International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 03, March-2019

Application of Critical Chain Project Management (CCPM) for infrastructure project: A case study

Milan R. Sheta[1], Neetu B. Yadav[2]

[1]*M.E. C.E.M, S.N.P.I.T & R.C,* sheta.milan79@gmail.com
[2]*Assistant professor, S.N.P.I.T & R.C,* n.neetuyadav@yahoo.com

Abstract*— Critical Chain Project Management is a scheduling tool which is used for planning and managing projects based on the resources that required to execute project tasks within predefined time and budget. In this research work primavera P6 based step by step process of scheduling which helps in applying CCPM infrastructure projects was identified. The detail process of scheduling starts with identification of tasks, resources, activities, calculation of labour productivity, labour assignment and at last assign duration for each activity based on which resource availability is checked and finally authors were able to prepared final CCPM schedule for particular activities.

Keywords*— Critical Chain; Primavera scheduler; Project Management; Scheduling; Software.

I. INTRODUCTION

Critical Chain Project Management (CCPM) was first introduced by Eliyahu Goldratt as a novel method of managing projects based on resource planning at the International Jonah Conference in 1990. Then in 1997, Eliyahu M. Goldratt published one book entitled 'Critical Chain' (Pai, 2014). In which he tried to simplify projects' monitoring and controlling mechanisms and reduce their overall duration through removing safety times from individual tasks and aggregation half of the total safety time at the end of each chain as feeding and project buffers by using 50% buffer sizing method (Ghaffari and Emsley, 2015; Vanhoucke, 2012). The CCPM project planning and control process directly addresses uncertainty and variation in project activity duration. CCPM mainly relies upon the Theory of Constraints (TOC) which is a tool for managing repetitive constructions based on the principle that every system has a constraint and system performance can only be improved by enhancing the performance of the constraining resources (Chawan, Gaikwad and Gosavi, 2012; Steyn, 2000). It helps get rid of undesirable behaviors fostered by using scheduled dates and milestones within a project plan. It focuses on developing and managing project performance to meet or exceed reduced activity times, thereby reducing the overall project duration (Raz, Barnes and Dvir, 2003). Simple means of tracking and monitoring project progress. CCPM has a number of improvements over the traditional Critical Path Method i.e. faster completion of projects, Elimination of multi-tasking, Amendment in the attitude of the workers, Absence of milestones, No chance of student syndrome (Sarkar, 2012; Lechler et. all, 2005).

The TOC is applied in five steps: 1. Identify the system's constraints, 2. Decide how to exploit the system's constraint, 3. Subordinate everything else to the above decision, 4. Elevate the system's constraint and 5. If, in the previous steps, a constraint has been broken, go back to step 1, and follow same procedure (Rand, 2000). CCPM helps in reducing undesired effects like Student Syndrome, Parkinson law, Multitasking and Murphy's Law (Vrincut, 2009; Burkhard, 2014). Countries like Romania, Japan, Australia and so on, which have already implemented the critical chain concept in their construction industries (Vrincut, 2009; Burkhard, 2014).

This paper explained the procedure for applying CCPM in infrastructure project by using peimavera P6 Scheduler software as below.

II. METHODOLOGY

For preparing critical chain network some basic steps that should be required to follow were described below step by step.

A. Site Selection

After approaching various sites author have found that very few project managers are practicing and preparing the schedule by using the software. Most of them are using excel sheet for scheduling. After approaching to project manager at Sardar Bridge I have found detailed drawing of the bridge. This project is 100 % useful for my research work as it is a very large scale project.

B. Detail Estimation of Bridge

After site selection first observe the various plans of building which were prepared in Auto-CAD. Now, before preparing CCPM network materials required for given site as well as labour requirement must be done. So for that from plan of Bridge detail estimation sheet was prepared in MS Excel sheet for different components. From the calculated quantity the material requirement was calculated (Dutta 2007). Final estimation of main material of construction work were described below.

