

INVESTIGATING CONSTRUCTION ACTIVITY, USING NETWORK ANALYSIS LIKE THE CRITICAL PATH METHOD (CMP)

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Abstract

Managing construction work is the process of breaking down the structures of the construction, determining the relationship between each activity to be carried out, the duration that is needed for every activity, and the creation of a schedule that is flexible. Problems might crop up in most constructions such as an increase in the cost of the project, the project not being finished at the stipulated time (schedule slippage), limitation of resources, and so on. The aim of this study is to investigate a network construction at Keffi new market, using the critical path method, this study will investigate the time of completion of a project and estimate the earliest and shortest time needed to complete the project, identifying the critical and non-critical task activity, data collection from project supervisor at Canonic Consult Ltd. Considering activities such as identification of all the activities necessary for the project construction, precedence relationship within the stated task, development of the network diagram, estimation of the earliest start time (EST) and latest start time (LST), determining the task that is critical and non-critical to timely completion of the project (float task). The outcome of the study shows that the expected completion time for the project is approximately 10 weeks, exactly 67 days and the critical activities are Foundation, Electrical & Plumbing, Floor, and Landscaping. The Noncritical activities are Site Clearance, Setting-out, Columns, Framework, Brick masonry, Roof structure, Plastering, Door & window fixation, Painting, and Electrical fittings and their “total float” is 19,17, 18, 28, 19, 17, 32, 28, 32, 28 and 22 days respectively.

Keywords: Predecessor activity, Successor activity, Float, Critical path, Project, Activity.

1. INTRODUCTION

Achieving a successful building project requires planning, coordination, and scheduling a number of activities that are related. Every building project involves a series of task activities, and the responsibilities of the activities are done in steps. Some can be done straight away while some of the tasks need to await others' completion before starting, and some of the tasks are done concurrently. Hence delay experienced during building a project may arise, if some of the tasks are not completed before the maximum stipulated time a problem may arise. One way of overcoming such a problem is by planning the project from start to complete time; this can be done by the use of network models (Kusumadarma, I.A. et.al 2020; hegazy, T., Ersahin, T. 2001).

Network models are techniques of finding a skillful way to link a number of tasks either directly or indirectly aimed at satisfying the demand and supply requirements for different project scheduling. Networking is very important in building construction, monitoring the progress of the construction at every stage, to enable the project to be completed at the stipulated time. Using networking will pinpoint the part of the project that is crucial, implying when some of the activities are delayed will automatically delay the entire project and increase the time before completion of the project (Adibhesami, M.A et.al 2019).

Zareei, S. (2018) presented a practical technique used in modeling and optimizing the entire construction schedule by the use of a spreadsheet model. The spreadsheet is used to integrate a critical path method scheduling trade-off analysis with time cost such as allocating resources, leveling resources, and lastly cash flow management. The model's main objective is to minimize the total project cost.

Mohamed and Celik (2002) Study shows an integrated technique for estimating scheduling construction cost, the study aimed at applying a graphical technique for analyzing the task involved in project completion time, and identifying the minimum and maximum time needed to complete a project. The latter technique can be achieved using the critical path method a robust technique for drawing project schedules. Koo et al. (2007) presented a formal identification and a sequencing process for achieving tasks using the technique of the critical path method, which is very effective in the development of a sequential alternative construction schedule.

1.1 Statement of the Problem

Scheduling a project is dependent on numerous factors, such as the availability of planning, engineering, and management of the project resources putting into consideration the scope and ability to break down the task involved into different activities in steps. Other factors considered in planning a project include the use of software to manage a larger project with a high number of complicated tasks, the time needed for completion of the project, and most importantly specifications needed for the project development (Ramani, P.V., Selvaraj,P., Shangapriya (2022); Lucky, F. & Linda, M.R. (2022); Andiyen. A., *et. al* (2021). A baseline schedule is the first step, then managing and control of the project in line with best practices, there is a variety of modeling techniques that can be used. This study aimed at estimating project completion time and the critical task will apply critical path method technique to achieve the objective of estimating the earliest and latest time for completion of the project at keffi new market.

