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RESEARCH ARTICLE

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OPTIMIZATION OF RESOURCED DEMANDS IN CONSTRUCTION OF A RESIDENTIAL BUILDING

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ABSTRACT

In order to minimize these negative impacts of utilizing multiple shifts, the number of labor hours during the evening and/or night shifts should be minimized whenever possible. Additionally, the utilization of multiple shifts needs to comply with labor availability constraints. Construction managers and planners need additional labor for the evening and/or night shifts in addition to those working in day shifts because labor unions often restrict laborers to work no more than one shift per day. In many projects, this required additional skilled construction labor is often not available. The recent study by Construction User Round Table (CURT) reported that 82% of responding companies experienced shortage of skilled workers on their projects, and 78% of them indicated that the trend has worsened over the past years (Srour et al. 2006). In order to comply with these labor availability constraints, construction planners need to distribute and utilize the limited number of construction labor among multiple shifts in the most efficient and effective manner in order to maximize project performance.

I. INTRODUCTION

Despite the wide spread utilization of network scheduling techniques such as the Critical Path Method (CPM) and Precedence Diagram Method (PDM) in the construction industry, they have a number of important limitations including the inability to (1) minimize fluctuations in resource utilization levels over the project duration (Hegazy 1999b; Hiyassat 2000; Son and Mattila 2004), as shown in Figure 1.1(A); (2) consider the availability limits of construction resources during various periods of the project (Brucker et al. 1998; Jiang and Shi 2005; Kim and Ellis 2008; Zhang et al. 2006a), as shown in Figure 1.1(B); (3) analyze the impact of utilizing multiple shifts and overtime hours on construction productivity, duration, and cost (El-Rayes and Kandil 2005; Jaskowski and Sobotka2006; Xiong and Kuang 2008), as shown in Figure 1.1(C); and (4) consider the uncertainties and risks involved in construction scheduling and cost estimating (Kannan et al. 2001; Lee and Arditi 2006; Nasir et al. 2003), as shown in Figure 1.1(D).

In order to overcome the aforementioned limitations of traditional scheduling techniques, a number of resource-driven scheduling models was developed that focused on (1) resource leveling (Ahuja 1976; Akpan 2000; Burgess and Killebrew 1962; Easa 1989; Harris 1978; Hiyassat 2000; Mattila and Abraham 1998; Son and Mattila 2004; Son and Skibniewski 1999); (2) resource allocation (Ahuja 1976; Bell and Han 1991; Boctor 1990; Chan et al. 1996; Chen and Shahandashti 2009; Gavish and Pirkul 1991; Leu and Yang 1999; Mingozzi et al. 1998; Zhang et al. 2006a);

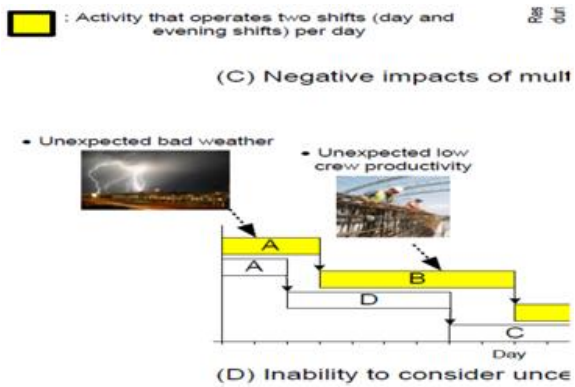
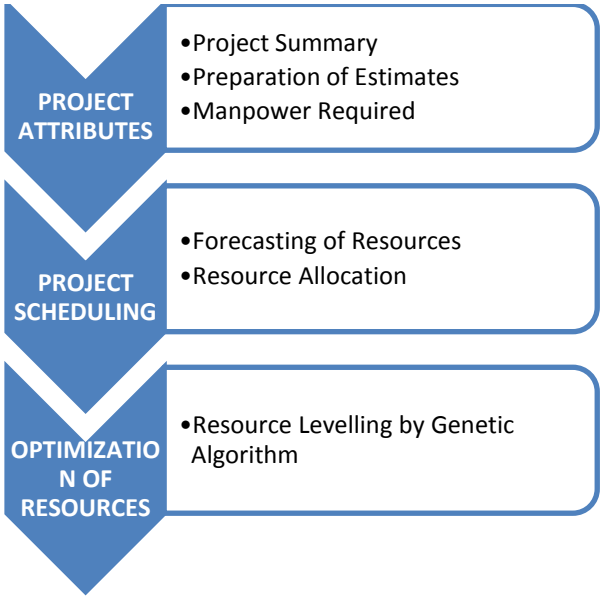