TABLE I
Total Quantity of Excavation, Steel, R.C.C. and shuttering in First Span Between PD- 1 to PD- 2

Description	Excavation quantity (m^3)	Quantity of steel (kg)	Total concrete quantity (m^3)	Shuttering Quantity(m^2)
PD – 1	20	20402	166.74	192
PD – 2	26	23431	220.25	99.48

C. Labour Productivity

For assigning duration as per quantity 1st materials are calculated then after based on estimation labour productivity were calculated and then duration were applied to each and every activity as per productivity. After detail study of various studies done by various authors and experts in the field in regard to labour productivity (Chitkara, 2011; Mistry, 2013), the authors have calculated the same for this research work and final labour productivity calculated was mentioned in (see table 3).

TABLE II
Labour Requirement for Bridge Construction

No.	Item name	Per day	Skilled	Unskilled	Quantity
1.	Excavation	1	1		25 cum
2.	R.C.C pile	1			
		1	Fitter – 1		220 kg
	Concreting work		Mazdoor - 1	1	100 cum
3.	R.C.C pile cap	1			
			Fitter - 1		200 kg
			Carpenter - 1		30 sq. meter
			Mazdor - 1	1	100 cum
4.	Pier	1			
			Fitter - 1		220 kg
			Carpenter - 1		25 sq. meter
			Mazdoor - 1	1	100 cum
5.	Pier-cap	1	Fitter - 1		200 kg
			Carpenter- 1		20 sq.meter
			Mazdoor - 1	1	100 cum
6.	Pedestal	1			
			Crapenter - 1		20 sq. meter
			Mazdoor - 1	1	100 cum
7.	Girder	1			
			Fitter - 1		190 kg
			Carpenter - 1		20 sq. meter
	Cable installation		Fitter - 1	1	4 NOS.
			Mazdoor - 1	1	100 cum
7.	Deck slab	1			
			Fitter - 1		220 kg
			Carpenter - 1		20 sq. meter
			Mazdoor - 1	1	100 cum
8.	Sidewall, kerb & central verge	1			
			Fitter- 1		180 kg
			Carpenter - 1		17 sq. meter
			mazdoor - 1	1	100 cum
9.	Wear coat	1			
			mazdoor - 11		50 meter length

After detail study of information given by Mr. chirag patel Author have calculated final labour productivity as mentioned below

TABLE III
Final Labour Productivity

Activity	Team member	Work done
Excavation	1 operator	25 cum per day
Pile work	9 fitter, 2 mazdoor	1800 kg, 80 cum per day
Pile cap work	10 fitter, 2 carpenter 1 helper, 2 mazdoor	2000 kg, 75 sq. meter, 150 cum
Pier work	7 fitter, 2 carpenter 1 helper, 1 mazdoor	1540 kg, 31 sq. meter, 38.81 cum
Pier cap work	8 fitter, 2 carpenter 3 helper, 1 mazdoor	1600 kg, 30.01 sq. meter, 39.52 cum
Pedestal	1 mazdoor	4.32 cum
Girder work	6 fitter, 5 carpenter, 1 mazdoor, 2 cabble fixer	1140 kg, 100 sq. meter, 78 cum, 4 Nos.
Deck slab work	12 fitter, 7 carpenter, 5 helper, 2 mazdoor	2400 kg, 140 sq. meter, 143 cum
Sidewall, kerb& central verge	4 fitter, 4 carpenter 5 helper, 1 mazdoor	720 kg, 68 sq. meter, 26 cum
Wear coat	mazdoor- 11	50 meter per day

D. Preparing List of the Activities for Network Diagram

1) First preparing Work Breakdown Structure: Project Work Breakdown Structure (WBS) is the basic tool employed to identify activities. WBS methodology facilities splitting of the project scope of work into hierarchy of work breakdown levels of sub-projects, tasks, work packages and activates. (See figure 1). Showed WBS prepared for the selected case study site.

2) List of Activities for network diagram: For the preparation of final network detailed activity list is prepared from project initiation to completion. Activities like Steel work, Excavation, concreting work, shuttering work etc. Total 16 activities were identified for final preparation of network.

