Optimization for Fluctuation in Resource Demands in Construction Projects

Maruthi S[1], Dr. J.R.Patil[2], Rohit S. Agawane[3]
[1] *PG Research Scholar, M.E. Civil (Construction & Management), Department of Civil Engineering, RMD Sinhgad School of Engineering, Pune, Maharashtra , India.*
[2] *M.E, PhD (Engg-Civil, NIT Warangal), Professor & Head, Department of Civil Engineering, RMD Sinhgad School of Engineering, Pune, Maharashtra , India.*

Abstract - *The proper utilization of resources is very important to achieve project success. In project management, there are two types of resource scheduling problems. The first is resource allocation in which activities are scheduled depending on` the availability of limited resources to ensure that resource limitations are not exceeded in any period. The second type is resource leveling which includes moving non-critical activities within their float to improve the resource profile while not extending the project duration.*

Unless matching resources are planned and procured, no activity can be executed according to a prefixed time schedule. Project managers must take complex decisions under different scheduling needs (such as smooth resource utilization profiles and resource constraints) and under conditions of uncertainty that sometimes extend beyond task durations.

The study has been carried out in two phases. In the first phase, the project schedule for various activities for the construction of a residential building has been prepared using Microsoft Project (MSP) software. Subsequently, requirements of resources have been attributed to the activities based on Standard Schedule Rates [1]. The requisite data has been collected from the detailed drawings and prevailing site conditions [2].

In the second phase, optimization has been carried out by modifying the resource requirement for various tasks to remove any sudden variations in demand of resources.

The present study deals with resource scheduling and optimization by optimizing the resources required to complete the project to avoid undesired fluctuations in manpower requirement.

Key Words: Construction project. Resource demand, Optimization, Fluctuation.

1. INTRODUCTION

Now a days many construction projects are coming out due to high demand of infrastructure developments. The construction project requires various resources and needs time for its completion.

A resource may be defined as the machine or person who will perform the scope of work. Resource planning is therefore forecasting the resources required to perform the scope of work within the time plan [3].

The crucial factor in successful implementation of a construction project not only depends on the quality and quantity of work, but also largely depends on availability of resources [2]. All activities involved in the project require certain amount of resources. Each activity is allocated with a specific resource and must be completed within the time limit, otherwise it may adversely affect the overall duration of the project.

The time and cost are directly dependent on the availability of resources such as manpower, material, money and equipments. The time required may be determined by dividing the productivity associated with the resources used on the activity into the defined quantity of work for the activity. The best combination of resources to use for performing a construction activity is based on contractor's ability to identify the interdependencies of the various resources [4].

The main developments included in the study contribute to the advancement of current practice in resource scheduling and planning in construction projects and this may lead to:

- An increase in the resource utilization efficiency in construction projects which can produce significant improvements in construction productivity, cost and duration.
- An improvement in utilizing the limited availability of resources [5].

2. METHODOLOGY ADOPTED

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.

3. 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.

3.1. Project Summary

Name of the project : Construction of Residential Building, Bengaluru area, Karnataka, India.
Built up area : 4,07,560 Sq ft
Number of Storey's : 1 Basement+1 Stilt+Ground+12floors
For present study the live project of residential building is considered.

3.2. 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.

3.3 Manpower Required

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].

3.4. Project Scheduling

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)

Activity	Labour output per day
1. Unskilled (including Excavation, transportation)	
- Excavation	1.5 M^3
- PCC and Concrete	0.2 M^3
2. Carpenters (for all activities)	6.0 M^2
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 M^3
- SSM	6.0 M^2
- Block Masonry	6.0 M^2
- Plastering	8.0 M^2
5. Painters (including preparatory works as required)	10.0 M^2

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

Activity	Per Unit	Mason	Bhisti	Beldar
Plain Cement Concrete	1 M^3	0.1	0.7	1.63
(PCC)				
Barbending work	1 Ton	7.5	-	10
Shuttering work	4 M^2	1	-	1
Reinforced Cement Concrete (RCC)	1 M^3	0.17	0.9	2
Masonry work	1 M^3	0.72	0.217	1.56
Plastering work	10 M^2	0.67	0.93	0.86
Painting work	10 M^2	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.

3.5. Forecasting of Resources

The estimation of required resources for the completion of the project is carried out based on following equation:

$$\text{Required resource (manpower)} = \frac{\text{Total Quantity}}{\text{Productivity X Duration}}$$

The Total Quantity is obtained from BOQ and productivity is obtained from productivity constants. In this case duration is the assumed duration derived from site expertise and also it has been cross checked.