Marnewick, C. & Marnewick, A.L., (2019) Critical path method technique is used widely for project management to enable project management time and critical path estimation. The techniques are used for small, large, and complex task activities needed for developing specific processes and facilitating implementation in achieving project objectives. The ability of the project manager to relate the CPM technique to project management minimized the risk of project failure (Salhab, D. *et. al.* (2022); Doefeshan, Y., Mousavi, S.M. (2018)). Hence this study will model the technique for the identification of existing related governing processes and provide a framework that can be implemented for new Keffi market building construction.

The aim of this study is to investigate a network construction at Keffi new market, using the critical path method, through the following objectives, determining the critical path in project management networks, identifying critical path fluctuations, and representing the various activity relationships more simply, estimating the earliest and latest time for each activity to be completed without delay, predicting the completion day for the building construction.

1.2 Significance of the Study

The study will be able to figure out the activities which can run parallel to each other, helps the project manager in identifying the most critical elements of the project, helps in optimization by determining the project duration, extensively used in industries, it also shows the activity and their outcomes as a network diagram and lastly gives practical and disciplined base which helps in determining the objectives. The structure of this research is to develop an innovative scheduling model using the CPM technique. The models will better handle schedule constraints, such as project deadlines and resource limits, facilitate corrective actions during construction, and produce accurate schedule analysis during and after construction.

2. LITERATURE REVIEW

Techniques used to plan and control projects, taking into consideration of time factors, resources, cost, and probability of events. There are different techniques used for such namely, Critical Path Planning (CPP), Critical Path Analysis (CPA), Critical Path Scheduling (CPS), Critical Path Method (CPM), and Programme Evaluation and Review Technique (PERT) (Yogeswaran, K., Kumaraswamy, M.M., & Miller, D.R., 1998). Network analysis is a very important technique in the process of effective management of the project in making decisions in project management, operational research and management, and system development.

Applying network analysis is very important and very useable anywhere and every time, this technique is best learned by managers and decision-makers in most organizations. There are numerous research has been used to address Factors contributing to delay, and factors in construction that lead to delays in production (Sawhney, Iyer, & Rentala, 2012; Kaliba, Muya, & Mumba, 2009). Factors are identified which include financial factors, poor contract management, availability of material and equipment, change in decision from the owner poor process of allocation of the project (Mahamid *et al.*, 2012; Park & Papadopoulou, 2012). In reporting a transportation project, a contributing factor for cost, time, change of order, the amount for completion of the contract, the difference between the first and the second bid, the difference between the winning bid and the losing bid, and also the estimates made by the engineers, the type of project and location. Santoso and

Soeng (2016) conducted research on the effect of delay, the outcome of the study shows time is the major factor that affects performance which is relative to cost and the quality of the project undertaken. This can be taken care of when the longest and shortest distance between the activities of the project can be determined.

A mathematical tool for estimation of time to complete a certain project can be described by the process of critical path method. One of the reasons for using the critical path method is, it reduces delay through optimization along the critical task activities, visualization dependencies by listing and prioritizing activities accordingly, improves organization, optimizing efficiency, and calculation of float (Syahputri, K., et.al (2020); Mahamud, I., Bruland, A., & Dwaidi, N. (2012)). The critical path method is used to estimate the longest time or the shortest time to be taken for a project to get to completion, this can be achieved by using the method of forward pass and backward pass respectively. The method of the forward pass is used to calculate the earliest and the latest time for all the project activity. The network analysis will allocate a start date on the first activity to be considered as the beginning of the project and subsequently determine the longest path the project can take.

3. RESEARCH METHODOLOGY

The population of the study is the Keffi local government area of Nasarawa state and the sample for the study is new Keffi market construction. The data collection method used during the research will be primary data collected through a structured survey interview. The area of study for this study is Keffi New Market, located in Nasarawa State, Federal Republic of Nigeria. The analytical technique used to achieve the stated objective is the critical path method, and the data Analysis Software used in this research is Micro Soft Excel (2016).

The method of analysis Critical path method is the most important and most enduring technique used for project management, this study used the technique for this network construction for analyzing, planning, and also scheduling the complex project. It was used to determine the critical path. It also identified the dependency between task activities and emphasizes the task activity that is critical for the project. As a cornerstone of project

management, the time a project takes to completion is very crucial, it is to be mapped out with its duration; hence an estimate of the time and budget is made reasonably.