E. Assign Duration after Resource Assignment for Different Activities

After preparation of the activity list, assign CPM and CCPM activity time duration to each and every activity. Finding parallel work possible as per availability of labours assigning them to activities (for example concrete work in pile PD – 1 and excavation work for piles below PD- 2 and so on), then find duration as per productivity of assigned labour and estimated quantity of work. Table (see table IV) showed the list of activities with completion duration by both the methods.

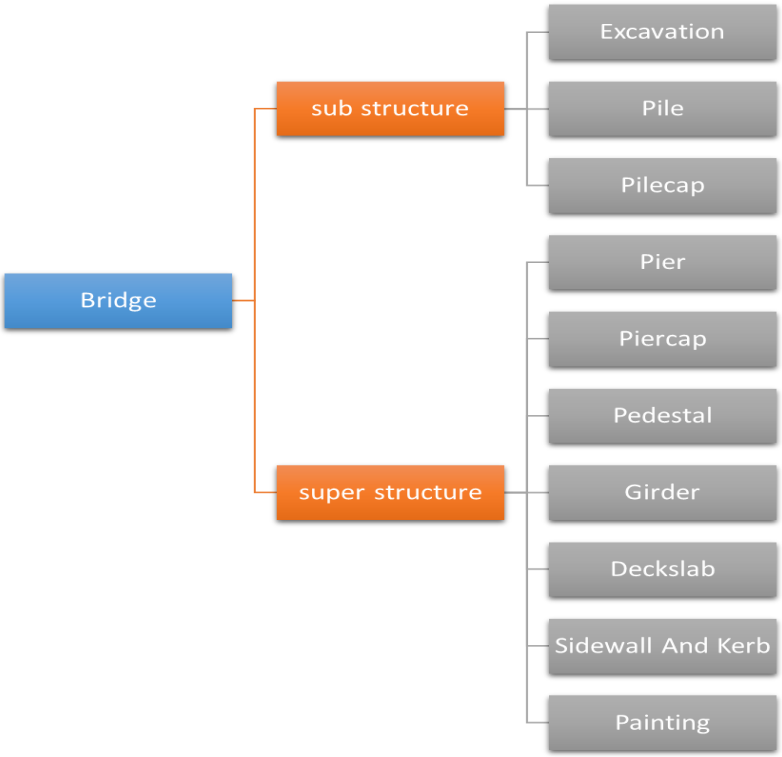

Fig. 1 WBS for Sardar Bridge

Table IV
Activities Duration by CPM &CCPM Method

Activity Name	Quantity of Excavation (m^3)	Total steel quantity (kg)	Total concrete quantity (m^3)	Shuttering Quantity(m^2)	CPM Days	CCPM days
1. Excavation of pile PD- 1	20	-	-	-	1	1
2. Excavation for pile PD -2	26	-	-	-	1	1
3. R.C.C for Pile PD- 1	-	1765	80	-	6	3
4. R.C.C for Pile PD- 2	-	2441	104	-	5	3
5. R.C.C for Pile Cap PD- 1	-	3212	46.8	36.72	4	2
6. R.C.C for Pile Cap PD- 2	-	4193.2	46.8	36.75	4	2
7. R.C.C for Pier PD- 1	-	808	10.94	23.32	4	2
8. R.C.C for Pier PD- 2	-	880	6.81	15.15	4	2
9. R.C.C for Pier Cap PD- 1	-	4333	30.51	47.58	4	2
10. R.C.C for Pier Cap PD- 1	-	3985	30.51	47.58	5	3
11. R.C.C. for pedestal PD- 1	-	-	2.52	-	1	1
12. R.C.C. for pedestal PD- 2	-	-	2.52	-	1	1
13. R.C.C. for Girder PD – 1 TO PD – 2	-	3450	52.92	138.80	5	3
14. R.C.C. for deck slab PD – 1 TO PD – 2	-	1159	26.13	104	10	5
15. R.C.C for side wall and curb & central verge	-	1311	14.78	82.4	3	2
16. Laying of bitumen	-	-	-	-	1	1

III. **Preparation of Critical Path Network (CPM) in primavera**

Step 1: Preparing PS (Enterprise Project Structure) & OBS Organizational Breakdown Structure for project.

