A Study on PERT and Theory of Constraints in the AHA.002 Project

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***Abstract*—Effective management and timely activity scheduling are essential for completing all project-related activities and events. Controlling the time taken for each activity plays a vital role in the smooth running of a company. This includes from the outset of design approval, procurement of raw materials, production, supply, etc. Numerous technologies are available for project management, including the work breakdown structure (WBS), Critical Path Method (CPM), Programme Evaluation and Review technique (PERT), Gantt, Kanban, Monte Carlo, Theory of Constraints, and so forth. In this paper, we compared the two project management techniques, PERT and Theory of Constraints, by calculating the project duration of the AHA.002 project (Multi Nut Runner Fly wheel MC for AE 1 Machine).**

Keywords—Time management, Program Evaluation and Review Technique (PERT), Theory of Constraints, Critical Chain.

I. INTRODUCTION

The primary issue for any business is finishing projects within the allotted time frame or sooner. By shortening the time needed for projects, this will enable them to enhance their profits. PERT and Theory of Constraints are two different techniques which will help the companies in achieving this optimum project duration to boost their profits. Program Evaluation and Review Technique [PERT] is used to calculate the minimum time taken by a project to complete. It is used to timeline the tasks and coordinate them in the project. It is mainly used when the time taken by activities to be completed in a project is uncertain. The theory of constraints seeks to maximise a process' efficiency only at its most crucial points, with the intention of maximising other corporate goals such as profitability and quality.

P.T. Matahari Megah is an engineering company where the customers provide orders of new customized machines. The company then conducts an analysis of the demand for these newly customized machines by holding meetings with the clients to discuss the product's design, functioning, and so forth. [1]

The company will then design the machine as per the requirements and discussion with the customers. The final design will be sent and accordingly, the raw materials and components will be purchased, and machinery will be assembled. [1]

In doing all this work in an organized way, time management plays an important role. The company analyses the time taken for the meeting, the purchase of raw materials, and the assembly of the machinery. In this research, we have considered the time taken for the completion of the AHA.002 project (Multi Nut Runner Fly wheel MC for AE 1 Machine) using the PERT technique and compared it with the project duration obtained using the theory of constraints. [1]

By shortening the time needed for specific tasks and computing the critical chain, we can determine which technique is less time-consuming and how quickly the project can be completed. In PERT, the three-time estimates can be used to determine the ideal project duration, and in the Theory of Constraints, the ideal project duration is determined by elevating the identified constraints.

II. METHODS

A. PERT

A Project Evaluation Review Technique [PERT] is a project management tool that helps in analysing a project's timeline, which shows all the individual tasks that are necessary to complete a specific project. It is a graphical representation that uses circles or rectangles known as nodes to represent project events. This technique helps organizations to evaluate the time taken for each task and the resources required to manage a project. Further, PERT also helps in analysing the budget required for the project.

PERT uses three time estimates namely optimistic, most likely and pessimistic time.

- Optimistic time is the minimum time in which the activity can be completed.
- Most likely time is the normal time taken by the activity
- Pessimistic time is the maximum time taken by the activity.

Using these three time estimates we'll get an expected time of each activity. After calculating the critical path of the activities, we need to calculate the standard activity variances for calculation of uncertainty of a project completion.

$$\sigma^2 = \frac{(a-b)^2}{6}$$

Where a represents the optimistic time and b represents the pessimistic time of the activities

The project variance is determined as the sum of the variances of critical path activities:

$$\sigma_p^2 = \Sigma(variances\ of\ activities\ on\ critical\ path)$$

Standard deviation of project duration is $\sigma_p = \sqrt{\sigma_p^2}$

The following assumptions are made in PERT in order to determine the probability of completion of project in the given time:

1. Project duration is normally distributed
2. Activity times are statistically independent

   With these assumptions, we can determine whether the project can be completed before the expected time or later the expected time using a standard normal equation

$$Z = \frac{X-\mu}{\sigma_P}$$

Here X is the given time, μ is the estimated project duration time and σ_p is the project standard deviation [2]

B. Theory of Constraints

Every company's primary goal is to boost profits. This holds that anything that stands in the way of achieving greater profit is a constraint. In order to increase revenues and do tasks faster, businesses focus on regulating these constraints by exploiting and elevating them.