This study considered of six steps to achieve its objectives. (a) problem definition, (b) research design planning, (c) sample planning for data collection, (d) data collection, (e) data analysis, and, (f) conclusion. The target informant of the research is from Canonic Consult Limited located at Area 11, Garki, Abuja.

4. RESULTS

Table 1: Description of activities involved in the construction process of one upstairs building in new Keffi market, Nasarawa State.

S/N	Activity	Description of Activities
1	A	Site Clearance
2	B	Setting Out
3	C	Foundation
4	D	Column
5	E	Frame Work
6	F	Brick Masonry Work
7	G	Roof Structure
8	H	Electrical and Plumbing
9	I	Plastering
10	J	Door and Window Fixation
11	K	Floor
12	L	Painting
13	M	Electrical Fittings
14	N	Landscaping

Gantt chart showing the activities and their respective durations. With activity C having the longest duration of 30 days while activity A is the activity with short duration Activities

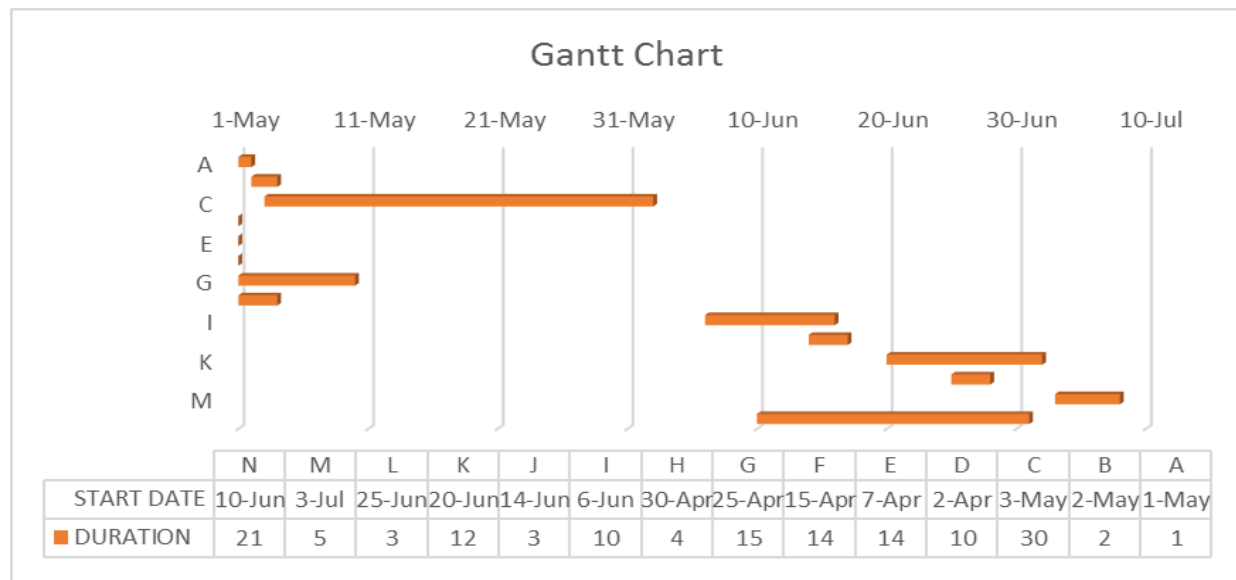


Figure1. Gantt chart representation

Activity-On-Node (AON) Diagram of project network showing the precedence and activities durations.

Below is the transformed network diagram after the necessary computations of both forward and backward passes showing both critical and non-critical paths.

