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Resource Scheduling of Construction Project: Case Study

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Abstract: ***Several construction activities can be managed to achieve the profit within limited funds and time. Thus project management techniques are useful in scheduling and coordinating the various resources by controlled method. Management techniques such as Critical Path Method, Program Evaluation and Review Techniques (CPM/PERT) have been successfully implemented prior to the 1970's, in various Civil Engineering projects in the countries like USA, Canada, Australia. These techniques help management in efficient and economic use of resources for completion of project objectives with unlimited availability of resources, though it is observed that resources are limited in real project scenario. It has been observed that the project delays occur due to insufficient supply of resources. In large scale projects, preparing an accurate and workable plan is very difficult. Computer packages like MS Project and Primavera project planner are used in construction industry. Project management techniques can be used to resolve resource conflicts and also useful in minimizing the project duration within limited availability of resources to make the project profitable. The main aim of this study is to analyze the Project management techniques by scheduling various construction activities, allocation of resources and resource leveling using Microsoft Project 2013 for residential building. This paper analyzes resource constrained project using Microsoft Project 2013 by resource leveling and compares the time cost implications with scheduled time and estimated cost.***

Keywords: Project management, Resource scheduling, Resource leveling, Microsoft Project

1. Introduction

Project is a onetime activity with defined objectives which has to be finished in a certain period of time using limited number of resources. The project management comprises the computation of the early and the late start schedule, slack times of the activities and the allocation of the available resources over time to the execution of the activities. The project management techniques such as CPM/PERT has been widely used for scheduling. CPM provides minimum time required for completion of project and gives an advanced warning about future problems.

Some variables affect completion of construction projects such as activity durations, early start time, late start time, early completion time, late completion time and budget of project. The constraints such as weather, traffic, and the limited availability of resources such as skilled workers, machines, equipment, etc., cause increase in duration and cost of project. Therefore, new critical sequences will get developed and float calculated using CPM techniques will lose its significance. Schedules that neglect material constraints may affect the control of projects. Thus for successful completion of project resource scheduling is very important task. Resource scheduling is the futuristic planning of activities that is limited by the available resources. Resource scheduling includes resource allocation to various activities and resource leveling. Resource leveling is a technique which is used to analyze unbalanced use of resources (usually people or equipment) over time, and resolves over-allocations or conflicts among different resources.

In large scale project preparing accurate and workable schedules with consideration of resources is very difficult task, for this use of project management software's like MSP, Primavera can be advantageous. Resource conflict or over allocation can be resolved in Microsoft Project 2013 by delaying activities, splitting certain task or updating task automatically. When project levels resources, assignments are distributed and rescheduled.

2. Literature Review

Any construction project requires proper scheduling of resources for its completion within time and cost. For this various scheduling techniques have been used. Critical Path Method (CPM) is a technique that has been used since 1950's for scheduling and controlling of projects, communicating plan and training new managers. Since, it has some limitations like; this technique doesn't consider the resources required for the execution of construction project.

A Critical Path Segment (CPS) mechanism was developed by [4] Tarek Hegazy and Wail Menesi (2010). In this technique, each activity was divided into separate time segments to accurately identify all critical path fluctuations, better allocation of limited resources, avoid multiple calendar problems and accurate analysis of project delays. CPS facilitates accurate schedule analysis by simplifying complex relationships and avoiding the use of leads and lags. CPS is expected to assist Project managers in preparing reliable schedules that reflect better reality and offer better support for planning, corrective action and schedule analysis decisions.

Apart from CPM technique, project duration can be minimized by employing a variety of crew scheduling

techniques. Standard crew schedule includes, 40-hr work per week, considering five 8-hr days, four 10-hr days or a second shift. Various crew scheduling techniques were applied by [5] Awad & Aviad (2013) to provide a comprehensive comparison that outlines a variety of crew scheduling options, along with their impact on labor efficiency, project duration, worker safety and project cost. The tables provided by authors can be used as a tool by contractors who are interested in selecting a scheduling technique that will meet the specific requirements of a project.

As the nature of construction industry is Resource driven and huge investment is involved in resources, resources are supposed to be properly utilized by different techniques. For proper scheduling of resources [6] Robert (1990) had developed a Packing method which is based on Critical Path Method (CPM). In this method, to measure the level of resources, the minimum moment of resource histogram was used. The heuristic program assigns project activities to specific days so that the final resource histogram approaches a rectangle and its moment approaches a minimum value.