In 1988, Eliyahu M. Goldratt developed the theory of constraints, which was derived from Optimized Production Timetables (OPT). The current TOC exemplar is the thinking process. The TOC Thinking Processes are comprehensive problem-solving techniques built on strict causation reasoning. They are also referred to as TP Tools. Through the recognition, testing, and correction of untested assumptions, experts help us develop ground-breaking solutions. The TP of TOC is thought to have the greatest long-term impact on business, according to experts. A simplified "3-Cloud Method," created by Dr. Goldratt, allows for quicker diagnosis and application. This approach, along with well-known TOC software and thorough implementation templates called "Strategy and Tactic Trees," is quite useful for resolving a variety of business issues. [3]

1) Drum-Buffer-Rope Theory: One example of how the theory of constraints is applied in production planning is the drum-buffer-rope method. It enhances the efficiency of processes that are impacted by internal constraints or resources with limited capacity. Drum-Buffer-Rope outlines a work schedule for the constraint (Drum), buffers the constraint so it never goes without work (Buffer), and establishes a release mechanism (Rope) to make sure work is delivered into the system at the appropriate moment.

2) *Critical Chain Method*: When adopting the critical chain method, projects will:

1. List the tasks' dependencies and resource limitations at the project's design stage.

2. Create a perfect project workflow

3.If necessary, provide more resources to the project.

Project managers then monitor development based on how well the available resources have been used.

III. Steps for the Basic Theory of Constraints:

Step 1: Identify the constraint.

The most significant and critical step in the procedure is recognizing the constraint. A constraint is a factor that inhibits a network efficiency.

Step 2: Exploit the constraint.

The formulation of a plan of action for the system constraint is called exploitation. The exploitation of constraints can be carried out in accordance with the system's objective.

Step 3: Subordinate everything else to the plan

The non-constraints are the emphasis of this step, which focuses on developing a plan of action for it in such a way it is in coordination with the predefined constraint plan.

Step 4: Elevate the constraint.

It is a technique for altering the value of constraints after strategically placing them while preserving statistical control over the network. There are various methods available to elevate the constraint.

Step 5: Go back to step one.

There is a probability in observing a shift of constraints in a system and it is vital to repeat the whole process till we attain an optimal value. [4] [5]

IV. Project and data Taken

The goal of this study is to determine the optimal amount of time needed to accomplish the project by applying the Theory of Constraints. The data gathered in this study is secondary data from an earlier investigation into the AHA.002 Project by Aurellia Kharisty Tjusila and Lina Gozali. Manufacturing of the Multi Nut Runner Flywheel MC for the AE1 Machine is the focus of the AHA.002 project. It involves activities like receiving customer machine specifications, acquiring design approval from the engineering team, designing the mechanical, electrical, and program layout, manufacturing, post-processing, assembling the machine's parts, delivering the machine, and installing it. [1]

The expected time is calculated and shown in the Table 1, along with time estimates for each activity. According to the research study by Aurellia Kharisty Tjusila and Lina Gozali, it takes 49.5 weeks to finish the entire project by employing PERT techniques. [1]

Table 1. Project Activities [1]