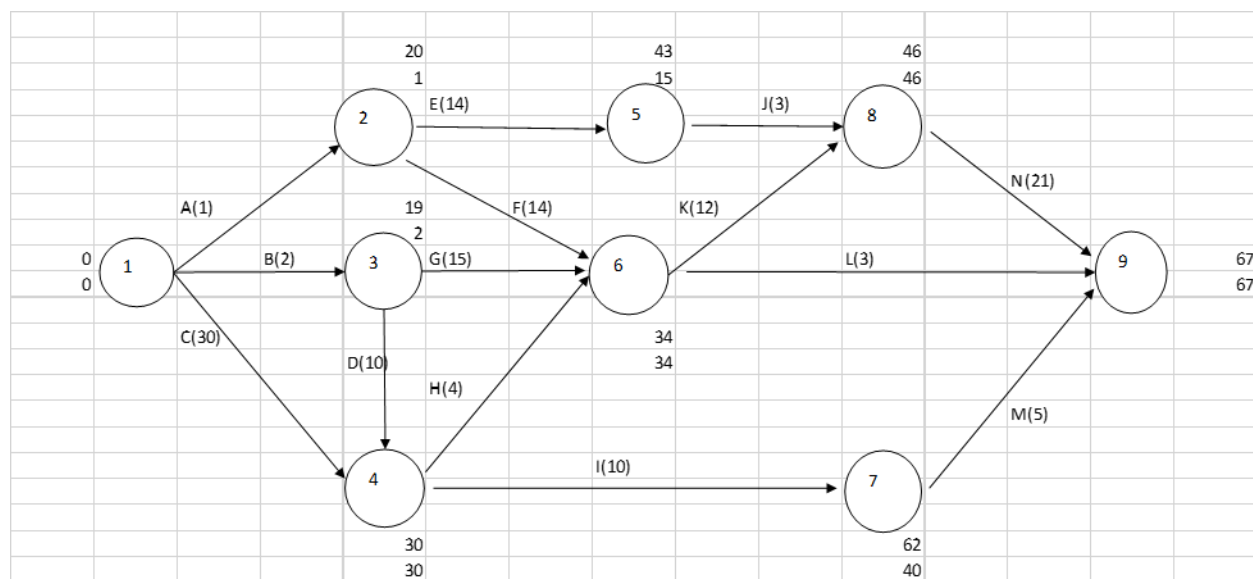


Figure 2. Network diagram showing the critical and non-critical paths

The earliest start time and latest completion time required to complete an activity. The values actually help in determining the paths numerically. Thus we have;

$$(A \rightarrow E \rightarrow J \rightarrow N) = (1 + 14 + 3 + 21) = 39$$

$$(A \rightarrow F \rightarrow K \rightarrow N) = (1 + 14 + 12 + 21) = 48$$

$$(A \rightarrow F \rightarrow L) = (1 + 12 + 3) = 16$$

$$(B \rightarrow G \rightarrow L) = (2 + 15 + 3) = 20$$

$$(B \rightarrow D \rightarrow H \rightarrow K \rightarrow N) = (2 + 10 + 4 + 12 + 21) = 49$$

$$(B \rightarrow D \rightarrow H \rightarrow L) = (2 + 10 + 4 + 3) = 19$$

$$(C \rightarrow H \rightarrow K \rightarrow L) = (30 + 4 + 12 + 21) = 67$$

$$(C \rightarrow H \rightarrow L) = (30 + 4 + 3) = 37$$

$$(C \rightarrow I \rightarrow M) = (30 + 10 + 5) = 45$$

Network path **(C → H → K → L) = (30 → 4 → 12 → 21)** this is called the critical path because it has the longest path. The shortest duration for the project is 67 days, let's assume there will be no delays in the activities of the critical path. We say that the critical path has no (zero) float. The project management guide (2006) describes an activity of float as the amount of time an activity is delayed without any negative effect on the completion date for the project. Another scholar (Williams 2003) states that any delay in an activity of a project with no (zero) float time will eventually affect the completion time of the project.

4.1 PROJECT SCHEDULING CONSTRUCTIONS

Project scheduling implies calculating the early start of an activity with an early finish of the activity and also late to start an activity and late to finish the activity on any network construction after every activity has been assigned its duration as reported. To calculate

an event activity of the earliest with its latest time of completion of an activity forward pass and backward pass are used respectively.

4.1.1 Float computations

Float, or slack, refers to the amount of flexibility of a given task. It indicates how much the task can be delayed without impacting subsequent tasks or the project completion time.

