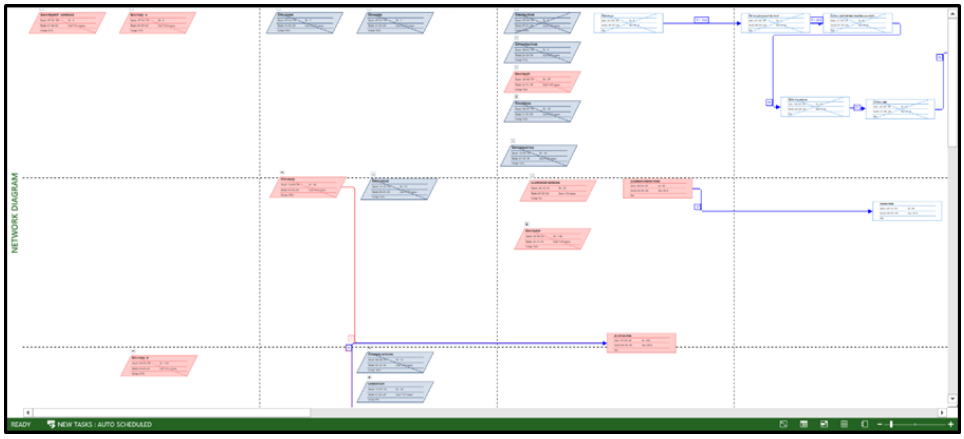


**Figure 3. Network diagram**

Some of the benefits observed after utilization of this software on the case study are:

- The chronological planning of the construction activities and graphical representation on the Gantt chart was obtained.
- The overall delay of the project was known exactly. And to overcome these delay proper measures were taken by crashing activities which reduced the overall project duration by 35 days.
- The total completion of the project with respect to each and every activity in terms of percentage was known.

**5.2. Early Contractor Involvement (ECI) Procurement strategy –** To apply adequate procurement and contractual management system:
Taking into account the benefits of implementing ECI procurement strategy, it can resolve the main issue of inadequate procurement of materials in this case study. Early involvement of the contractor can lead to proper procurement of the resources required at site without any shortage and also can help in optimizing the material design which will ultimately reduce the cost of procurement and the material.
Implementing ECI in this case study saves the extra cost of procurement and total delay of 45 days caused due non availability of material at site.

**5.3. Value Engineering –** To optimize the cost by using alternatives:
In this research the cost is optimized for the following elements:
1. Piling technique – At the project site, Rotary rig piling method was used for piling works. Cost of this method per building with 120 piles was Rs. 61,70,288 (M) + Rs. 43,22,825 (L) = Rs. 1,04,93,113. To reduce the cost, DMC method can be used as an alternative method for piling works.

**Table 3. Piling works BOQ**

| DMC RIG METHOD | | | | | |
|---|---|---|---|---|---|
| **Sr.No** | **Description** | **Unit** | **Qty** | **Rate** | **Cost** |
| **A** | **PILING work for Wing A** | | | | |
| **1** | **Mobilization of machinery:** | | | | |
| a | 50% on mobilization | RIG | 7.00 | 11,000.00 | ₹ 77,000.00 |
| b | 50% on demobilization | RIG | 7.00 | 11,000.00 | ₹ 77,000.00 |
| 2 | **Boring** | | | | |
| 2.1 | 600mm dia | RM | 1800.00 | 1,100.00 | ₹ 19,80,000.00 |
| 3 | **Reinforcement steel** | MT | 57.43 | 3,500.00 | ₹ 2,01,001.94 |
| 4 | **Concrete** | | | | |
| 4.1 | 600mm dia | RM | 1800.00 | 150.00 | ₹ 2,70,000.00 |
| 5 | **Muck removal:** | PILE | 120.00 | 3,800.00 | ₹ 4,56,000.00 |
| 6 | **Testing & Report** | | | | |
| (i) | Low strain Integrity testing of piles | PILE | 120.00 | 400.00 | ₹ 48,000.00 |
| (ii) | High strain Dynamic testing of piles . | PILE | 2.00 | 40,000.00 | ₹ 80,000.00 |
| 7 | **Concrete breaker** | Cum | 27.13 | 2,500.00 | ₹ 67,824.00 |
| | **Total amount excluding taxes** | | | | **₹ 32,56,825.94** |
| | **Additional cost of bentonite tank (25x10x8)** | | | | **₹ 2,80,000.00** |
| | **Bentonite powder** | No. | 360 | 185 | **₹ 66,600.00** |
| | **Total amount excluding taxes** | | | | **₹ 36,03,425.94** |

For DMC method, Total cost of labour is Rs. 32,56,825.94. Also, the material cost reduces as 15% less concrete is used in this method due to less vibration and thus maintaining proper diameter of the pile, which saves about Rs. 3,07,200. Therefore, the cost is Rs. 91,19,913. But DMC method requires bentonite tank, so the cost of bentonite tank and bentonite powder need to be added, i.e. Rs. 2,80,000 + Rs. 66,600. So, the overall cost of building is Rs. 94,66,513. And the overall saving for one building is Rs. 10,26,600.