Serial methods for resource levelling and a measure for judging the effectiveness of resource leveling techniques was presented by [8] James and Gerald (1991). This paper deals with establishment of initial resource profiles for construction projects, resource levelling of the schedule, analysis of resource usage verses assumed levels and the adjustment of resource profiles based upon this analysis.

To minimize undesirable resource fluctuations and to maximize efficiency of resource utilization on construction site [7] Khaled and Dho Heon (2009) developed two innovative resource levelling matrices. The first metric considers the total amount of resources that need to be temporarily released during low demand periods and rehired at a later stage during high demand periods. The second metric measures the total number of idle and non productive resource days because of undesirable resource fluctuations. Application examples of these two matrices highlights that these two matrices are useful to construction planners and schedulers to enhance the efficiency of resource utilization and improvement in construction productivity.

Artificial intelligent methods are exploited in the form of expert system, artificial neural networks for scheduling of construction project. An expert system is a computer system that emulates the decision-making ability of a human expert. Expert systems are designed to solve complex problems by reasoning about knowledge, represented primarily as if–then rules rather than through conventional procedural code. An expert system for the progress scheduling in the construction of modular multi-storeyed building was developed by [9] O. Shaked and Warszanski (1992).

Practical limitations of heuristic methods cause the writers search for optimal & suboptimal schedules for construction projects using evolutionary algorithms.

An evolutionary algorithm was developed by [10] Piotr and Anna (2006) to solve the problem of minimizing construction project duration in deterministic conditions, with – in time changeable parameter and limited accessibility of renewable resources.

To achieve the project objectives that are minimizing cost and time under resource restrictions fuzzy logic have been used. [11] Danial, Gursel, Julian and Yates (2009) evaluated the viability of using fuzzy mathematical models for determining construction schedules and for evaluating the contingencies created by schedule compression and delays due to unforeseen material shortage.

Resource scheduling is normally used to minimize the duration & cost of project, by proper allocation and leveling of resources. For schedule monitoring Earned Value Management (EVM) technique is used. [3] Antony and Thirumalai (2014) have compared the budgeted cost of work performed against actual cost of work performed and budgeted cost of work scheduled to access cost and schedule variance respectively.

For project scheduling CPM/PERT, different softwares like MSP, Primavera and optimization techniques, fuzzy logic is used. [2] Indrasen and Venkateswarulu (2014) had successfully applied Primavera software to National Highway project for planning & controlling cost and resources and help to achieve timely completion of project.

Similarly, [1] Nagaraju & Reddy (2012) applied Primavera software for resource scheduling of a fast track construction of a commercial building with constrained time duration. In this paper, the study has been carried out in two phases. In the first phase, using PRIMAVERA software, project was scheduled for various activities for the construction of a commercial building. Subsequently, requirements of resources were calculated to the activities based on Standard Schedule Rates (CPWD) and IS 7272 (part I – 1974). The required data was collected from the detailed drawings and prevailing site conditions. In the second phase, a Resource Constrained Analysis was carried out by Resource Leveling for various activities by decreasing resources with increased duration of float activities.

3. Methodology

In early years CPM/PERT methods were used for project management. However now a days project management softwares have been adopted. As per the survey conducted by Liberatore[13], 83% of professional project managers use project management software for planning and control, and that in construction industry resource levelling is used by 58% for planning and by 44% for project control. Also it was derived that Primavera Project Planner and MS Project are the most popular software packages used for construction projects. In this paper, Microsoft Project 2013 is used for resource constrained analysis by resource levelling to compare the time cost implications with scheduled time and estimated cost. The study is carried out in two phases. In the first phase data is collected from site and quantities are calculated as per the drawings. Also required manpower is calculated considering the quantities of various activities.

In the second phase, various construction activities are defined in Microsoft Project 2013. Identifying construction sequence project schedule is prepared in the form of Gantt chart. Resources (manpower) were assigned to these activities. Analyzing actual available resources on construction site resource levelling has been performed.

I. PHASE I

A. Project Attributes

Name of the project: Construction of Residential Building Asha residency, Pinnac Housing Group
Location of project: Karvenagar, Pune
Number of Storey's: Two parking floors + 12 floors
Floor to Floor height: 2.9m
Depth of Foundation: 1.50 m below Ground Level.
External Wall: 250 mm thick including plaster
Internal Wall: 250 mm thick including plaster
Parapet Wall: 250 mm thick including plaster

B. Estimates

Quantities of various activities are very essential to calculate direct cost of the project. These quantities are calculated from drawings collected through site. Also using these quantities labor requirement for various activities are calculated.

