Implementation of Critical Path Method (CPM) Technique to a Road Construction Project in Jalgaon District, Maharashtra

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Abstract - *Road Construction Industry is always looking to extend its effectiveness and efficiency to a greater limit while using its techniques and methods. This study deals with managing the resources used in an effective way and minimizing the cost. The primary data has been collected from a private construction company which has various infrastructure projects running. The present work of the research paper is based upon the data of a Jalgaon District, Maharashtra road construction project, in which there are various activities and approaches available for different options to the contractor. Considering the project as a network we use CPM technique to achieve a critical path of the network by dividing the road construction into various number of operations, thus arriving at a critical path which is the longest path as it will involve all the critical activities required to complete but it will also be with least number of days taken. The solution provided by this technique is such that it gives the company an insight towards the complete duration of the project and specific activities that need precise attention regarding delays. Thus, the study indicates that CPM techniques do result in gaining an advantage for a contractor and the company.*

Keywords *- Critical Path Method, Program Evaluation Review Technique, Operations Research, Jalgaon, Road Construction, Maharashtra*

I. INTRODUCTION

India has one of the largest and widest road networks in the world, about 4.42 million kilometers at present. India has been continuously investing huge amounts of its financing in road construction, so that the network keeps on expanding. The government of India has planned and implemented several of its road construction projects such as the famous GT road, Yamuna Expressway which stretches from New Delhi to Agra is India's longest motorway and also Mumbai's Eastern Freeway which again shows the amazing piece of engineering and road Management. The applications of Operations research can be seen in the whole infrastructure industry, particularly in construction of buildings, highways, freeways etc. The primary objective of any project is to look for cost saving opportunities in the various processes of construction whether it's a road or an airport or a building. For Example, finding the optimal number of workers required, which activity is to be performed at what time or which activity will precede which. The decision makers, thus can decide and make use of several traditional operations research techniques such as CPM to better understand their projects and minimize the time taken and the cost. CPM was developed by Du Pont and Remington Rand in late 1950s.CPM is mainly used in construction projects which are based on the knowledge and also the experience of the projects which are done in the past and will help to predict the time taken by each activity and also estimate the costs. The objective of this paper is to examine the feasibility and desirability of application of operations research to the road construction project of a company which is headquartered in New Delhi and has an undergoing project in Jalgaon, Maharashtra which acts as the main subject for the research paper.

II. LITERATURE REVIEW

CPM Analysis of Rolai-Rinjlai Road Construction
Khurana Sunita and Banerjee Snigdha
Received 04th November 2012, revised 28th December 2012, accepted 23rd January 2013

There has been a constant effort by the government to improve the roads of India for better traveling, but they have to make sure that this improvement causes minimalistic disruption of traffic which would be caused by the construction of the road. This could be made sure if the contractor divides the project into smaller subdivisions to minimize the time of completion of the project and to minimize the cost of the project. This can happen by using the method of CPM and PERT.

Considering the Rolai-Rinjlai road construction project to be a network, we used CPM method to obtain the critical path of the network and suggested the best approach for acquiring material and construction of road under certain constraints. The construction of this road took around 97 days to complete but after calculating the critical path method, the calculations showed that the project could have taken only 45 days with a reduction in cost from Rs.54,85,240.00 to Rs.55,41,995.00.

Project Planning and Scheduling Using PERT and CPM Techniques with Linear Programming
Wallace Agyei
International Journal of Scientific & Technology Research Volume 4, Issue 08, August 2015

Generally, completing a construction project on time and within the given budget is not an easy task. A large number of factors play a role in the delay of the completion of the project. These delays, in the long run many problems like time bound and cost overrun. This is because some of the activities involved the projects are of a criticalnature and would delay the overall project time. Hence, proper planning of the project is required to deal with this problem.
The project of Ghana faced a major time and cost overrun with an increased amount of complexity. The project took around 79 days to be completed. This project was then analyzed and done through the CPM and PERT method. Even though CPM and PERT differ from each other in certain ways, their main aim is the same. After this analysis and different resources taken into consideration, the given project could be completed with a span of 40 days which is 39 working days less but there would have been a slight increase in the cost of this project.