Activities	Activities that preceded	The most optimistic time (a) (weeks)	The Most likely time (m) (weeks)	The most pessimistic time (b) (weeks)	The expected time μ (weeks)
A (PO received)	-	1	1	1	1
B (Approve Design)	A	24	25	25	24.83
C (Mechanical Design)	B	5	6	6	5.83
D (Electrical and Program Design)	B	7	7	10	7.5
E (Layout Design)	C, D	3	5	5	4.67
F (Raw Material, Mechanical Structured and fabrication)	B	11	11	12	11.17
G (Standard part)	B	12	12	14	12.3
H (Pneumatic and Festo Component)	B	11	15	15	14.35
I (Control Component)	B	11	11	15	11.67
J (Estic system/NMS supply)	B	10	11	11	10.83
K (Electric and wiring component)	B	10	14	14	13.33
L (Mechanical Part)	B	12	12	12	12
M (Electro Plating)	B	6	6	10	6.67
N (Wet painting)	B	7	7	10	7.5
O (Assembly Mechanical)	M, N	6	6	7	6.17
P (Assembly electrical, control, pneumatic, standard)	M, N	4	4	5	4.17
Q (Programming and wiring diagram)	M, N	4	9	9	8.17
R (Trial all System and function)	E, F, G, H, I, J, K, L, O, P, Q	1	1	1	1
S (Review progress pre delivery inspection and trial)	E, F, G, H, I, J, K, L, O, P, Q	2	2	2	2
T (Improvement Request)	E, F, G, H, I, J, K, L, O, P, Q	4	4	4	4
U (Delivery)	R, S, T	1	1	1	1
V (Layout and Positioning)	U	2	2	2	2
W (Trial and improvement)	U	1	1	1	1
X (Adjustment)	V, W	1	1	1	

V. RESULTS

The theory of constraints is a technique for locating and exploiting of the constraining element in project scheduling. In this study, the AHA.002 project uses the five basic steps of the Theory of Constraints, and the outcomes are as follows.