The floats were calculated from the results to obtain from the forward pass and backward pass techniques

$$\text{Total Float (TF)} = \text{LCT} - \text{EST} - \text{Dij} \quad \text{or} \quad \text{LFT} - \text{EFT} = \text{LST} - \text{EST} \quad (1)$$

$$\text{Independent Float (IF)} = \text{EFT} - \text{LST} - \text{Dij} \quad (2)$$

$$\text{Free Float (FF)} = \text{EFT} - \text{EST} - \text{Dij} \quad (3)$$

Where:

Dj = Activity Duration, EST = Earliest Start Time, ECT = Earliest Completion Time,

LST = Latest Start Time, LCT = Latest Completion Time

4.1.2 Free float: This refers to how long an activity can be delayed without negatively impacting the following activity as discussed previously. To calculate the free floats of individual activity, we have,

$$\text{Free Float (FF)} = \text{EFT} - \text{EST} - \text{Dij}$$

$$A = (1 \rightarrow 2) = 1 - 0 - 1 = 0$$

$$B = (1 \rightarrow 3) = 2 - 0 - 2 = 0$$

$$C = (1 \rightarrow 4) = 30 - 0 - 30 = 0$$

$$D = (3 \rightarrow 4) = 30 - 2 - 10 = 18$$

$$E = (2 \rightarrow 5) = 15 - 1 - 14 = 0$$

$$F = (2 \rightarrow 6) = 34 - 1 - 14 = 19$$

$$G = (3 \rightarrow 6) = 34 - 2 - 10 = 22$$

$$H = (4 \rightarrow 6) = 34 - 30 - 4 = 0$$

$$I = (4 \rightarrow 7) = 40 - 30 - 10 = 0$$

$$J = (5 \rightarrow 8) = 46 - 15 - 3 = 28$$

$$K = (6 \rightarrow 8) = 46 - 34 - 12 = 0$$

$$L = (6 \rightarrow 9) = 67 - 34 - 3 = 30$$

$$M = (7 \rightarrow 9) = 67 - 40 - 5 = 22$$

$$N = (8 \rightarrow 9) = 67 - 46 - 21 = 0$$

The Project Management Body of Knowledge Guide (2006) describes the activity float as the amount of time in which an activity can be delayed without negatively impacting the project completion date.

4.1.3 Total float: This is the amount of time that an activity can be delayed from the early start date without delaying the project finish date or violating a schedule constraint.

$$\text{Total Float (TF)} = \text{EFT} - \text{EST} - \text{Dij}$$

$$A = (1 \rightarrow 2) = 20 - 0 - 1 = 19$$

$$B = (1 \rightarrow 3) = 19 - 0 - 2 = 17$$

$$C = (1 \rightarrow 4) = 30 - 0 - 30 = 0$$

$$D = (3 \rightarrow 4) = 30 - 2 - 10 = 18$$

$$E = (2 \rightarrow 5) = 43 - 1 - 14 = 28$$

$$F = (2 \rightarrow 6) = 34 - 1 - 14 = 19$$

$$G = (3 \rightarrow 6) = 34 - 2 - 15 = 17$$

$$H = (4 \rightarrow 6) = 34 - 30 - 4 = 0$$

$$I = (4 \rightarrow 7) = 62 - 30 - 10 = 32$$

$$J = (5 \rightarrow 8) = 46 - 15 - 3 = 28$$

$$K = (6 \rightarrow 8) = 46 - 34 - 12 = 0$$

$$L = (6 \rightarrow 9) = 67 - 34 - 3 = 30$$

$$M = (7 \rightarrow 9) = 67 - 40 - 5 = 22$$

$$N = (8 \rightarrow 9) = 67 - 46 - 21 = 0$$

(Williams 2003, cited Yogeswaran, 1998) stated that delays in activities with zero float time could eventually impact project completion.