A Practical Approach using CPM/PERT: For Certain Activity Times in Construction Parking Project
Aznida Hayati Zakaria, Norizah Haron, Fadhilah Ahmad, Ahmad Nazari Mohd Rose and Mustafa Mat Deris
World Applied Sciences Journal 35 (7): 1180-1184, 2017© IDOSI Publications, 2017

Every project management is applied knowledge, skills and techniques used by a person to execute the project in an efficient and timely manner. It is a strategic way of ensuring the company meets its goals. This paper is based on a construction project. A construction project is bases on three aspects; time, cost and performance.In this paper, the given project is solved by the CPM and PERT method to come to a minimized time and budget for the project.
This project, through CPM and PERT was could be completed within 26 weeks whereas in reality it took 37 weeks to be completed.

III. METHODOLOGY

Road Construction can be referred to as a scheduled and systematic way of planning, scheduling, executing, monitoring, controlling the different aspects of the project. Critical Path Method (CPM) and Project Evaluation & Review Technique (PERT) are the two network-based techniques that can be used to optimize the project management.

CPM method involves the making of a network with all the activities of the project with the desirability to shorten the duration of the project. Crashing concept is applicable in this method i.e. reducing the duration of an activity by devoting additional resources at a higher cost. The activity with the minimum cost per unit time is selected to crash. This method is continued until all activities have been crashed to their respective shortest possible durations, the project completion schedule is arrived to be within the desired time frame, and the cost of crashing further outweighs the benefits.

PERT method works upon the same idea of CPM of making of a network, but instead of using likely time estimates, it uses probabilistic time estimates for completion of an activity. PERT also focuses only on high precision time and not on time-cost trade off.

In this paper, we will be studying the different activities or operations that gets dealt with while road construction and we will be creating a CPM network to analyze each one. Using the network analysis, we calculate the floats and the slacks for each activity. The basic objective of exercising a CPM technique is to figure out the critical activities with the least floats and help the company to understand the different areas of operation which requires precise attention to ensure there is no delay in the project's Time of Completion (TOC).

The primary data collected is from a private construction company which has a currently undergoing road construction project in Jalgaon district of Maharashtra. The data is given regarding to the different activities deployed for the completion of the project, the different ways to approach said activities, their duration and the cost per activity in regard to construction of 10 meters of road.

IV. DATA ANALYSIS

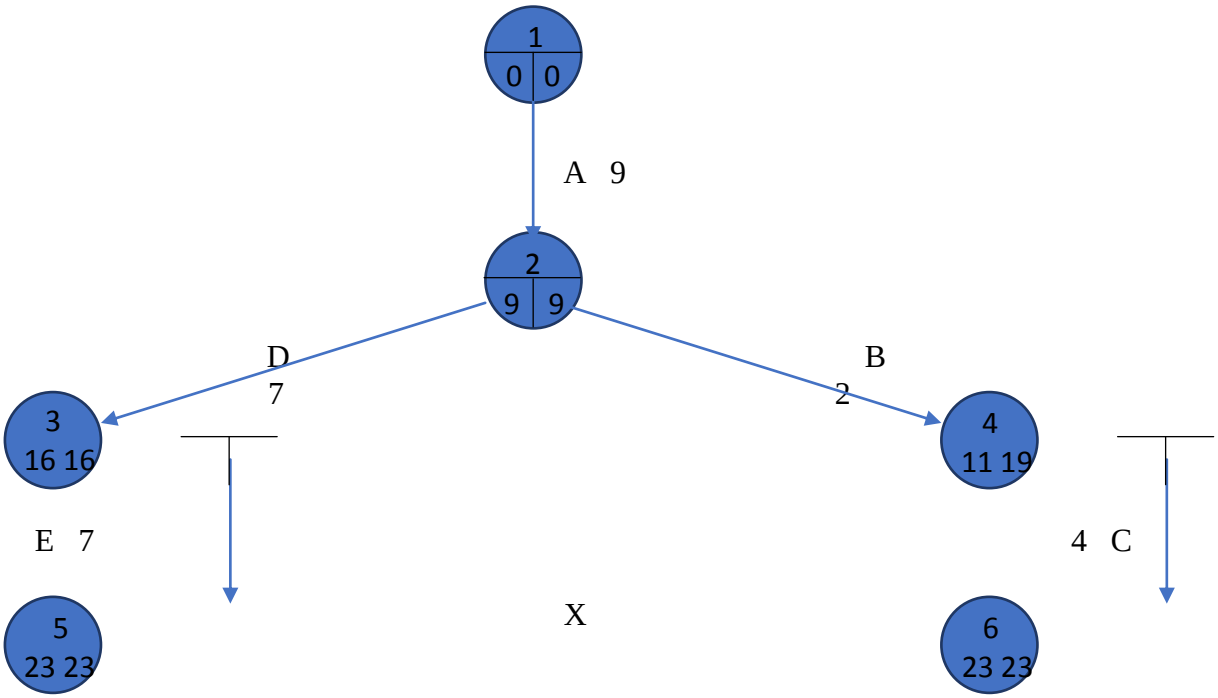
Table 1. The different activities involved in the construction project with details given by the company