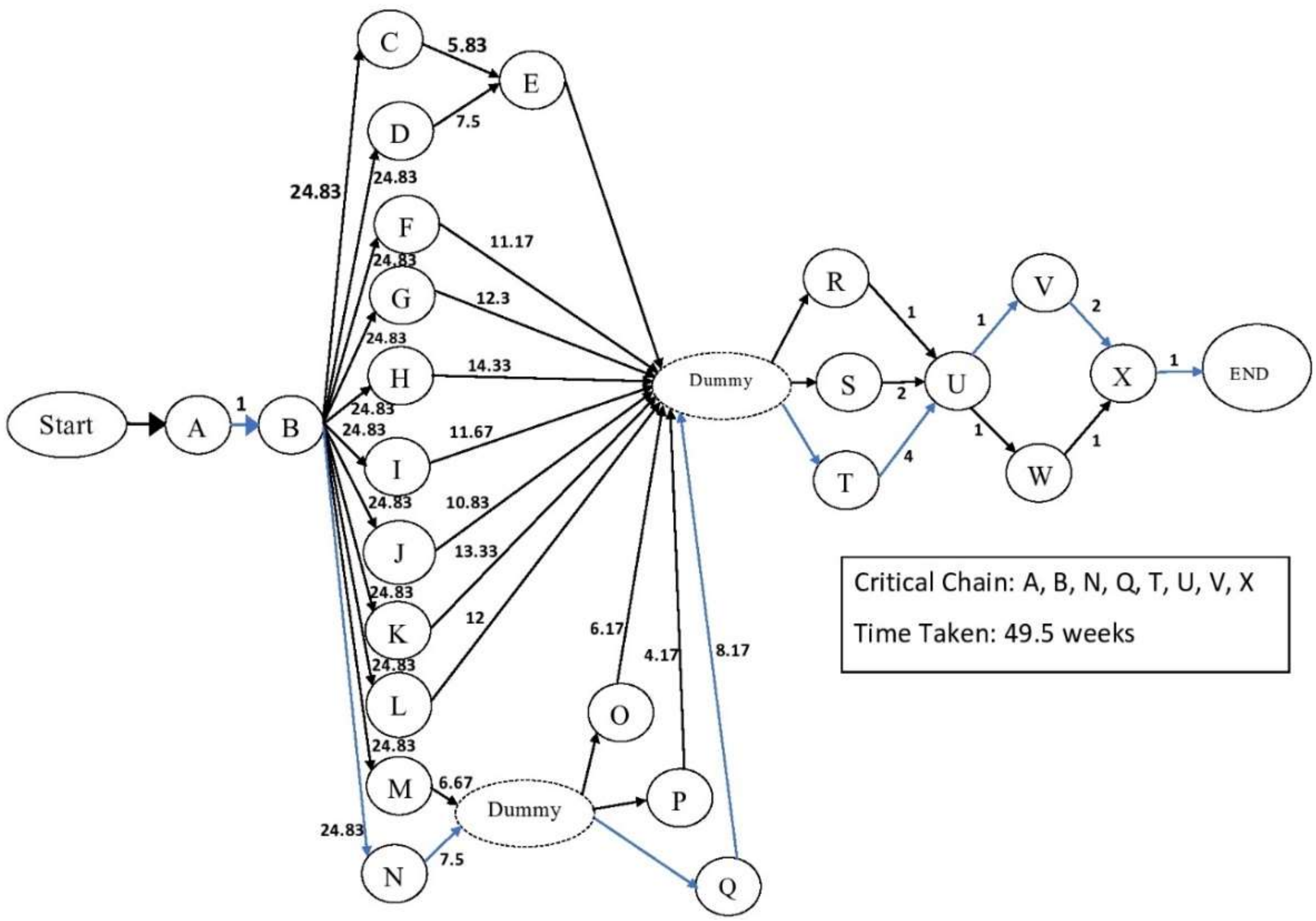

Figure 1. Network Diagram based on Expected time

By using the critical chain in figure 1, the time required is discovered to be 49.5 weeks. The constraints are N, Q, T, U, V, and X are identified from the Figure 1. By taking their optimistic time with submitting to all the other non-restrictions, these constraints are exploited. These steps are iterated till it attains an optimal time.

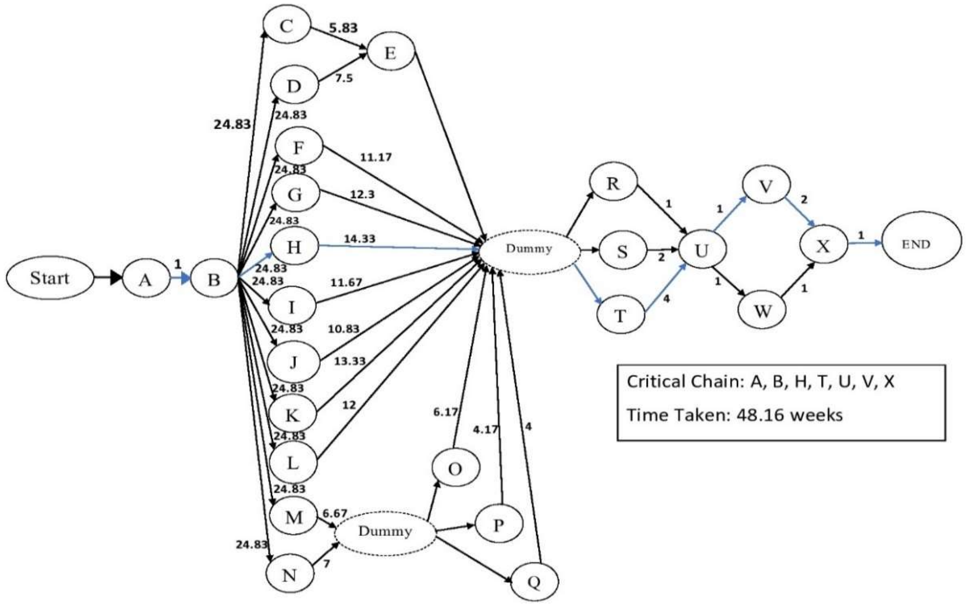

Figure 2 Iteration 1.