Fig1. Negative impacts of labor productivity

II. METHODOLOGY



III. PROJECT SCHEDULING

The study is carried out in to two phases: In phase I, the data has been collected from the Bill of Quantities (BOQ) and Productivity Constants from IS: 7272 (Part I) – 1974 [6]. BOQ helped to understand the scale of the project, and to generate the cost flow for the project. Productivity constants helped to obtain the required manpower and duration of works to complete this stage of the project. The phase II includes scheduling of project, resource allocation and optimization of manpower resource. In this phase MSP software has been used to prepare the project schedule and based on BOQ and productivity constants manpower resource are allocated for each activity. Then the „visual graphs" generated by the software for the project are studied. Since graphs indicate large fluctuation of manpower requirement between two successive months. So, it has optimized manually in MSP schedule. By doing this manpower can be utilized efficiently without any losses. It is also helpful for arranging the manpower resources

IV. PROJECT ATTRIBUTES

Project attributes present the details of an ongoing project in terms of project schedule, manpower required for different activities to carryout resource constrained analysis. The costs incurred in the project are also presented. The brief project details, preparation of estimates, manpower required, project scheduling, forecasting of resources, resource allocation are described in following section.

PROJECT SUMMARY

Name of the project: Construction of Residential Building, Chennai Area, Tamilnadu, India.

Built up area: 4,07,560Sqft

Number of Storey"s: 1 Basement+1 Stilt+Ground+12floors

For present study the live project of residential building is considered.

PREPARATION OF ESTIMATES

Generally, for resource constrained analysis the manpower requirements for various activities are very essential and these are to be calculated based on the quantities. These quantities required for manpower study are calculated from the drawings. Manpower output is the output quantity i.e., the quantity of work which can be done per day per person considering all safety and quality measures as required by client. This was calculated based on the [1] and [6] and also considering views based on the experiences and thorough technical knowledge of many project managers, architects, engineers and many contractors who are experts and have been working in this field for many years. Some of the output constants for various types of activities are shown in Table 1 and Table 2. The study is limited to these activities only under normal working and site conditions [2]. The schedule contains different types of activities with different durations based on their nature of work and

quantities calculated from drawings. From these quantities, manpower required for various activities have been calculated.

Table-1: Manpower output constants for different labours as per IS: 7272 (PART I – 1974)

S.No	**Activity**	**Labor output per day**
1.	Unskilled (including Excavation, transportation)	
	Excavation	1.5 M3
	PCC and Concrete	0.2 M3
2.	Carpenters (for all activities)	6.0 M2
3.	Barbenders (for all activities) (including cutting, bending, fabrication, transportation etc.,)	0.2 MT
4.	Masons (includes shifting of materials within the site, wetting in water and dressing in Size stone masonry (SSM))	0.9 M3
		6.0 M2
	SSM	6.0 M2
	Block Masonry	8.0 M2
	Plastering	
5.	Painters (including preparatory works as required)	10.0 M2

Table-2: Manpower required for various works as per CPWD analysis of rates

S.No	**Activity**	**Per Unit**	**Mason**	**Bhisti**	**Beldar**
1.	Plain Cement Concrete	1 M3	0.1	0.7	1.63
2.	(PCC) Barbending work	1 Ton	7.5	-	10
	Shuttering work	4 M2	1	-	1
3.	Reinforced Cement Concrete (RCC)	1 M3	0.17	0.9	2
4.	Masonry work	1 M3	0.72	0.217	1.56
5.	Plastering work	10 M2	0.67	0.93	0.86
6.	Painting work	10 M2	0.54	-	0.54

Based on the quantities, manpower required and realistic durations in the current situations are taken in to account and activity durations have been calculated. Based on the data obtained, network diagram is prepared and relations are assigned to the activities to calculate the critical path. Finally the total duration of the project is calculated by MS Project. After preparing the schedule in MS Project software the total project duration is estimated as 658 working days. In project management resources have to be allocated in the schedule to carry out the project work 26 efficiently and complete the project as per the schedule and duration. Assigning resources help to increase the accuracy of the schedule, the Microsoft Project software adds the working time and availability of resources into the scheduling calculations. Allocated manpower resource pool is shown in Table 3.

The resources are first allocated as per procedures discussed above in MS Project software. The fluctuations in demands have been identified in resource histograms for Masons, Barbenders and other resources mentioned in the table for different days. Then the optimization procedure had been carried out. In order to illustrate the resource optimization procedure adopted in this study, only data and procedure pertaining to masons has been presented as an example. The materials required for carrying out each of the works involved in the construction project are identified and allocated in the baseline schedule. The manpower both the number or magnitude, and the type, necessary for carrying out each individual work of the construction project is also determined and allocated in the same baseline plan to each of the respective works. Manpower resource pool available at site and its 27.