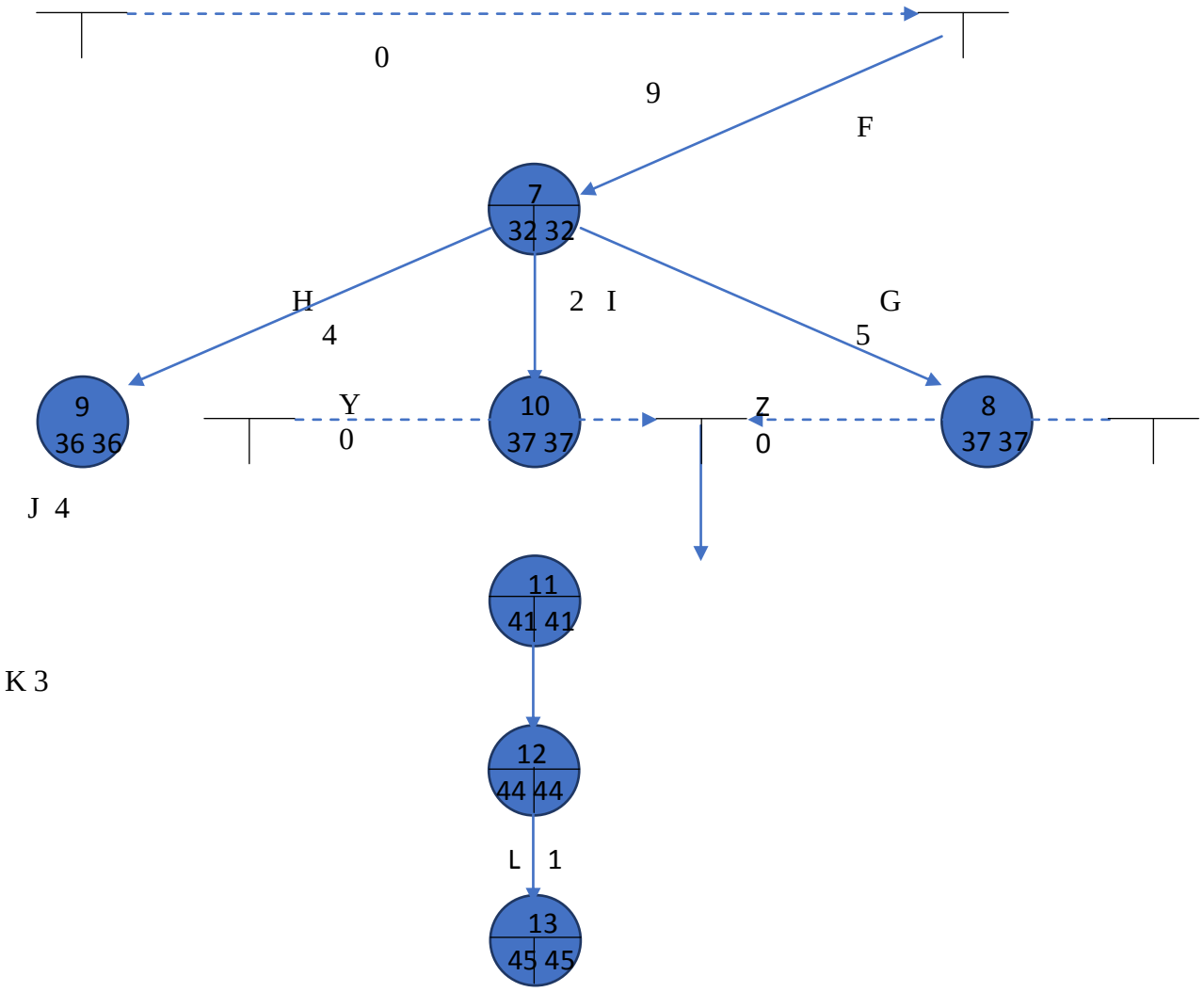
OPERATION	ACTIVITY	PREDECESSOR ACTIVITY	DURATION (Days)	COST (Rs.)
Clearing & Grubbing	A	-	9	140000
O.G.L Recording	B	A	2	70000
Embarkment Layer	C	B	4	244000
Subgrade 1st	D	A	7	195000
Subgrade 2nd	E	D	7	195000
Subgrade Top	F	C, E	9	256000
G.S.B	G	F	5	86000
W.M.M	H	F	4	43000
Prime Coat	I	F	2	240000
D.B.M	J	G, H, I	4	37000
B.C	K	J	3	41000
Road Furniture	L	K	1	412000