2. Backfilling –
At the project site, Total backfilling of 1888 cum was done with 40 % from excavated soil and 60% from outside. So, 755 cum of excavated soil and 1133 cum. from outside was used that resulted in cost of backfilling as Rs. 11,60,080.
To save the cost, using overall excavated soil as backfilling and remaining can be ordered, the results are shown in the below table. This gives an overall saving for one building of Rs. 1,69,088.63.

**Table 4. Backfilling BOQ**

| Backfilling Work | Unit | Qty | Rate | Amount |
|---|---|---|---|---|
| Manual backfilling with good quality earth/murum available within the site premises | Cum | 1119 | 336 | 3,76,084.80 |
| Backfilling with murum from outside premises | Cum | 769 | 800 | 6,14,906.57 |
| **Total** | | | | **9,90,991.37** |

3. Flooring Alternative –
At the site, tiles of 10mm thickness were used for flooring work inside the flats that costs Rs. 13,04,672.19 for flooring works. As an alternative to reduce the cost of material, tiles

of good quality with less thickness can be used. That gives results as shown in the table below with an overall saving of Rs. 1,14,289.28.

**Table 5. Flooring BOQ**

| Different Tile Manufacturer | | | | |
|---|---|---|---|---|
| **Material description** | **Qty (sft)** | **Rate** | **Thickness** | **Amount** |
| Ivory Vitrified Tiles 600 X 600 mm | 52186.888 | ₹ 22.81 | 8.2mm | **₹ 11,90,382.90** |

4. Compound Wall –
Compound wall of chain link fencing was constructed at site of 225 meters with overall foundation of RCC that costs Rs. 28,38,625.19. As an alternative to reduce the cost, foundation of 6-inch brickwork with coping on top and RCC columns at 2 meters interval was designed, that costs Rs. 21,62,224.11. This saved an overall cost of Rs. 6,76,401.08 for the project with four towers.

**5.4. EOQ model –** For cost effective order of materials:
The data collected is for month of January 2020. By this data site requires 3500 gypsum bags for finishing. Each bag cost Rs. 200. The procurement cost and inventory carrying cost are given by store in charge which is Rs. 30 and 15% of gypsum bag cost respectively. Also, supplier offer discount of Rs. 25 per bag if every single order is at least of 3000 bags.
EOQ formula = $\sqrt{\ }$ $[(2.\ s.\ Cp)/Cu.\ i]$
$= \sqrt{\ } [(2 * 3500 * 30)/200 * 0.15]$
EOQ without discount = 100 no. of bags. Reduction in material cost = (difference in price per unit) * (monthly requirement) = 25*3500 = Rs. 87500.
Decrease in procurement cost per month = (reduction in number of orders of month) *(procurement cost per order) = ((3500/100) - (3500/3500)) * 30 = Rs. 0
Monthly saving due to discount = Rs. 87500.
Increase in monthly inventory carrying cost = (Monthly inventory carrying cost for 3000) - (Monthly inventory carrying cost for 100) = (0.5*3500*175*0.15) - (0.5*100*200*0.15) = Rs. 44,438.

**5.5. Assignment model –** to increase the labour productivity:

**Table 6. Slab Size**

| Sr. No. | Slab Type | Concrete Qty |
|---|---|---|
| 1 | S1 | 240 Cu.m |
| 2 | S2 | 235 Cu.m |
| 3 | S3 | 237 Cu.m |
| 4 | S4 | 238 Cu.m |

After solving the below assignment model following result as in table no. 8, was obtained

**Table 7. Assignment Model**

| Gang no. | S1 (in hrs) | S2 (in hrs) | S3 (in hrs) | S4 (in hrs) |
|---|---|---|---|---|
| **A** | 14 | 12 | 13 | 14 |
| **B** | 16 | 13 | 12 | 14 |
| **C** | 14 | 14 | 12 | 15 |
| **D** | 16 | 13 | 14 | 14 |

**Table 8. Slab Allocation**

| Gang no. | Slab allotted | Minimum time in hrs |
|---|---|---|
| A | S2 | 12 |
| B | S3 | 12 |
| C | S1 | 14 |
| D | S4 | 14 |
| Total times in hrs | | 52 hrs |

**5.6. Transportation model –** For improving the equipment productivity:
Total slabs considered are: tower A=1 slab: SA1, Tower B =1 slab: SB1, Tower C=1st pour: SC1 and No. of RMC plants: 2
Wages of operator: 15,000 Rs per month i.e. 500 Rs per day. Size of transit mixer is 6 cu.m and 4 transit mixers are used. But for this transportation model the concreting activity of date considered is 15/01/2020 in which 245cu.m of total concreting done. So, wage of the transit mixer operator per cubic meter is Rs. 8.5. And diesel cost per liter in Jan 2020 is Rs. 71.11and mileage is 2.5 kmpl. Oil is 250 Rs per lit and about 18 litters are required and need to change after 3000 kms so per km cost is Rs. 1.5.