Example:

Activity : Block Masonry work
Quantity : 483 M^2
Productivity : 10 M^2/day/team
Assumed duration : 12 days

Therefore, required resource (Mason) = 483 / 10 x 12
= $4.02 \approx 4$

Required are 4 in the ratio of 1:1 i.e. 4 Masons and 4 Mason helpers.

3.6. Resource Allocation

In project management resources have to be allocated in the schedule to carry out the project work 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.

4. OPTIMIZATION OF RESOURCES

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.

4.1. Manpower Resource Allocated Schedule

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 respective costs are shown in Table 3.

Table- 3: Manpower Resource Pool

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	12,000.00/month
15	Surveyor	Work	SUR	1	20,000.00/month
16	Surveyor Helper	Work	SH	1	300.00/day

4.2. Un-optimized Resource Usage

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.

4.3 Optimization of Mason

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 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.

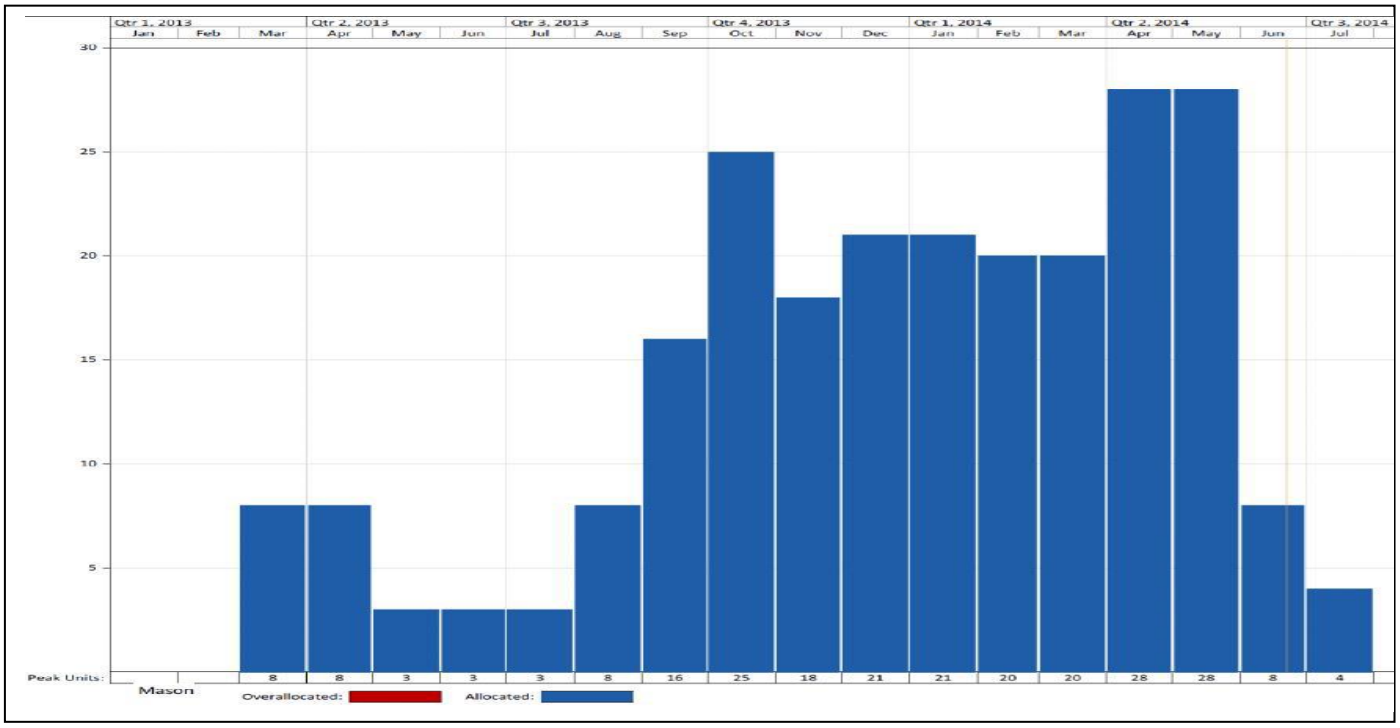

Fig- 1: Un-Optimized visual graphs for Mason.

Table- 4: Optimization Steps for Various Activities.