Table 1 shows us the various operations that go into the road construction project and the activity codes assigned to each one of them. It shows the Predecessor activities as well. These indicate the different activities that need to be completed to start that particular activity. The duration and the costs are also given in regard to 10 meters of road.

The next step is to create a network of activities using the data given in Table 1. The said network is created keeping in mind the predecessor activities given and the duration of the activities as well to calculate the early start, early finish, late start and late finish for each activity.

In our study, to inculcate all the predecessor activities, we use the concept of dummy paths symbolized by dotted lines. The blue circles indicate the events i.e. the current state of the project and the lines between indicate the activities performed between these 2 events.





The network analysis shows the different paths available to the company to go from event 1 i.e. the start of the project to event 13 i.e. the end of the project. X, Y & Z are the dummy paths formed to meet the requirements of predecessor activities. The duration for each activity is shown besides the activity code. The tail circle for each activity shows the early start and the late start for the activity on the bottom-left and the bottom-right respectively.
The head circle shows the early finish and the late finish for the activity on the bottom-left and bottom-right respectively.

Table 2. The start and finish details for each activity on separate basis

ACTIVITY	EARLY START	LATE START	EARLY FINISH	LATE FINISH
A	0	0	9	9
B	9	17	11	19
C	11	19	15	23
D	9	9	16	16
E	16	16	23	23
F	23	23	32	32
G	32	32	37	37
H	32	33	36	37
I	32	35	34	37
J	37	37	41	41

K	41	41	44	44
L	44	44	45	45

Table 2 gives us details regarding the early start, early finish, late start and late finish of each activity. Although there is a difference between the details of each activity in Table 2 and the network. This is because the start and finish calculations done in the network are done by taking into consideration all the paths and their prerequisite condition, while the calculations done in Table 2 are done by discarding the different paths and just taking into consideration the particular activity and its duration only. This helps us figure out the difference in the realistic duration of each activity when all the paths are kept into consideration.

Table 3. The floats and slacks

ACTIVITY	TOTAL FLOAT	FREE FLOAT	INDEPENDENT FLOAT	INTERFERING FLOAT	TAIL SLACK	HEAD SLACK
A	0	0	0	0	0	0
B	8	0	-8	8	8	8
C	8	0	-8	8	8	8
D	0	0	0	0	0	0
E	0	0	0	0	0	0
F	0	0	0	0	0	0
G	0	0	0	0	0	0
H	1	0	-1	1	1	1
I	3	0	-3	3	3	3
J	0	0	0	0	0	0
K	0	0	0	0	0	0
L	0	0	0	0	0	0