**Table 9. Cost of Diesel**

| RMC Plant | SA1 (110cum) | SB1 (90cum) | SC1 (45cum) |
|---|---|---|---|
| Distance from 1 | 13 km | 13.2 km | 13.35 km |
| Distance from 2 | 15.2 km | 15.4 km | 15.55 km |
| Diesel req. by 1 (lit) | 10.4 | 10.56 | 10.68 |
| Diesel req. by 2 (lit) | 12.16 | 12.32 | 12.44 |
| Cost of diesel for 1 (Rs) | 739.54 | 750.92 | 759.45 |
| Cost of diesel for 2 (Rs) | 864.69 | 876.08 | 884.62 |
| Per cubic meter cost for 1 | 123.24 | 125.15 | 126.57 |
| Per cubic meter cost for 2 | 144.12 | 146.013 | 147.43 |

**Table 10. Cost of Oil**

| Oil cost | SA1 | SB1 | SC1 |
|---|---|---|---|
| From 1 | Rs. 39 | Rs. 39.6 | Rs. 40.05 |
| From 2 | Rs. 45.6 | Rs. 46.2 | Rs. 46.65 |
| Cost of oil per cum (1) | Rs. 6.5 | Rs. 6.1 | Rs. 6.675 |
| Cost of oil per cum (2) | Rs. 7.6 | Rs. 7.7 | Rs. 7.775 |

**Table 11. Transporting Cost Coefficient Per Cubic Meter**

| RMC plant | SA1 | SB1 | SC1 |
|---|---|---|---|
| Plant 1 | 138 | 140 | 142 |
| Plant 2 | 160 | 162 | 164 |

**Table 12. Demand and Supply for Transportation Model (6 Cum Transit Mixer)**

| RMC plant | SA1 | SB1 | SC1 | Supply in cu.m |
|---|---|---|---|---|
| Plant 1 | 138 | 140 | 142 | 122 |
| Plant 2 | 160 | 162 | 164 | 123 |
| Demand in cu.m | 110 | 90 | 45 | 245 |

After solving this model by NW corner method, the result generated is given as,
Minimum transportation cost = (110*138) + (12*140) + (78*162) + (45*164) = Rs. 36,876.00
That means the transportation of concrete from 2 RMC plant should be done by following ways only to obtain minimum cost in transportation.

**Table 13. Transportation Model**

| RMC plant | SA1 | SB1 | SC1 |
|---|---|---|---|
| Plant 1 | 110 cubic meters | 12 cubic meters | |
| Plant 2 | | 78 cubic meters | 45 cubic meters |

## 6. Result and Conclusion

From the analysis of various problems, it is concluded that construction manager is able to save much cost and time by using this Integrated Project Management framework consisting operational research techniques, Value engineering, effective procurement strategy and advanced construction management or scheduling software to monitor the project more effectively.

1. Planning and scheduling in Microsoft project (MSP) helped to reduce an overall duration of 35 days by crashing the activities.
2. ECI can solve the issue of inadequate procurement of materials in this case study that caused a delay of 45 days.
3. Value engineering implemented in this case study helped to reduce the cost of piling by Rs. 10,26,600, backfilling by Rs. 11,60,080, flooring material by Rs. 1,14,289.28 & compound wall for 4 towers by Rs. 6,76,401.08. In this way VE reduce an overall cost of Rs. 24,70,069.55 for one building.
4. EOQ for the gypsum bags comes 100 but as supplier provide much better offer for 3000 bags per order, client should go with supplier offer. The saving earned by client when going with supplier offer is Rs. 87,500 per month and extra cost incurred is Rs. 44,438. So, the total savings for one building which requires 34326 bags is Rs. 4, 22,327.
5. In assignment model the minimum hours required for concreting for different gangs are calculated. The model explains which gang is able to complete the concreting activity of particular slab of a tower in minimum time. This will help contractor to complete 1 slab in minimum time and thus reducing the overall time required for concreting which is by 2 hrs. and thus reducing 3 days for a single building.
6. Using transportation model client is able to save transportation cost for RMC. The minimum transportation cost by NW corner method comes as Rs. 36,876, which is less than Rs. 1,424 as compared to the actual cost required on the site i.e. Rs. 38,300 and thus saves an overall cost of Rs. 39,600 for one building.

From the above analysis and results it is concluded that implementing the proposed framework reduced an overall cost of Rs. 29,31,996.55 i.e. 2.3% of the planned budgeted cost and overall duration by 83 days.

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