C. Labor output

Manpower constant is the quantity of work that can be done by one person in one day (8 working hours) considering all safety and quality measures. This output was calculated based on IS 7272: 1974(Part I) and All India schedule of rates. The quantity of work done by one person divided to total quantity of construction activity gives number of workers required to finish that activity. Some output constants of various construction activities are given in table I.

Table 1: Recommended Labor Output Constant for Building Work

Sr. No	Description	Unit	Labor in days (8working hours)				
			Head mason	Mazdoor	Mason	Bhisti	Blacksmith
1	Excavation	10cum	-	3 ¾	-	-	-
2	Concrete work	10cum	¼	10	2	2	-
3	Reinforcement work	Per qtl	-	1	1	-	1
4	Brick work	10cum	½	14	8	2	-
5	Flooring	10sqm	½	3 ½	½	0.3	-
6	Plastering	10sqm	1/20	1.4	1	0.1	-

II. PHASE II

A. Project scheduling in MSP

The construction project schedule involves various types of construction activities with different durations based on their nature of work and construction sequence. From drawings quantities of activities are calculated and from these quantities man power required for various activities are calculated. Based on the quantities and manpower required durations are calculated. Based on the data obtained, relations such as start to start, finish to finish, start to finish are assigned to various activities and schedule is prepared in the form of Gantt chart. Finally using Microsoft Project 2013 total duration of project is calculated. Total project duration estimated is 708 days as shown in figure 1.

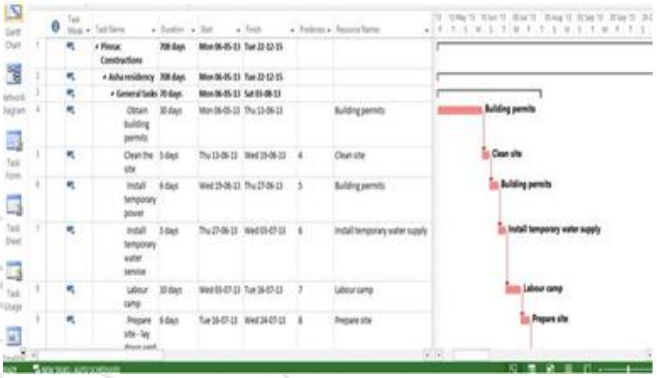

Figure 1: Scheduling in MSP with duration of project 708 days

B. Project Cost

Project cost includes direct cost and indirect cost of the project. Direct Cost of the Project is Rs. 123,246,000. Indirect cost is taken as 10% of direct cost. Indirect Cost of the present Project is Rs. 12,324,600. Thus the total cost of project is Rs. 135,570,600. Figure 2 shows relation between Duration and cumulative direct cost.

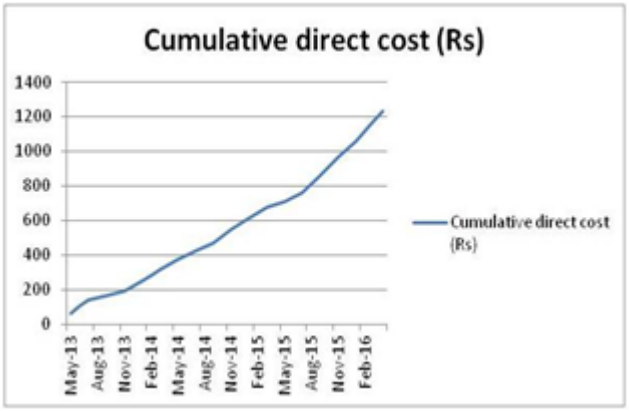

Figure 2: Duration vs. Cumulative direct cost

C. Resource constrained analysis

The resource-constrained scheduling procedure is adopted where the resource demand exceeds the resource availability. For this first resource histogram is generated based on the manpower required for different activities. This histogram will provide scheduled dates for which resources are over allocated. For optimum utilization of resources resource levelling is essential. In Microsoft Project 2013 resource levelling can be done by following methods.

1. Delaying task until resources are available.
2. Splitting the activity within available float.
3. Other than resources standard work time, overtime by resources will reduce the time required to complete the work.
4. Different contours can be used to control the resources work hours.
5. Provide maximum number of resources at peak time.

