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Optimal Project Management Schedule for PhD Studies with Focus on Selected Northern Sector Universities in Ghana Using CPM and PERT

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Abstract Planning and scheduling techniques are very crucial in executing a successful project. Unfortunately, planning and scheduling can be very difficult, complicated and time consuming. The study aimed at establishing the critical activities involved in a PhD studies and developing an optimal project management schedule for PhD students in selected Northern Sector Universities in Ghana using CPM and PERT. Survey questionnaire was used to elicit responses from final year PhD students and PhD holders in the selected universities. The technique adopted was convenience sampling. The critical activities identified included, Literature Review, Proposal Writing, Proposal Defense, Results Generation, Results Presentation, Thesis Writing, Thesis Submission, Final Examination, Final Corrections, Final Submission and Graduation. We obtained an optimal time for a PhD program as 36.75 months and the probability of finishing the program within the obtained period of time to be 0.96. Implications of the findings were discussed. Based. It is recommended to all PhD students in the selected Northern Universities to use the determined optimal project management schedule as a guide. Also, every PhD student should take a cue from this study.

Keywords Project Management, Critical Path Method (CPM), Project Evaluation and Review Technique (PERT), Optimal Schedule, Critical Activities

1. Introduction

Project management refers to the practice that is essential for a group to accomplish set aspirations and meet the standards for success on its own time. Until recently, there was no universally accepted project management technique. The management relied on the experience level of the project manager and his personal judgment. Therefore, according to Hancher [1], every project manager had a diverse system, normally including the application of Gantt charts or bar charts. However, because projects are usually more difficult, it is necessary to advance complex tools that can cater for the complex needs of the project. Habibi et al [2] stated that Successful project management needs to ensure sufficient project schedule and cost plans.

The project management process includes initiation, planning, implementation, monitoring, and completion. According to Lau et al [3], efficient project management is essential for any organization. Also, Lusha [4] indicated that effective project management can utilize time and resources effectively. Smallwood [5] found that the number of proficient planners existing is far less than the number required. Complicating this skill shortage problem is that experienced project managers must plan most construction projects in a limited time as indicated by Kelsey and Lin [6]. Greenwood [7] stated that, in academia effective management of time and resources is very crucial in achieving higher certificates. Luidjei [8] also stated that effective project management is quite critical in every institution. Despite many researches carried out in the field of project management in recent years, an empirical work on project management for PhD studies was yet to be carried out. This study was therefore intended to fill that gap in literature.

The general objective of the study was to develop an optimal project management schedule for PhD studies in some selected Northern Sector Universities in Ghana using Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT). Specifically, the study sought to construct an optimal project management schedule for PhD studies in UDS, CKT-UTAS and SDD-UBIDS in Ghana using CPM. Also, it sought to determine the critical and non-critical activities involved in PhD studies in UDS, CKT-UTAS and SDD-UBIDS in Ghana using CPM. Finally, the study sought to determine the probability of completing a PhD program in UDS, CKT-UTAS and SDD-UBIDS in Ghana before the stipulated optimal time

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using PERT.