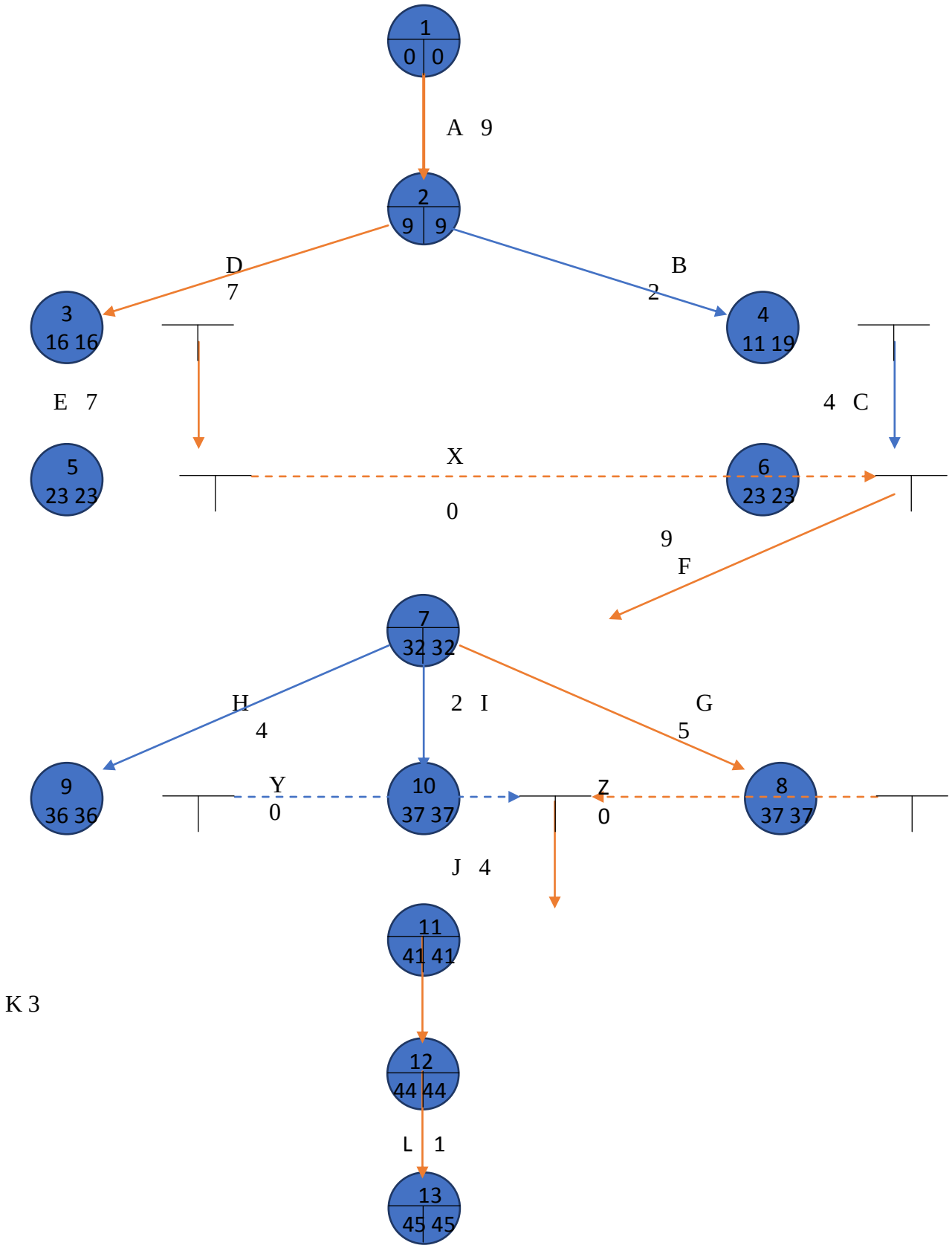
The formulas used to calculate the headers in Table 3 are mentioned below.

- Tail Slack = Late Start – Early Start
- Head Slack = Late Finish – Early Finish
- Total Float = (Late Start – Early Start) or Tail Slack
- Free Float = Total Float – Head Slack
- Independent Float = Free Float – Tail Slack
- Interfering Float = Head Slack

The Starts and Finishes used to calculate the floats are the ones calculated in the Table 2 as we are calculating floats and slacks for each activity on separate basis as well.

The objective of calculating floats is to see the amount of delay that can take place while performing each activity. This, as mentioned below, the aim of CPM technique is to reduce the floats as much as possible. This gives the company a better approach to opting a path for the completion of the project with the least possible delays.

To determine the critical path, we highlight the activities with zero floats and zero slacks in the network analysis.


1
0 0
A 9
2
9 9
D
7
B
2
3
16 16
4
11 19
E 7
4 C
5
23 23
X
0
6
23 23
9
F
7
32 32
H
4
2 I
G
5
9
36 36
Y
0
10
37 37
Z
0
8
37 37
J 4
11
41 41
K 3
12
44 44
L 1
13
45 45

In the highlighted network analysis, we see that A>D>E>X>F>G>Z>J>K>L form the critical path. This means that these activities form the longest duration of the entire project i.e. the maximum time that can be taken for the project if the durations of each activity are kept to. These activities indicate that there is no scope for any kind of delay as any delay in one of these critical activities will be delaying the projected completion time of the project i.e. 45 days in this company's case.

To understand the possible delay in activities and their position in the network, we use the Gantt Chart.

Table 4. Calculations for Gantt Chart

ACTIVITY	DURATION	EARLY START	LATE FINISH
A	9	0	9
B	2	9	19
C	4	11	23
D	7	9	16
E	7	16	23
F	9	23	32
G	5	32	37
H	4	32	37
I	2	32	37
J	4	37	41
K	3	41	44
L	1	44	45

Table 4 depicts the calculations and the information required to obtain the Gantt Chart.