4.1.4 Earliest Completion Time: This is the earliest time an activity is completed in a project and is computed as;

$$ECT = EST + D_{ij} \quad (4)$$

$$A = 0 + 1 = 1$$

$$B = 0 + 2 = 2$$

$$C = 0 + 30 = 30$$

$$D = 2 + 10 = 12$$

$$E = 1 + 14 = 15$$

$$F = 1 + 14 = 15$$

$$G = 2 + 15 = 17$$

$$H = 30 + 4 = 34$$

$$I = 30 + 10 = 40$$

$$J = 15 + 3 = 18$$

$$K = 34 + 12 = 46$$

$$L = 34 + 3 = 37$$

$$M = 40 + 5 = 45$$

$$N = 46 + 21 = 67$$

4.1.5 Latest Start Time: This is the latest time that an activity can be started on a project. If an activity is started beyond this time, it will affect the critical path. To calculate the latest start time, we have;

$$LST = LCT - D_{ij} \quad (5)$$

$$A = 20 - 1 = 19$$

$$B = 19 - 2 = 17$$

$$C = 30 - 30 = 0$$

$$D = 30 - 10 = 20$$

$$E = 43 - 14 = 29$$

$$F = 34 - 14 = 20$$

$$G = 34 - 15 = 19$$

$$H = 34 - 30 = 4$$

$$I = 62 - 10 = 52$$

$$J = 46 - 3 = 43$$

$$K = 46 - 12 = 34$$

$$L = 67 - 3 = 64$$

$$M = 67 - 5 = 62$$

$$N = 67 - 21 = 46$$

Table 2: Tabular Representation of above computations

S/N	Activity	Description	EST	LCT	ECT	LST	Dij	FF	TF
1	A	Site Clearance	0	20	1	19	1	0	19
2	B	Setting out	0	19	2	17	2	0	17
3	C	Foundation	0	30	30	0	30	0	0
4	D	Columns	2	30	12	20	10	17	18
5	E	Frame work	1	43	15	29	14	0	28
6	F	Brick masonry	1	34	15	20	14	19	19
7	G	Roof structure	2	34	17	19	15	22	17
8	H	Electrical & plumbing	30	34	34	30	4	0	0
9	I	Plastering	30	62	40	52	10	0	32

10	J	Door & window fixation	15	46	18	43	3	28	28
11	K	Floor	34	46	46	34	12	0	0
12	L	Painting	34	67	37	64	3	30	30
13	M	Electrical fittings	40	67	45	62	5	22	22
14	N	Landscaping	46	67	67	46	21	0	0

Table 3 shows activity, floats, and their respective status

Activity	Total Floats	Critical Path
A	19	No
B	17	No
C	0	Yes
D	18	No
E	28	No
F	19	No
G	17	No
H	0	Yes
I	32	No
J	28	No
K	0	Yes
L	30	No
M	22	No
N	0	Yes

The float is the length of time to which an activity can be delayed or extended without delaying the total project completion time. The total float of an activity is the amount of time by which the completion of an activity could be delayed beyond the earliest expected completion time of the project.

The result shows that all the critical activities have zero floats meaning; any delay in it can affect the completion time of the entire project. On the other hand, a delay in any of the non-critical activities can affect the duration of the project.

To calculate the floats for all the paths, we have,

CPD – PD

(6)

Where, CPD = Critical path duration and PD = Path Duration

CPD = 67

For the first path we have;

First Path: $(A \rightarrow E \rightarrow J \rightarrow N) = (1 + 14 + 3 + 21) = 39, \quad 67 - 39 = 28$

Hence the float of the first path is 28 days.

Using the same process, we can calculate the float for other paths as well.

Second Path: $(A \rightarrow F \rightarrow K \rightarrow N) = (1 + 14 + 12 + 21) = 48, \quad 67 - 48 = 19$

Hence the float of the second path is 19 days

Third Path: $(A \rightarrow F \rightarrow L) = (1 + 12 + 3) = 16, \quad 67 - 16 = 51$

Hence the float is 51 days

Fourth Path: $(B \rightarrow G \rightarrow L) = (2 + 15 + 3) = 20, \quad 67 - 20 = 47$

The float is 47 days

Fifth Path: $(B \rightarrow D \rightarrow H \rightarrow K \rightarrow N) = (2 + 10 + 4 + 12 + 21) = 49,$

$$67 - 49 = 18$$

Hence the float is 18 days

Sixth Path: $(B \rightarrow D \rightarrow H \rightarrow L) = (2 + 10 + 4 + 3) = 19, \quad 67 - 19 = 48$