Activity	Duration in days.		Resource Leveling(Mason)	
	Earlier	Updated	From	To
Beam and slab concreting of stilt floor.	1	2	3	6
Concreting of column and shear wall of first floor and third floor.	2	1	2	4
Concreting of column and shear wall of sixth floor	2	4	2	1
Block masonry work of third floor	12	24	4	2
Block masonry work of eleventh floor	Starts 2 days before predecessor	Starts 4 days before predecessor	-	-
Block masonry work at terrace	Starts 1 day before predecessor	After completion of predecessor	-	-
Internal plastering of stilt floor.	16	14	10	12
Internal plastering of ground floor.	14	15	10	9
Internal plastering of third and fourth floor.	14	13	10	11
Internal plastering of tenth and eleventh floor.	14	18	10	8
Internal plastering of tenth and twelfth floor.	14	20	10	7
Internal plastering of terrace.	10	20	6	3
External plastering of terrace to stilt floor.	40	50	10	8
Flooring of first and third floor.	10	20	4	2
Flooring of first and eleventh floor.	10	6	4	8

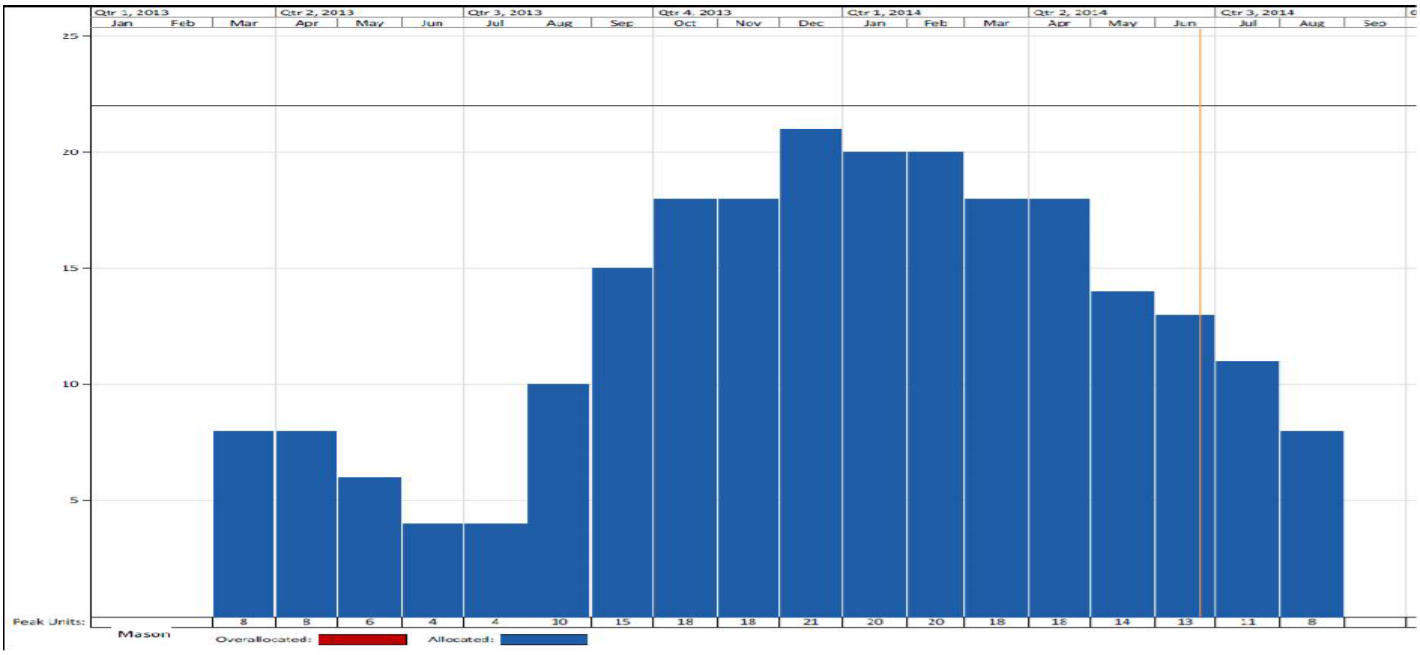

Fig.2: Visual Graph showing Mason Optimization.