D. Procedure adopted for resource leveling

- From resource histograms the 'peak' and 'low' demands are observed for Masons, Electricians and male coolies etc. Resource leveling procedure for masons is only mentioned here as an example.
- In masons histogram the peak unit is 39 in a day and total project duration was 708 days. Total duration for masons = Duration for superstructure RCC + Duration for brickwork + Duration for internal plastering + Duration for external plastering + Duration for concealed plumbing +Tiling + Window fixing
- Therefore total duration for masons = 519 days
- By adopting first method, resource constraints are reduced from 39 to 35 without increasing total duration of project. However duration for mason increased from 519 days to 534.5 days.
- By adopting second method, resource constraints are reduced from 35 to 31 without increasing total duration of project. Duration of mason increased from 534.5 days to 555.5 days.
- In this project overtime is not provided to workers, thus by increasing duration of activity resource constraints are reduced to 20.

Figure 3 illustrates over allocation of masons in which red color indicates over allocation. Figure 4 shows the relation between % decrease in resource constraints and %increase in mason duration

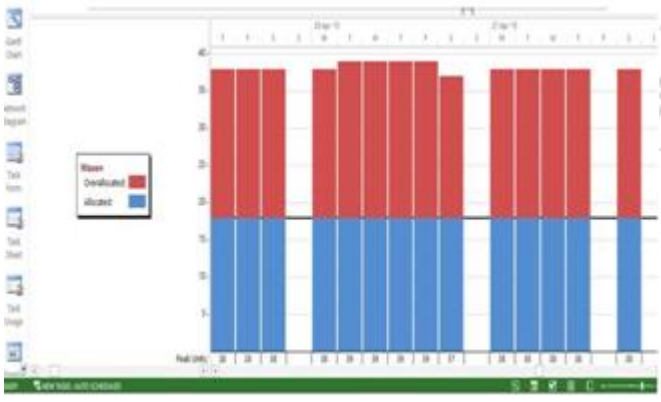

Figure 3: Mason over allocation

Table 2: Change in mason duration for different resource constraints

Resource constraints	39	35	31	29	26	20
Duration for mason	519	534.5	555.5	614.87	644.57	668.1
Total increased duration	708	708	708	708	735	749.95

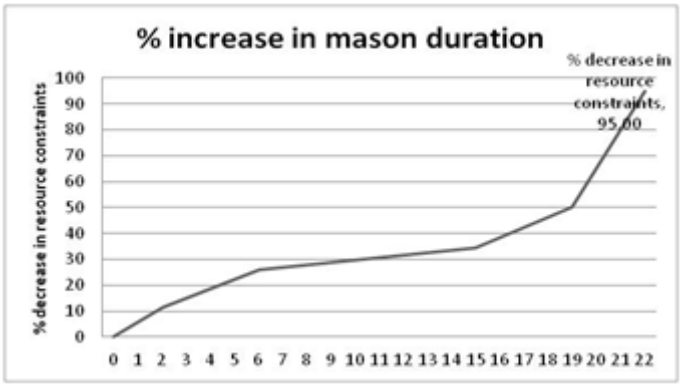

Figure 4: % decrease in resource constraints vs. %increase in mason duration

Similarly decreased resource constraints for male coolies and Electricians of different trials are shown in Tables.

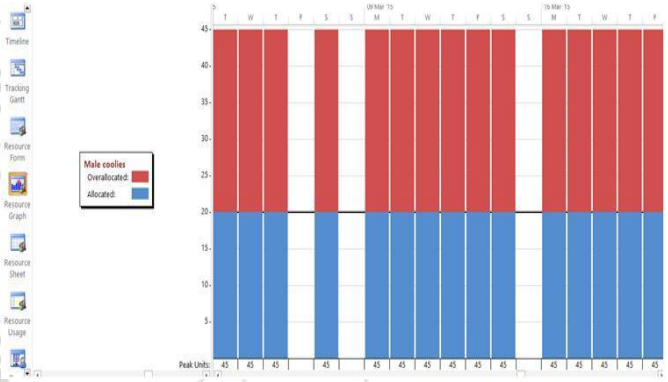

Figure 5: Male coolie over allocation

Table 3: Change in male coolie duration for different resource constraints

Resource constraints	45	40	35	30	28	25
Duration for male coolie	544.9	548.4	550.8	556	560.05	569.85
Total increased duration	749.95	749.95	755	760.28	760.28	779.67