2. Literature Review

The concept of project management has received much attention. A number of papers in the theory and applications of project management have been reported in the literature. Johnson et al [9] developed a new method to determine activity productivity, activity interruptions and restrictions, and activity intervals in highway projects. In their research, they proposed a chart that considered the period on the x-axis and the position on the y-axis to denote the landscape of the activity in the direct project. Chrzanowski and Johnston [10] expressed tedious events as constant or changing slope lines on two axes over time. They stated that, "discrete activities can be displayed at the suitable time and place in the linear schedule itself, and then check the network schedule for more details". Larry and Richard [11] stated that, "critical chain project management improves project performance and explained that critical chain project management provides an important step for continuous improvement of project organization and project management". Ming Lu and Abourizk [12] introduced simplified CPM/PERT simulation technology on the basis of traditional CPM technology and simulation to provide alternative solutions for risk analysis and evaluation of other possible scenarios in project management. Francosis et al [13] briefly reviewed the values of critical chain programming in project management. They stated that if the project is arranged with CCPM, project performance can be improved. According to Singh et al [14], "simulation technology has been used to estimate the duration of road projects, but the use of network technology in this work may not be compatible with the linear relationship in road project activities". Lu and Lam [15] introduced a way to join the impact of multiple resource calendars on CPM scheduling, and suggested a different technique to assess accurately, the effect of an activity on prolonging the total duration of the project, and the results are generated. Correia and Antonio [16] determined that the Critical Chain (CC) method and Theory of Constraint (TOC) calculations are suitable for project management as essential factors that aid in promoting the development of the construction field. They discussed the CPM and PERT methods in detail, and added some discussions about the advantages and disadvantages of CC over traditional methods. Sarkar and Babu [17] proposed the use of the CCPM technique to the construction of private projects. The research and analysis were carried out using MS project software, and the conclusion reached was that CCPM provides a more effective method for project management. Dolabi et al [18] utilized CPM to obtain a consistent project plan and established that CPM can partly decrease the uncertainty of the project schedule, but any small changes in activities may lead to infeasibility of the planned time. Bhosale et al [19] pointed out that Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) are corporate instances of setup programming procedures designed to help project managers observe the movement of all phases of the task. Zareei [20] applied CPM to analyse the planning of biogas plant construction. According to the researcher, the project schedule must be properly managed to meet available deadlines and budgets.

From the reviewed literature and to the best of our knowledge, application of the concept of Project Management to PhD studies in the manner presented in this paper appears non-existent. The study was therefore intended to fill that knowledge or research gap.

3. Materials and Methods

The underpinning concept of the study was project management which refers the process of leading the work of a team to achieve a set goals and meet success criteria at a specified time under given constraints. Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) under project management were the methods employed for the study.

Project Evaluation and Review Technique (PERT) used in project management is a statistical tool designed to analyze and represent the tasks involved in completing a given project. Also, the time needed to finish each task and to find out the minimum time needed to complete the entire project.

The events or activities to be completed are usually represented with circles and arrows linked together, often known as Activity on Arrow (A on A) network. PERT uses three-time estimates namely optimistic, most likely and pessimistic, thus probabilistic. According to Arun [21], optimistic time (t_o) is the least possible amount of duration needed to accomplish a project, supposing everything goes better than projected; pessimistic time (t_p) is the maximum time needed to finish a job or project, supposing things go wrong and most likely time (t_m) is the most possible amount of time needed to accomplish the tasks, giving that all things go alright. It assumes a beta probability distribution for its estimates. The expected time for each activity can be approximated using the weighted average:

$$\text{Expected time} = [\text{optimistic} + 4(\text{most likely}) + \text{pessimistic}]/6 \quad (1)$$

With the variance of the critical activities, one can compute the probability of completing the project by a certain given date assuming a normal probability distribution for the critical path. The procedures for finding expected project completion time using PERT are as follows:

a. Construct the activity network using circles (nodes) and arrows
b. Calculate the expected durations and variances of each activity using equations 2 and 3:

$$t_e = \frac{t_o + 4t_m + t_p}{6} \quad (2)$$

$$v = \sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2 \quad (3)$$

where t_e is the expected time, t_o represents optimistic time, t_m is the most likely time, t_p represents pessimistic time, v denotes variance and σ is the standard deviation according to Kramer and Jenkin [22].

c. Compute the Earliest Start Time (EST) (by forward pass) and the Latest Completion Time (LCT) (by backward pass) using equations 4&5 and 6&7 respectively:

$$ES_{ij} = max(EF_i) \quad (4)$$

$$EF_{ij} = ES_{ij} + D_{ij} \quad (5)$$

$$LS_{ij} = LF_j - D_{ij} \quad (6)$$

$$LF_{ij} = \min(LS_{ij}) \quad (7)$$

where ES_{ij} denotes earliest start of the activity, EF_i represents earliest finish of the starting node, EF_{ij} is the earliest finish of the activity, D_{ij} represents the duration of the activity, LS_{ij} is the latest start of the activity, LF_j denotes latest finish of the ending node and LF_{ij} represents latest finish of the activity according to Kramer and Jenkin [22].