Figure 2. is the Iteration 1 (Repetition of the process) obtained from Figure 1. on the implementation of Theory of Constraints. A shift in the critical chain can be witnessed. According to the Theory of Constraints the emphasis switches to the following constraint when the previous constraint no longer limits throughput. Hence for Iteration 1, the constraint is the activity 'H' and the time taken to complete the project is 48.16 weeks.

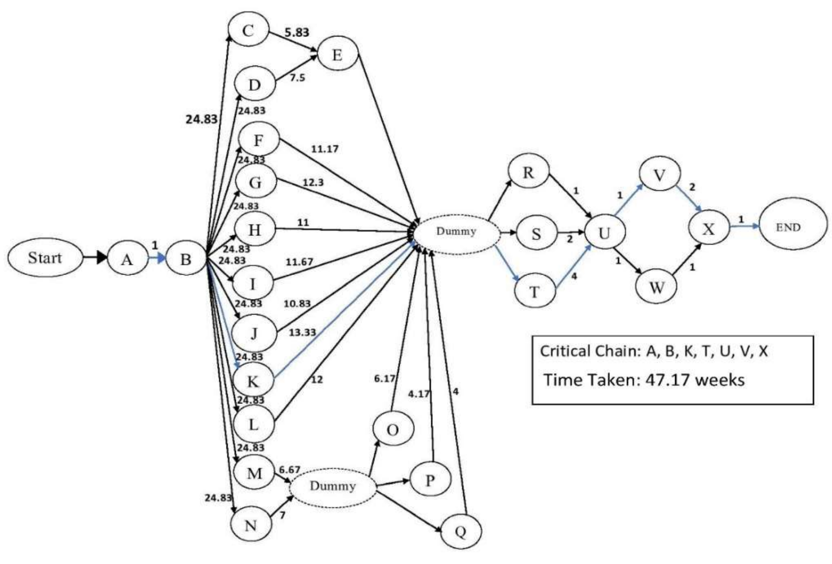

Figure 3 Iteration 2.

For Iteration 2, the constraint is changed to activity 'K' and hence the focus shifts to in improving the present constraint. The time taken to complete the project is 47.17 weeks.

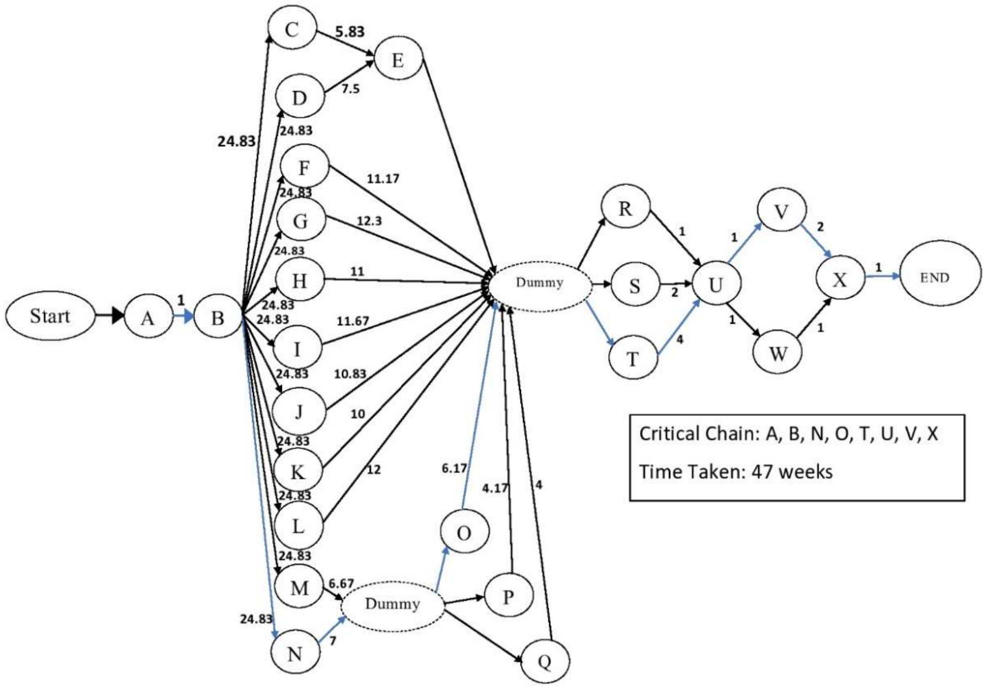

Figure 4 Iteration 3.