- The Enterprise Project Structure (EPS) is a hierarchical structure used to depict the organization's structure on the software.
- OBS depicts the organizational structure in terms of hierarchy, roles and responsibilities, just like the organizational chart.
- For generating EPS go to Enterprise Menu' and select EPS and then click on add button to generate new EPS.

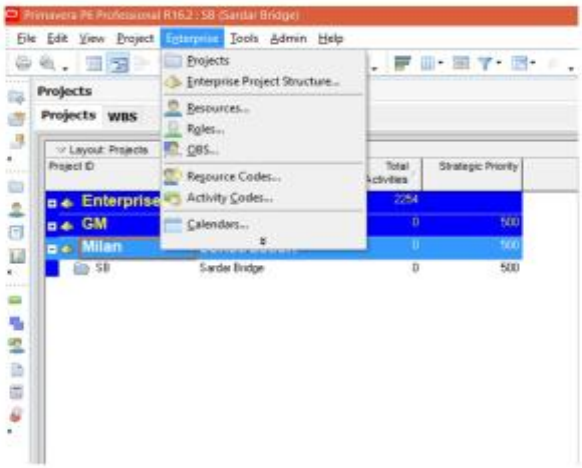

Fig. 2 first set EPS and OBS

Step 2: Create New Project

- Click on 'Enterprise Menu' and select 'Project' icon or directly click on Project icon'. So Project tab will open and now click on add button' to add new project.
- Then set calendar and assign it.
- Also set Duration type and Activity type of project.

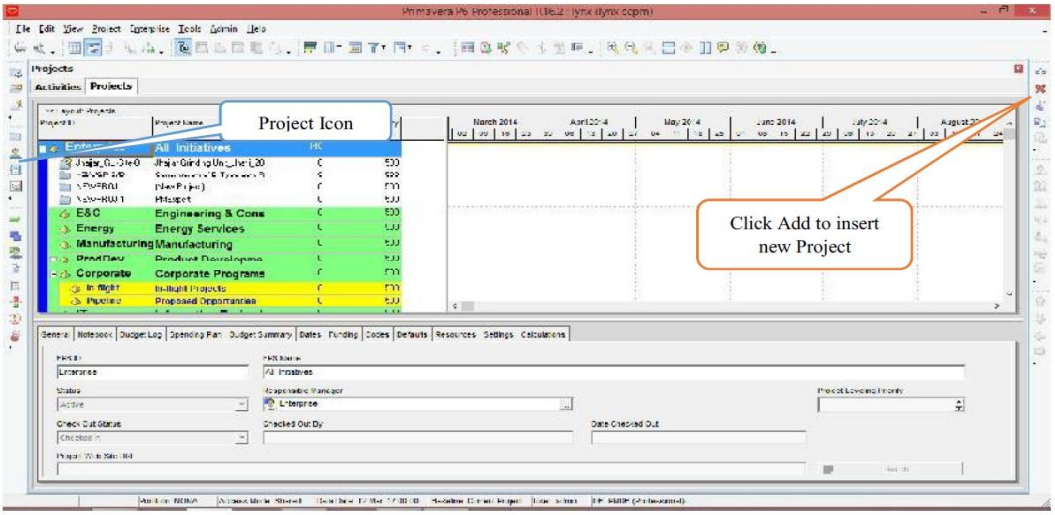

Fig. 3 Create new Project

Step 3: Create WBS of Project

- Click on 'WBS icon' directly or go to 'Project menu' and click on 'WBS icon'. Then add new WBS by clicking on 'Add button'