Table- 5: Manpower Optimization Chart

Month	M		MH		C		CH		B		BH		Total	
13-14	Un-Op	Op	Un-op	Op	Un-op	Op	Un-op	Op	Un-op	Op	Un-op	Op	Un-op	Op
Mar	8	8	24	16	15	17	19	17	30	26	30	26	126	110
Apr	8	8	24	16	30	23	36	23	20	23	20	23	138	116
May	3	6	18	18	16	16	20	20	13	29	13	20	83	104
Jun	3	4	18	18	16	16	18	18	13	20	13	18	81	92
Jul	3	4	18	18	16	16	18	18	13	18	13	13	81	82
Aug	8	10	23	22	16	16	18	18	13	13	13	13	91	92
Sep	16	15	26	24	16	16	18	18	13	13	13	13	102	99
Oct	25	18	36	26	16	16	18	18	13	11	13	11	121	100
Nov	18	18	32	26	16	16	18	18	13	11	13	11	110	100
Dec	21	21	36	30	16	16	18	18	13	11	13	11	117	107
Jan	21	20	36	27	21	14	23	14	13	11	13	11	127	97
Feb	20	20	20	20		8		8					40	56
Mar	20	18	20	18									40	36
Apr	28	18	28	18									56	36
May	28	14	28	14									56	28
Jun	8	13	8	13									16	26
Jul	4	11	4	11									8	22
Aug		8		8									0	16

After Optimization it has been observed that, the total requirement of un-optimized manpower in the month of March 2013 was 126, and it has been reduced to 110. Similarly in the month of April 2013 total un-optimized manpower requirement was 138, and is reduced to 116. Also in some months, manpower requirement has been increased but it is feasible as compared to un-optimized manpower requirement.

5. Discussion on Results

The study deals with the optimization of manpower resources i.e. mason, mason helper, carpenter, carpenter helper, barbender and barbender helper. Their efficient use may be monitored and maintained throughout the execution of project. It helps in determining the smooth cash out flow which is required for an efficient project management.

The un-optimized plan has been optimized to get the reduced cost and is depicted in Table.6.

The mason optimized visual graph is shown in the Figure.3. The upper curves show the cumulative optimized and un-optimized manpower cost for the entire project duration and the lower curves shows the optimized and un-optimized monthly cost of manpower. After optimization the required manpower cost for every month has considerable significant variations as seen in the above cost outflow graph compared to the un-optimized cost outflow graph.

By optimization, the total cost of manpower resource for the project can be reduced to Rs. 26,900.00/- by which the cost of project on manpower resource reduces significantly from Rs. 6,08,150.00/- to Rs. 5,81,250.00/-

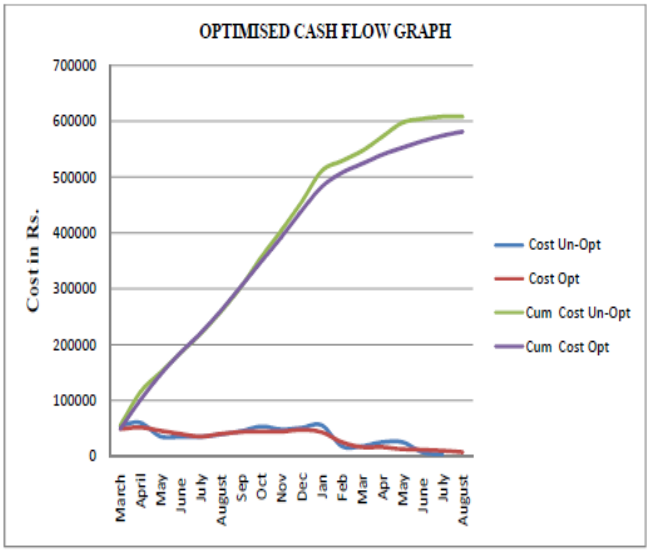

Fig. 3: Optimized Cash Flow Graph.

Table.6: Cost of Manpower After Optimization

Month	Total Nos.		Cost	Cum. Cost	Cost	Cum. Cost	**Cost Reduction (Rs.)**
14-15	Un-op	Op	Un-op	Un-op	Op	Op	Op
Mar	126	110	54700	54700	48700	48700	6000
Apr	138	116	59900	114600	51400	100100	8500
May	83	104	35450	150050	45600	145700	-10150
Jun	81	92	34750	184800	39800	185500	-5050
Jul	81	82	34750	219550	35300	220800	-550
Aug	91	92	39250	258800	40000	260800	-750
Sep	102	99	44700	303500	43450	304250	1250
Oct	121	100	53150	356650	44000	348250	9150
Nov	110	100	47900	404550	44000	392250	3900
Dec	117	107	50950	455500	47050	439300	3900
Jan	127	97	55450	510950	42950	482250	12500
Feb	40	56	18000	528950	25200	507450	-7200
Mar	40	36	18000	546950	16200	523650	1800
Apr	56	36	25200	572150	16200	539850	9000
May	56	28	25200	597350	12600	552450	12600
Jun	16	26	7200	604550	11700	564150	-4500
Jul	8	22	3600	608150	9900	574050	-6300
Aug	0	16	0	608150	7200	**581250**	-7200
TOTAL COST REDUCTION (Rs)							26900

6. 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.