d. Find the critical path which is defined as the longest path in the network. According to Arun [21], for a critical path, the following conditions must all be satisfied:

(i) $EST_i = LCT_i$
(ii) $EST_j = LCT_j$
(iii) $EST_j - EST_i = LCT_j - LCT_i = D_{ij}$

e. Compute the float using equation 8:

$$Total\ Float\ (TF)_{ij} = LS_{ij} - ES_{ij} = LF_{ij} - ES_{ij} \quad (8)$$

f. Identify and mark the critical activities.

g. Calculate the project duration using equation 9 according to Cohen [23]:

$$\mathrm{D_p} = \sum_i^n D_{C_i} \quad (9)$$

where $\mathrm{D_p}$ and D_{C_i} represent project duration and duration of critical activities respectively.

h. Lastly, compute the probability of finishing the project at due date.

Critical Path Method (CPM) is a project modeling technique used by project managers to find important deadlines and deliver a project on time. CPM is similar to PERT in appearance but the circles or nodes usually represent the activities and thus referred to as Activity on Node (A on N) network. In CPM, only one-time estimate is useful for each activity and does not require any statistical computations and hence it is deterministic. The Procedures for finding project completion time using CPM are as follows:

(a) Construct the activity network using nodes and arrows.
(b) Calculate the Earliest Start Time (EST) (by forward pass) and the Latest Completion Time (LCT) (by backward pass) using equations 10 and 11 respectively:

$$EST_j = \max_i (EST_i + D_{ij}) \quad (10)$$

$$LCT_i = \min_j (LCT_j - D_{ij}) \quad (11)$$

where EST_j denotes "earliest start time" of the ending node, EST_i represents "earliest start time" of the starting node, D_{ij} represents the duration of the activity, LCT_i is the "latest completion time" of the starting node and LCT_j denotes "latest completion time" of the ending node according to Arun [21].

(c) Find the critical path in the same manner as presented in the case of PERT.
(d) Compute the float in the same manner as presented in the case of PERT.
(e) Identify and mark the critical activities.
(f) Lastly, compute the project duration (project completion time) using equation 9 presented above.

4. Results and Discussions

Results of activity times/durations using CPM

118 PhD holders and some final year PhD students comprising 41 from University for Development Studies in Tamale, 29 from C. K. Tedam University of Technology and Applied Sciences in Navrongo and 48 from Simon Diedong Dombo University of Business and Integrated Development Studies in WA were conveniently and purposively interviewed using a questionnaire about the duration of the various activities involved in a PhD program in those universities. Based on their responses, calculations were done to obtain the optimal project management schedule for PhD studies in those universities as presented in Table 1.

Table 1. Optimal project management schedule for PhD studies in the selected Northern Universities in Ghana

Activity	Durations (in months)
Literature Review (LR)	6
Problem Identification (PI)	0.75
Proposal Writing (PW)	3.5
Proposal Defense (PD)	0.5
Results Generation (RG)	9
Results Presentation (RP)	2
Thesis Writing (TW)	3.5
Thesis Submission (TS)	2
Final Examination (FE)	3
Final Defense (FD)	0.75
Final Corrections (FC)	1.5
Final Submission (FS)	1.25
Graduation(G)	3
Total	**36.75**

The CPM Activities Diagram

Figure 1 represents activities network diagram of the project using CPM.