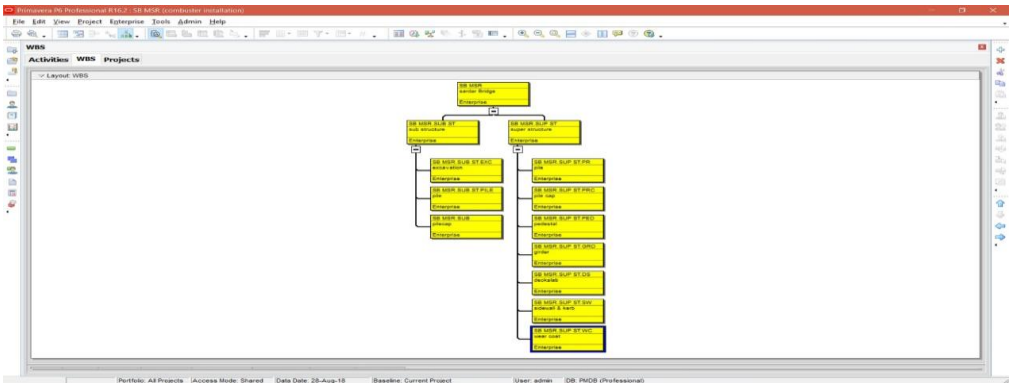

Fig. 4 Create WBS For project

Step 4: Add activities under WBS

- click on icon directly and add activity below WBS

- then Add duration of each activity

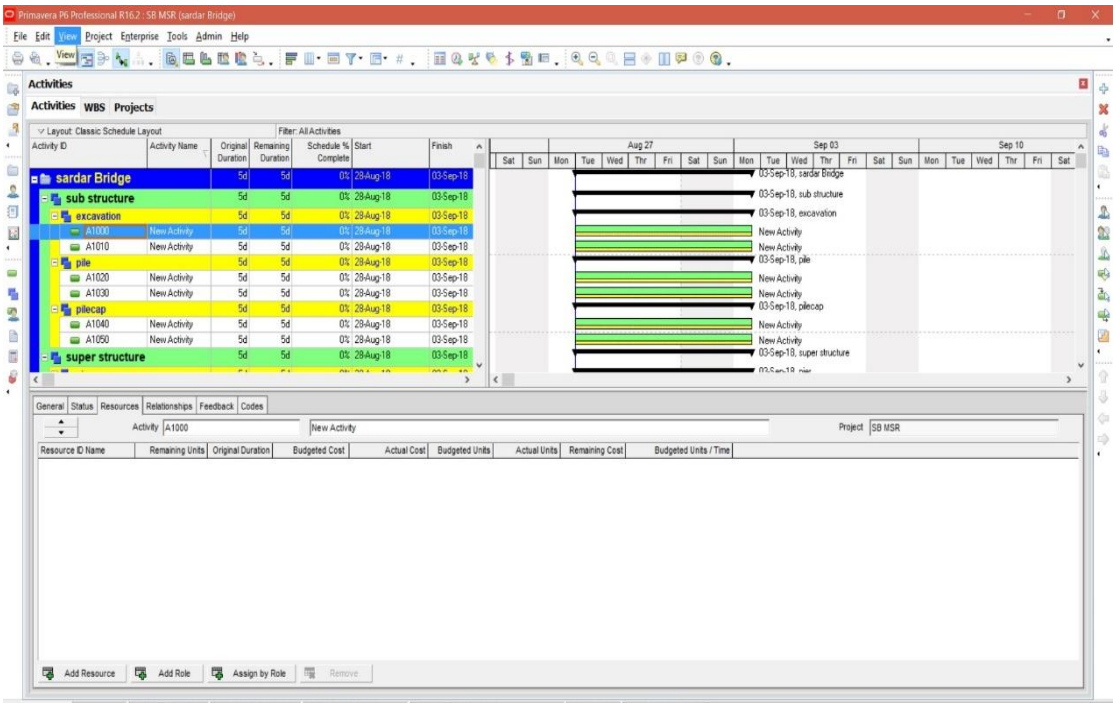

Fig. 5 Add activity and time

Step 5: Add Predecessor or successor to each and every activity

- Click on Predecessor tab below activity table. Now select an activity to which you want to assign predecessor
- Same process is required to assign a successor, but select successor tab. For all activity either assign predecessor or successor.
- After checking those relationships properly schedule it by clicking on schedule icon. By scheduling it will calculate the overall project duration, critical activity and non- critical activity of the network.

