

# Precedence Network Analysis for Project Time Estimation

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## Abstract

*A project is a temporary endeavor undertaken to create a unique product, or result as the tasks within a project have links between them, all tasks cannot all happen at the same time. A technique entitled Critical Path Analysis (CPA) can be used to determine what can happen when. It calculates how quickly and how slowly the tasks can be performed, taking into account the sequence of tasks and the interrelationships between them. Project reports such as Gantt charts are created as a result of critical path analysis. This paper identifies project duration and critical activities by using critical path method. Time schedule is important for all engineers in every field whom are in charge of any project. The intended system can serve as a tool for engineers to estimate time schedule. The precedence network analysis can be used for estimating the project time and produce time estimation by four days such as Early Start(ES), Early Finish(EF), Late Start(LS), Late Finish(LF) and float. It also highlights the critical activity.*

## 1. Introduction

The precedence diagramming method refers to a specific project management technique in which the project management team and or the project management team leader employs a schedule network diagramming technique in order to graphically represent any known and preexisting schedule activities via the use of boxes. Tasks in a precedence analysis are often identified with a range of potential start and finish times, as opposed to just one [6].

The Critical Path Method (or CPM) is the method by which the critical path through a project schedule is calculated. It helps to know the duration of project going to take. The critical path is the sequence of tasks which have zero float. Each task is assigned a start date, duration, and end date. The common way to perform this task is to draw the tasks as horizontal boxes against a vertical time scale. The resulting chart is called a Gantt chart.

The first known Gantt Chart was developed in 1896 by Karol Adamiecki, who called it a harmonogram. The chart is commonly known after

Henry Gantt, who designed his chart around the years 1910–1915 [4].

The remainder of the paper is structured as follows. Section 2 include motivation of the system, Section 3 explains precedence network analysis. The explanation of critical path method is also described in Section 4 and Section 5 describes the CPM algorithm and section 6 include the example calculation of critical path duration and implementation and conclusion are expressed in section 7 and 8 respectively.

## 2. Motivation

Critical Path Method (CPM) as a management methodology has been used from the mid 50s. The main objective of the CPM implementation was to determine how best to reduce the time required to perform routine and repetitive tasks that are needed to support an organization.

Estimating the duration of future projects is one of the most important areas of software engineering. Estimates are crucial to go/no-go decisions on every project. Questions about the ability of SE to provide meaningful estimates call into question all plans for future projects and all current projects. Software engineering researchers are really looking for an estimating method that is somewhat accurate, most of the time.

## 3. Precedence Network Analysis

Precedence Network is a diagram which shows the tasks and their scheduling dependencies. The Critical Path Method (CPM) identifies the tasks on the critical path within the network of tasks [3]. Tasks in a precedence analysis are often identified with a range of potential start and finish times, as opposed to just one, to indicate best- and worst-case scenarios. It also opens the door to more nuanced analyses, such as finding the maximum allowable time for a problematic task if all other tasks are performed at optimal times.

In real life, one project's schedule often impacts other schedules, and thus CPM software and analysis is also applied to a multiple-project environment.

### 3.1 Steps in Precedence Network Analysis

Steps in Precedence network are

- **List the activities:** Analysis starts when have a table showing each activity for project. For each activity, need to know which other activities must be done before it starts, and how long the activity takes.
- **Draw the diagram:** Draw by hand a network diagram of the project that shows which activities follow which other ones. This can be tricky. The analysis method being used requires an "activity-on-arc" (AOA) diagram. An AOA diagram has numbered "nodes" that represent stages of project completion. Make up the nodes' numbers as constructed the diagram. Connect the nodes with arrows or "arcs" that represent the activities that are listed in the above table. Some conventions about how to draw these diagrams:
  1. All activities with no predecessor come off of node 1.
  2. All activities with no successor point to the last node, which has to have highest node number.
- **Set up the CPM spreadsheet:** There are specialized commercial programs for doing CPM analysis.
- **Use Pathfind to get the paths:** or made by hand.
- **Paste the path information into spreadsheet,**
- **Calculate the paths' times and**
- **Identify the critical path:** The critical path is the path that takes the longest.

### 4. The Critical Path Method (CPM)

Basic steps in critical path methods are

1. Decompose project into Individual Jobs or Activities.
2. Determine Precedence Relationships among jobs. They come from technological constraints.
3. Draw the Arrow Diagram, or AOA Diagram, or Project Network representing precedence relationships.
4. Estimate job durations.
5. Use CPM to schedule activities over time to minimize project duration
6. In operation, if any job delayed, use CPM to revise schedule for remaining jobs [3].