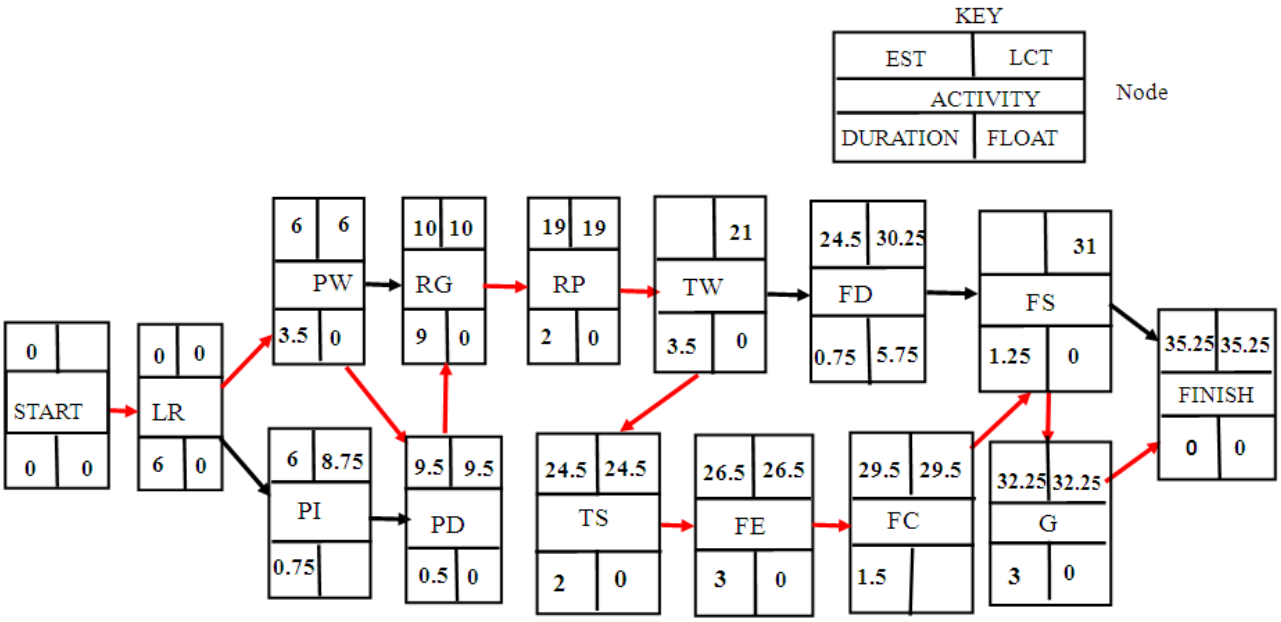

Figure 1. The activities network diagram

Calculation of Floats/Slacks from the CPM Diagram

A float is the difference between Latest Completion Time (LCT) and Earliest Start Time (EST). Table 2 provides details of the floats of the activities.

Table 2. Activities and their floats from the CPM diagram

Activity	Float/Slack
Literature Review (LR)	0
Problem Identification (PI)	2.75
Proposal Writing (PW)	0
Proposal Defense (PD)	0
Results Generation (RG)	0
Results Presentation (RP)	0
Thesis Writing (TW)	0
Thesis Submission (TS)	0
Final Examination (FE)	0
Final Defense (FD)	5.75
Final Corrections (FC)	0
Final Submission (FS)	0
Graduation(G)	0

In Table 2, an activity with a zero float value indicates that such activity is a critical one. Otherwise is a non-critical activity.

Critical Path and Critical Activities from the CPM diagram

A Critical activity is an activity that has a zero float/slack. The path through these activities is the longest path in the activity network which cannot be delayed. Any delay in such activities will lead to the delay of the entire program or project duration. The critical activities and their respective durations are summarized in Table 3.

Table 3. Critical activities with their durations from the CPM diagram

Activity	Duration (in months)
Literature Review (LR)	6
Proposal Writing (PW)	3.5
Proposal Defense (PD)	0.5
Results Generation (RG)	9
Results Presentation (RP)	2
Thesis Writing (TW)	3.5
Thesis Submission (TS)	2
Final Examination (FE)	3
Final Corrections (FC)	1.5
Final Submission (FS)	1.25
Graduation (G)	3
Total	**35.25**

From Table 3, the critical activities identified are Literature Review (LR), Proposal Writing (PW), Proposal Defense (PD), Results Generation (RG), Results Presentation (RP), Thesis Writing (TW), Thesis Submission (TS), Final Examination (FE), Final Corrections (FC), Final Submission (FS) and Graduation (G). The sum of the durations of these activities is 35.25 months.