The horizontal headers in the Gantt Chart are 45 representing each day in the total time of completion of the project. The vertical headers depict the activities. The blue bars show the number. of activities corresponding to the number of days its performed for. As seen in the Gantt Chart, activities A, F, J, K & L are the only activities being performed during their duration, thus they are certain activities compulsory to any path chosen for completion.

As for the duration from Day 10 to Day 23, 4 activities i.e. B, C, D & E can be used to choose a path. As for the duration from Day 33 to day 37, 3 activities i.e. G, H & I can be opted for. In such cases, a process called crashing is undertaken to reduce the duration of the critical activities by increasing the cost and resources within the specified limit. But due to the lack of specific data in regards to our measures of comparison, crashing could not be done.

V. CONCLUSION

According to the Critical Path Method, we determined the critical path for the road construction project and the respective critical activities. If these paths were to be followed, the company would be ignoring activities B, C, H & I. These activities respectively coordinate to certain operations, O.G.L Recording, Embarkment Layer, W.M.M & Prime Coat. Thus, CPM helps the company build the road in the most efficient standards for time but compromises the safety of the road. Therefore, sometimes CPM can be used but not at the cost of certain ethical conduct, especially in the construction industry.

If the company was to follow the critical path, it would achieve its project completion in 45 days. Therefore, the company should make sure to pay specific attention to the critical activities to ensure timely completion of project. Although, its possible for the company to complete the project even in lesser time if it were to gather adequate information and execute crashing on certain activities.

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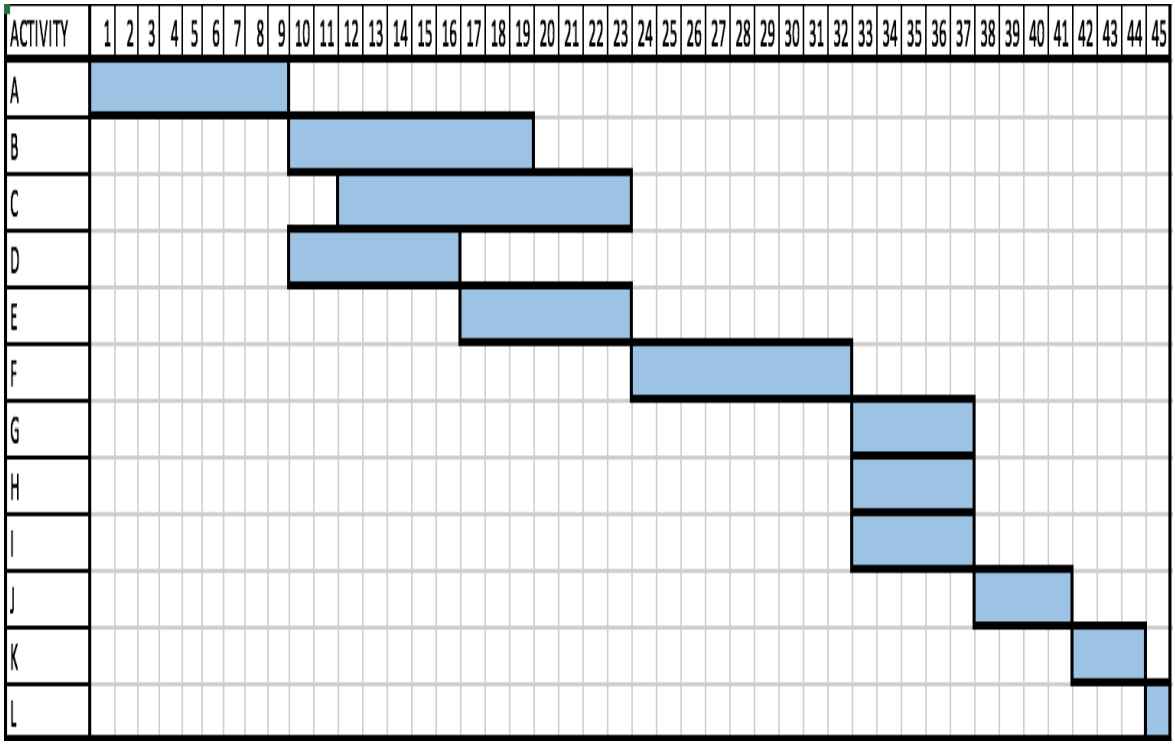

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