#### 4.1 Forward Pass Algorithm

The steps of this pass are:

1. Set the initial task's  $ES = 0$ .
2. Calculate the task's  $EF = ES + \text{duration} - 1$ .

3. Calculate an ES for the task's successors;  $ES_{\text{successor}} = EF_{\text{task}} + 1$ .
4. Visit all of the task's successors.
5. If the successor's current ES is less than the ES from step 3:
  - a. Replace the current ES with the step 3 value.
  - b. Repeat steps 2–5 for the current task's successors, unless there are no more because the last task has been reached.
6. Go back up the path just completed to a task with unvisited successors.  
Repeat steps 4–6 until all successors have been visited, which will cover all paths from those successors to the final task.

#### 4.2 Backward Pass Algorithm

The steps of this pass are:

1. Set the final task's  $LF = \text{the task's } EF$ . (The final task is always on the critical path and has no float. This means that its  $EF$  and  $LF$  are equal.)
2. Calculate the task's  $LS = LF - \text{duration} + 1$
3. Calculate an  $LF$  for the task's predecessors;  $LF_{\text{predecessor}} = L_{\text{task}} - 1$
4. Visit all of the task's predecessors
5. If the predecessor's current  $LF$  is greater than the  $LF$  from step 3:
  - a. Replace the current  $LF$  with the step 3 value.
  - b. Repeat steps 2–5 for the current task's predecessors, unless there are no more because the first task has been reached.
6. Go back down the path just completed to a task with unvisited predecessors.  
Repeat steps 4–6 until all predecessors have been visited, which will cover all paths from those predecessors to the initial task.

### 5. Critical Path Algorithm

Critical Path Algorithm involves four parameters:

- **ES** - earliest start time: the earliest time at which the activity can start given that its precedent activities must be completed first.
- **EF** - earliest finish time, equal to the earliest start time for the activity plus the time required completing the activity.
- **LF** - latest finish time: the latest time at which the activity can be completed without delaying the project.
- **LS** - Latest start time, equal to the latest finish time minus the time required to complete the activity.

The algorithm proceeds as follows:

1. Mark the value of **S** to left and right of Start

2. Consider any new unmarked job, all of whose predecessors have been marked. Mark to the left of the new job the largest number to the right of its immediate predecessors: (**ES**)

3. Add to **ES** the job time **t** and mark result to the right (**EF**)

4. Stop when **Finish** has been reached

## 6. Experimental Result

Table1.Example data for Time Estimation

NO.	Activity	Precedence	Duration(days)
1	1	-	120
2	2	1	190
3	3	1	45
4	4	1	300
5	5	1	165
6	6	2	84
7	7	3	77
8	8	4	20
9	9	5,8	40
10	10	9	80
11	11	6,7	20
12	12	2,11	80
13	13	2,3	72
14	14	12	200
15	15	13	190
16	16	13	80
17	17	14,15,16	150
18	18	17	100
19	19	10,18	25
20	20	19	800