Determining the probability of finishing the program within the stipulated time using PERT

Results from the administered questionnaire revealed various durations of the three- time estimates namely optimistic, most likely and pessimistic times. Table 4 gives detailed results of averages of the three-time estimates (optimistic, most likely and pessimistic) from the data collected.

Table 4. Durations of activities involved in a PhD program in the selected Northern Universities in Ghana

Activity	Durations (in months)		
	Optimistic (o)	Most likely (m)	Pessimistic (p)
Literature Review (LR)	5	6	7
Problem Identification (PI)	2	0.75	5
Proposal Writing (PW)	2.5	3.5	4
Proposal Defense (PD)	0.25	0.5	1.25
Results Generation (RG)	8	9	10
Results Presentation (RP)	1.5	2	3
Thesis Writing (TW)	3	3.5	4.5
Thesis Submission (TS)	1.5	2	2.75
Final Examination (FE)	2.75	3	4
Final Defense (FD)	1	0.75	7
Final Correction (FC)	0.75	1.5	2.25
Final Submission (FS)	0.75	1.25	2.25
Graduation (G)	2	3	4

Source: Survey Data, 2021

Calculation of variances of the critical activities

The variances of the various critical activities were computed and the results are presented in Table 5.

Table 5. Critical Activities with their corresponding expected durations and variances

Critical Activity	Mean Duration (in months)	Variance
LR	6	0.11
PW	3.5	0.06
PD	0.5	0.03
RG	9	0.11
RP	2	0.06
TW	3.5	0.06
TS	2	0.04
FE	3	0.04
FC	1.5	0.06
FS	1.25	0.06
G	3	0.11
TOTAL	**35.25**	**0.74**
$\boldsymbol{\sigma}$	$= \sqrt{\mathbf{0.74}}$	**= 0.86**

From Table 5, the probability of completing the project on or before 36.75 months using the Standard Normal Distribution (STD) table is given as:

$$P(X \leq 36.75) = P(\frac{X-\mu}{\sigma} \leq \frac{36.75-35.25}{0.86})$$

$$P(Z \leq 1.74) = 0.96$$

Therefore, the probability of completing the program on or before 36.75 months is 0.96.

Discussions

Literature Review, Proposal Writing, Proposal Defense, Results Generation, Results Presentation, Thesis Writing, Thesis Submission, Final Examination, Final Correction Final Submission and Graduation were the critical activities based on the results from the CPM activity diagram. The path through these activities is known as the critical path and the sum of their respective durations shown in Table 3 is 35.25 months. The zero-slack value of each of these activities shown in Table 2 indicates that, they cannot be delayed without affecting the project duration.

On the other hand, Problem Identification and Final Defense were the only non-critical activities per the results from the CPM activity diagram. Their slack values of 2.75 and 5.75 respectively show that these activities can be delayed up to 2.75 months and 5.75 months respectively without affecting the project duration.

Calculations using PERT indicated that, the sum of variances of the critical activities is 0.74 and the standard deviation is 0.86. The probability of completing the project/program on or before 36.75 months was then calculated to be 0.96 using the standard normal distribution table. It can therefore be concluded that the probability of finishing the program/project within 36 months is 0.96. Hence, there is higher possibility of completing the project within the stipulated period.

5. Conclusions

Critical Path Method (CPM) and Project Review and Evaluation Technique (PERT) under Project Management have successfully been applied to a PhD program in three selected northern sector universities in Ghana. Specifically, an optimal project management schedule for PhD studies in those universities has been constructed using CPM. Also, the critical and non-critical activities involved in a PhD program in those universities have been determined using CPM. Moreover, the probability of completing a PhD program in the selected universities before the stipulated optimal time has been determined using PERT.

The study recommends that all PhD students in the selected universities and Ghana should use the determined optimal project management schedule as a guide. Also, the students should not lose sight of the critical and non-critical activities involved in a PhD program. Finally, every PhD student should take a cue from this study.

The study has contributed significantly to knowledge by proposing an optimal schedule for PhD studies. It has also successfully applied the concept of Project Management to PhD studies in the manner presented in this paper which appeared non-existent.

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