For Iteration 3, the constraint are the activities 'B' and 'O' .On taking their optimistic times, the time taken to complete the project is shifted to 47 weeks.

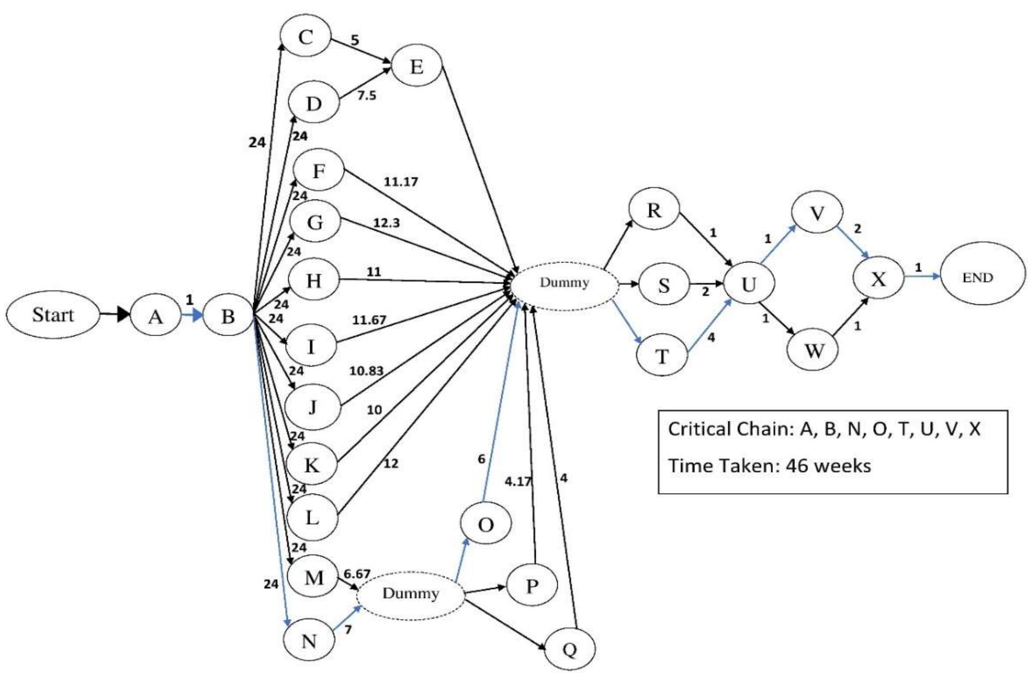

Figure 5 Iteration 4

The iteration ends after all constraints have been exploited and hence the final time taken for the project completion is observed to be 46 weeks.

VI. COMPARISON AND CONCLUSION

According to the findings, shortening the completion time can be achieved by identifying bottlenecks in the project network and elevating or demoting them. The manufacturer can use any iteration to accomplish the project in the specified amount of time by applying the principle of constraints. The Table below shows the comparisons between different methods and iterations.

Methods	PERT	Theory of Constraints			
		Iteration 1	Iteration 2	Iteration 3	Iteration 4
Completion Time (Weeks)	49.5	48.16	47.17	47	46

Table 2

We can see that we can achieve a shorter time period through the theory of constraints than Program Evaluation and Review Technique as it takes 49.5 weeks for Project completion through PERT whereas the maximum time taken for project completion is 48.16 weeks through theory of constraints.

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