Therefore, the float is 48 days

Seventh Path: $(C \rightarrow H \rightarrow K \rightarrow L) = (30 + 4 + 12 + 21) = 67, \quad 67 - 67 = 0$

As already stated that critical path float is constant, which is always equal to zero

Eighth Path: $(C \rightarrow H \rightarrow L) = (30 + 4 + 3) = 37, \quad 67 - 37 = 30$

For the eighth path, the float is 30 days

Ninth Path: $(C \rightarrow I \rightarrow M) = (30 + 10 + 5) = 45, \quad 67 - 45 = 22$

The float of the ninth path is 22 days

5. SUMMARY

This research explains the critical path method (CPM) and its applications in the field of Project Management, a construction project in particular, and a quick review of the general applications of the critical path method (CPM) in the real world.

A detailed literature review of the use of CPM in the construction industry. Numerous researchers and practitioners have studied CPM and reported both benefits and criticisms. A list of the most important critical views of CPM and the pitfalls inherent in commercial software is presented along with a description of the recent efforts of researchers to enhance CPM.

A detailed description and methodology of the research work. A critical path model that addressed the problem at hand is then presented. The critical path Method (CPM) representation of the project network and activity progress is described. The mathematical formulation of the CPM mechanism and comments about it. The CPM calculation process is described. The CPM approach for calculating accurate total float values in the case was introduced, and the detailed CPM formulation for progress analysis is then described.

The first three objectives of this study are to determine the critical path in project management networks, identify critical path fluctuations, and represent the various activity relationships more simply which was achieved and presented in figure 2.

The last objective is to estimate the earliest and latest time for each activity to be completed without delay and to predict the completion day for the building construction was also achieved.

5.1 Managerial Implications

The case study shows that the Critical Path Method (CPM) technique can be used effectively in the scheduling of projects, and building construction at Keffi New Market in this case, and the analysis was done with the use of MS Project Software (Excel 2016).

Budget allocations can be done effectively by mapping the critical paths, identifying the most important task activity that can be used to effectively allocate resources, and increasing or reducing resources based on the importance of the activity task. Hence this will reduce wastage on the allocation of resources on task activities that are not critical and appropriate for the critical activities.

The conclusion can be drawn as; the duration of the project was reduced by 23 days, saving 20.7% of the initial time plan, meaning, after rescheduling the normal project activity duration, the rescheduling duration is 67 from 90 days of normal time. This study suggests monitoring and evaluation is very necessary to maintain the project performance in accordance with the planning.

In addition, the critical path method (CPM) can be a reference for project leaders, the project that works on the critical path must be timely in order for the project to finish on time.

The Critical Path Method or the network model analysis by itself will not solve any problem, however, many times they can provide management with the information required to point out where the problem areas exist. Budget allocations can be done effectively by mapping the critical paths, identifying the most important task activity that can be used to effectively allocate resources, and increasing or reducing resources based on the importance of the activity task. Hence this will reduce wastage on the allocation of resources on task activities that are not critical and appropriate for the critical activities.

5.2 Recommendations for Future Research

Considering the widespread use of CPM, the finding of an increased fraction and length of project delay with the use of CPM scheduling is not unexpected by the authors. This research conjectures that one or more of the following are occurring:

1. Construction personnel are not using CPM scheduling properly.
2. The use of CPM provides an unwarranted belief that the project will be delivered on time until late in the project.
3. Having a CPM schedule does not automatically allow one to manage all the risks associated with construction projects and mitigate delays.
4. There was an unidentified selection bias of waving CPM schedules for projects with less risk of delay.

Additional research is needed to verify if one of the reasons contributed to the ineffectiveness of CPM scheduling. The survey of the state of contractors revealed some of the key issues regarding the use of CPM:

- i. **Selection Criteria:** The CPM schedules are selected based on the perceived complexity and risks, generally measured in terms of project size and duration. More sophisticated risk analysis should be incorporated into the selection criteria.
- ii. **Enforcing:** Specifications for schedule do not necessarily request cost/resource-loaded schedules. Hence, regular updates and reviews should be enforced.
- iii. **Scheduler:** CPM schedules require a skilled person to implement them correctly. Most contractors do not employ a dedicated scheduler in their workforce. As a result, the full potential of CPM schedules is not put into practice.

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