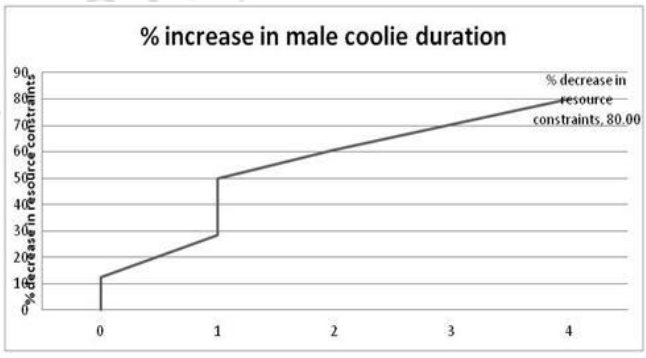

Figure 6: % decrease in resource constraints vs. %increase in male coolie duration

Figure 7: Electrician over allocation

Table 4: Change in Electrician duration for different resource constraints

Resource constraints	19	17	15	13	12
Duration for Electrician	222	234	248	252	254.89
Total increased duration	779.67	779.67	780.5	780.5	781.5

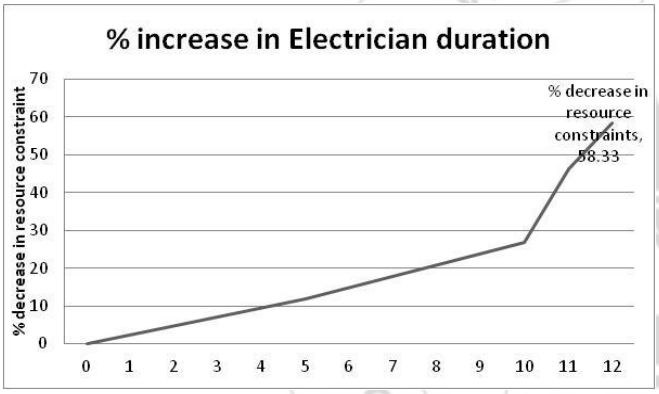

Figure 8: % decrease in resource constraints vs. %increase in Electrician duration

A. Cost of Project

Total indirect cost = Rs.12, 324,600
Average indirect cost per day = Rs.17410
The total increased cost for increased duration is shown in table 5.

Table 5: Increased cost for increased duration

Increased duration in days	Increased cost in Rs	% increase in cost
708	135,570,600	0
735	136,040,670	0.35
749.95	136,300,950	0.54
755	136,388,871	0.60
760.28	136,480,796	0.67
779.67	136,818,376	0.92
780.5	136,832,827	0.93
781.5	136,850,237	0.94

Figure 9 Illustrates the relation between increased cost of project and increased duration of project.

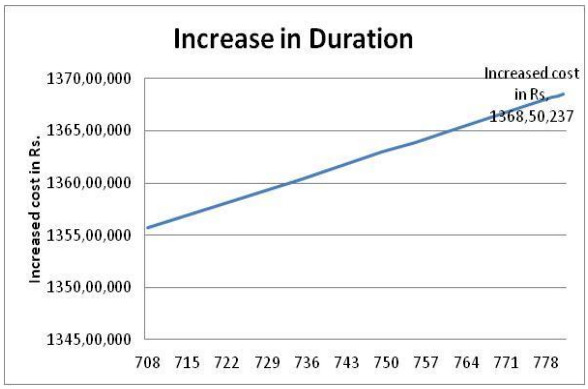

Figure 9: Increased cost vs. increased duration

4. Result

Actual required duration to complete the project is 708 days.
After resource levelling duration of project is increased to 781.5 days.
Thus the project duration increased by 10.38%.
Increase in project duration causes increase in the project cost.
Project cost is increased to Rs.136, 850,237.
Thus, project cost increases by 0.94%

5. Conclusion

The paper presents a resource constrained project schedule as per the site conditions. For resource constrained analysis resource levelling is done. The resource type for this project is considered manpower (labor) only. The project schedule increases day by day cost due to sudden requirement of labor or any unavoidable circumstances thus, it has an impact on the overall cost of the project. Duration is increased for decrease in resource constraints. The resources are masons, Male coolie and Electricians etc. Increase in duration (% increase) is 10.38% which causes increase in project cost by 0.94%. Thus the resource scheduling reduces the unexpected loss of the project which may be caused due to the huge variations in the usage of the resources.

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