Table 3. Manpower Resources Availability

ID	RESOURCE NAME	TYPE	INITIALS	MAXIMUM AVAILABILITY	STD RATE IN Rs
1.	Mason	Work	M	30	550.00/day
2.	Mason helper	Work	MH	38	350.00/day
3.	Carpenter	Work	C	35	550.00/day
4.	Carpenter helper	Work	CH	38	350.00/day
5.	Barbender	Work	B	32	550.00/day
6.	Barbender helper	Work	BH	33	350.00/day
7.	Painter	Work	P	9	550.00/day
8.	Painter helper	Work	PH	9	350.00/day
9.	Female carpenter	Work	F	5	550.00/day
10.	Female carpenter helper	Work	FH	5	350.00/day
11.	Male coolie	Work	MC	35	350.00/day
12.	Female coolie	Work	FC	20	250.00/day
13.	Site engineer	Work	SE	5	20,000.00/month
14.	Supervisor	Work	SUP	5	12,000/month
15.	Surveyor	Work	SUR	1	20,000.00/month
16.	Surveyor helper	Work	SH	1	300.00/day

costs are shown in Table 3. The visual graph in Figure.1 indicates the skilled mason requirement for a period of 17 months i.e. March 2013 to August 2014. Here, the variations in the mason requirement for the different months are too large. For example the mason requirement in the month of May 2014 is 28 and it is 8 in the month of June 2014. There is a sudden decrease in the mason requirement and 20 masons remain unemployed. As a result, the contractor suffers losses as the masons available are more than the requirement. Also there is sudden increase in mason requirement i.e. between August, September and October of 2013. Apart from this, there are several other significant variations, i.e. November to December of 2013 and March to April of 2014, which prompt to optimize this resource. Optimization of mason is carried out by rescheduling the non-critical activities within available slack i.e. by changing the duration of a particular activity or shifting the start date of a particular activity or by increasing or decreasing the magnitude of manpower. In some cases critical activities also to be rescheduled, but total project duration may be increased, that must be within exceptional value. In the first part of optimization, duration of beam and slab concreting of stilt floor is reduced 1 day from 2 days and magnitude of mason is changed from 3 to 6, before it was started 1 day before finishing its predecessor, now it starts after finishing its predecessor. And similarly the optimization procedure is carried out for

few other activities as show in Table 4. The visual graph in Figure.2 represents the skilled mason requirement of the construction project after optimization. Initially there was a huge decrease in the mason requirement of 20 masons in the month of June 2014. But after optimization it can be seen that there is only a small decrease of 1 between the month of May 2014 and June 2014. Also there was sudden increase in manpower of 8 between March and April 2014. After optimization has 28

been reduced to zero, this is feasible. Apart from this, there was sudden increase of 9 mason requirement between September and October 2013, and it has been reduced to 3, a feasible value. Similarly the whole graph has been modified to be free of any sharp fluctuations. Similarly, the procedure was carried out for barbenders, mason helpers and all other human resources. The results of optimization of all human resources facing fluctuations have been presented. Based on

optimization process, the optimization chart has been prepared as shown in Table 5.

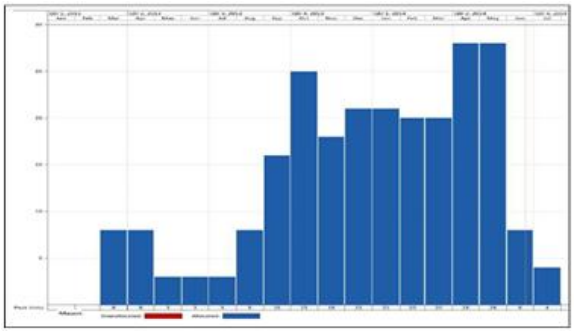


Fig 2. Variations of labor availability

V. CONCLUSIONS

Baseline plan and schedule has been prepared using MSP software, and with respect to baseline plan different kind of resources has been assigned, then visual aids in the form of bar graphs (histogram) has been generated. This indicated the undesired fluctuations in the requirement of manpower resources with respect to time. From these visual aids, manpower resource has been optimized by modifying the particular activities duration and by modifying predecessors without affecting the project duration.

Finally the following conclusions are obtained:

1. Optimized utilization of manpower resource has been achieved.
2. The over-allocated and under-allocated resources for different tasks have been eliminated.
3. Acceptable cash out flow curve has been obtained.
4. The manpower cost has been reduced by 4.4% i.e. Rs.26,900.00/- on optimization of manpower resource.
5. Optimization has been done without affecting total project duration.

Finally, the paper presents understanding the process of planning, scheduling and optimization of the various resources required for carrying out a project by optimizing the resource of manpower requirement of a construction project.

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