REFERENCES

[1] Central Public Work Department (CPWD), *"Analysis of Rates"* Director General (Works) CPWD, New Delhi. (2012).

[2] Nagaraju, S. K., Prof. Chaudhuri, A. R. and Sivakonda Reddy, B. (2012), "Resource Management in Construction Projects – A Case Study." *IRACST– Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498, Vol.2.* 660-665.

[3] Rory Burke (1999), *Project Management Planning and Control Techniques* (3rd ed.) 1-7 and 162-175. Available: www.kocaeliaben.gov.tr/ISBNW71-98762-X

[4] Mikhail Hanna and Ruwanpura, J. Y. (2007), "Simulation Tool for Manpower Forecast Loading and Resource Leveling." *IEEE Winter Simulation Conference*, 7099-7103.

[5] Dho Heon Jun and Khaled El-Rayes, (2011), "Multiobjective Optimization of Resource Leveling and Allocation during Construction Scheduling." *Journal of Construction Engineering and Management @ ASCE*, 1080-1088.

[6] IS7272 (Part I), "*Recommendation for Labour output Constants for Building Work*" (1974).

[7] Aftab Hameed Memon, Ismail Abdul Rahman, Ade Asmi Abdul Aziz, Kumarason V. Ravish and Noor Ikmalah Mohammad Hanas, "Identifying Construction Resource Factors Affecting Construction Cost: Case of Johor," in *proceedings of Malaysian Technical*

Universities Conference on Engineering & Technology, 2011.

[8] Ali Alshubbak, Eugenio Pellicer, Joaquín Catalá, "A collaborative approach to project life cycle definition based on the Spanish construction industry," in *Third Conference on Engineering Work in Palestine*, November, 2009, 1-19.

[9] Fred Moavenzadeh, "The Construction Industry in Developing Countries," presented at Technology Adaptation Program, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States of America, spring 1975, 28-33.

[10] Jose Luis Ponz-Tienda, Víctor Yepes, Eugenio Pellicer, Joaquin Moreno-Flores. (2013), "The Resource Leveling Problem with multiple resources using an adaptive genetic algorithm." *Automation in Construction*, 161–172.

[11] Kastor, A. and Sirakoulis, K. (2009), "The effectiveness of Resource Leveling tools for Resource Constraint Project Scheduling Problem." *International Journal of Project Management*, 493–500.

[12] Min-Yuan Cheng, Ming-Hsiu Tsai, Zhi-Wei Xiao. (2006), "Construction management process reengineering: Organizational human resource planning for multiple projects." *Automation in Construction*, 785–799.

[13] Mustafa Çağdas Mutlu, "A branch and bound algorithm for resource leveling problem," Master Of Science Thesis, Dept of Civil Engineering, Middle East Technical University, August 2010. 2-6.

[14] P. Aslani, S. Christodoulou, F.H. Griffis, G. Ellinas and L. Chiarelli. (2009), "Activity Prioritization Under Resource Constraints Using a Utility Index Method." *The Open Construction & Building Technology Journal*, 33-41.

[15] Tarek Hegazy, Member, ASCE. (1999), "Optimization of Resource Allocation and Leveling using Genetic Algorithms." *Journal of Construction Engineering and Management @ ASCE*, 167- 175.Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.

BIOGRAPHIES

Mr. Maruthi S
Working as a PG Research Scholar in Department of Civil Engineering, RMD Sinhgad School of Engineering, Warje, PUNE, Maharashtra, India.

Dr. Jalindar R. Patil
B.E., M.E., Ph.D. (Engg.: Civil-Geotechnical, National Institute of Technology, Warangal), MISSMGE, FIGS, MIRC, MISTE, MISRMTT, Professor of Civil Engineering, RMD Sinhgad School of Engineering, S.No.111/1, Warje, PUNE, 411058 M.S. INDIA, Teaching and Administrative Experience of 24 years and 3.5 years of experience of Research, Published more than 35 international/national papers in journal and conference, Received 3 merits and awards at national level.

Mr. Rohit S. Agawane
Working as a PG Research Scholar in Department of Civil Engineering, RMD Sinhgad School of Engineering, Warje, PUNE, Maharashtra, India.