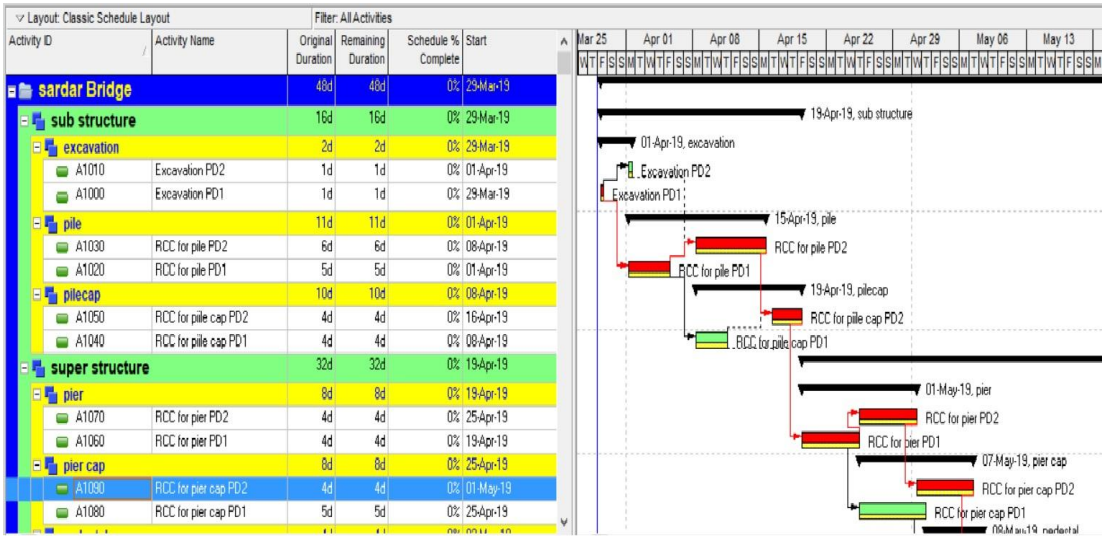

Fig. 6 final CPM network for project

Here after scheduling project author have found that total 48 days (see figure 6) are required to complete project by CPM method.

IV. Preparation of sample of Critical Path Network (CCPM) in primavera

For preparing CCPM network in primavera same steps were adopted in primavera as mentioned above. But the activity duration were calculated as per cut and paste method and assigned to every activity according to time calculated by cut & paste method.

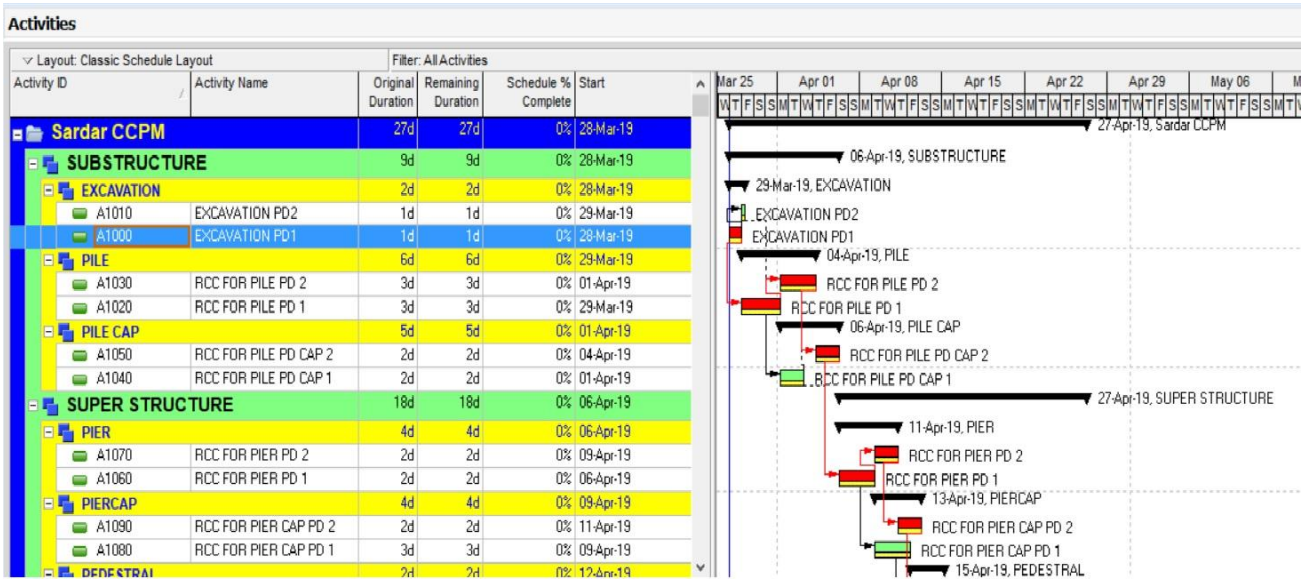

Fig. 7 final CCPM Activity duration for project

Here after scheduling project author have found that total 27 days (see figure7) are required to complete project by CCPM method. And it has one buffer of 13 days which is added at the end of project schedule to save project from overshoot predefined time and cost.

After preparing the CCPM network this network was compared with the CPM primavera project scheduler. This comparison showed that the total time of 48 days initially required in CPM network was reduced to 40 days using CCPM and also by better management of resources on site CCPM ensures not exceeding scheduling time by using resource buffer.

V. CONCLUSIONS

Prior image based on literature investigation shows CCPM network preparation was time consuming but this limitation overcome with the help of Primvera P6 software. In this research work author drawn attention of CCPM based scheduling for infrastructure project as previous research shows major benefits by applying CCPM for infrastructure construction projects. If one have better understanding of Primavera P6 software then its time saving and better management in terms of cost saving and resource saving possible to achieve with the application of CCPM. This case study also shows that CCPM resulted in better control on project progress by tracking project at certain time interval and also advance resource planning assure on time availability of resources and completing project with calculated cost.

REFERENCES

[1] Chawan P.M., Gaikwad Ganesh P. and Gosavi Prashant S. (2012) '*CCPM: TOC Based Project Management Technique*'. International Journal of Engineering Research and Applications (IJERA), 2(3), 1048-1052.

[2] Ghaffari Mahdi and Emsley Margaret W. (2015) '*Current status and future potential of the research on Critical Chain Project Management'*. Surveys in Operations Research and Management Science, ELSEVIER, 20, 43-54.

[3] Kumar D. Pragadeesh and Vasan L.Sabari Giri. (2016) '*Developing an Appropriate Critical Chain Project Management System to MRTS Elevated Station Platform Structure at Adampakkam'*. International Journal of Innovative Research in Science, Engineering and Technology (IJIRET), 5(3), 4333-4338.

[4] Lechler Thomas G., Boaz Ronen and Stohr Edward A. (2005) '*Critical Chain: A New Project Management Paradigm or Old Wine in New Bottles?*' Engineering Management Journal, 17(4), 45-58.

[5] Pai Siddesh K. (2014) '*Multi-Project Management using Critical Chain Project Management (CCPM) – The Power of Creative Engineering*'. International Journal & Magazine of Engineering, Technology, Management and Research, 1(1), 15-20.

[6] Rand Graham K. (2000) '*Critical chain: the theory of constraints applied to project management'*. International Journal of Project Management, 18, 173-177.

[7] Raz Tzvi, Barnes Robert and Dvir Dov, (2003) '*Critical Look at Critical Chain Project Management'. Project Management Journal*, 34(4), 24-32.

[8] Sarkar Srijit, (2012) '*Transition from Critical Path to Critical Chain: A Case Research Analysis'*. International Journal of Scientific & Engineering Research, 3(9), 1-10.

[9] Steyn Herman, (2000) '*An investigation into the fundamentals of critical chain project scheduling'*. International Journal of Project Management, 19, 363-369.

[10] Thirumalai Rajan Arumugam and Koshy Varghese (2014) '*Characterization of Flow in Multi Storied Residential Building Construction'*. Proceedings IGLC-22, Oslo, Norway, 559-569.

[11] VRINCUT Mihai, (2009) '*Critical Chain Project Management and the Construction Industry in Romania'.* Review of International Comparative Management, 10(5), 1060-1067.

[12] Mona P. Prajapati , and Neetu B. Yadav & Neeraj d. sharma" *Buffer Based CCPM Scheduling: A Modern Approach for Indian Constraints*" Kalpa Publications in Civil Engineering Volume 1, 2017.