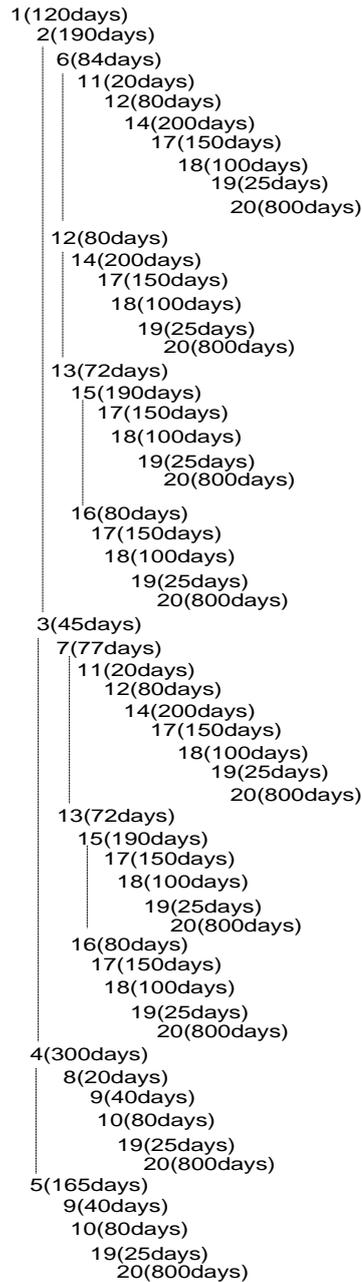


Figure 1.Activity Tree Diagram

Task	Precedence	Duration	ES	EF	LS	LF	Float	CPW
1	-	120	0	120	0	120	0	Yes
2	1	190	120	310	120	310	0	Yes
3	1	45	120	165	120	165	0	Yes
4	1	300	120	420	120	420	0	Yes
5	1	165	120	285	120	285	0	Yes
6	2	84	310	394	310	394	0	Yes
7	3	77	165	242	165	242	0	Yes
8	4	20	420	440	420	440	0	Yes
9	5,8	40	440	480	440	480	0	Yes
10	9	80	480	560	480	560	0	Yes
11	6,7	20	242	262	242	262	0	Yes
12	2,11	80	440	520	440	520	0	Yes
13	2,3	72	120	192	120	192	0	Yes
14	12	200	440	640	440	640	0	Yes
15	13	190	192	382	192	382	0	Yes
16	13	80	192	272	192	272	0	Yes
17	14,15,16	150	640	790	640	790	0	Yes
18	17	100	790	890	790	890	0	Yes
19	10,18	25	560	585	560	585	0	Yes
20	19	800	585	1385	585	1385	0	Yes

Figure1.Resulting ES, EF, LS, LF, Float and Critical

The user input data is used to find the Early Start, Early Finish by forward algorithm and calculate Late Start and Late Finish by backward algorithm, the results are shown in figure 1. The critical path of example is 1-2-6-11-12-14-17-18-19-20 and duration is 1769 days.

### 7. Implementation of the System

This system was implemented with the aim of estimating project time by critical path analysis. Firstly user must input the project data such as project name, activity name, duration and preceding activity. Secondly, estimation start by calculating forward pass it produces ES and EF. After forward pass, LS and LF are produced by calculating backward pass. And then, the system calculates the float to define critical activity. The resultant ES, EF, LS, LF, Float and Critical or not are shown by table. The critical pass duration is shown by message box and on the right top of the result form. It also gives the results by Gantt chart for (ES, EF) and (LS, LF) separately. In Gantt chart, activities are on the Y-axis and duration (day) is on the X-axis. User can view old estimated project and can update the project.

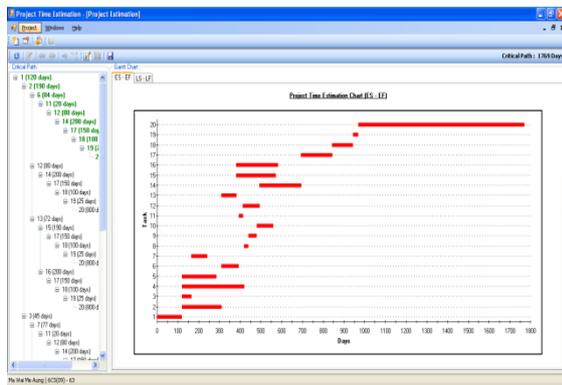


Figure3. Gantt chart Result For ES, EF

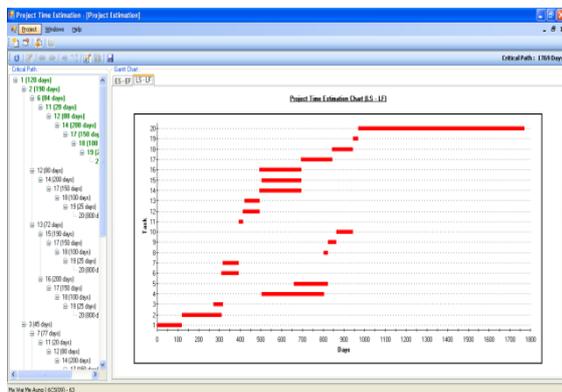


Figure4. Gantt chart Result for LS, LF

### 8. Conclusion, Limitation and Further Extension

CPM uses a safety net to manage the uncertainty that arise in the process of completing the project. It has offered project managers with effective ways to estimate the time needs to completion for the project.

The system can give critical path by table and tree structure and give Gantt chart. Sometimes projects use different calendars for the scheduling and planning and this can cause more complications. This system can find critical path duration and schedule by Gantt chart for the same calendar format.

As project manager, this system was support as a computerized tool to estimate the project time scheduling effectively within short period. This CPM method performs estimation only known the activity duration and preceding activity, it not requires knowing the information about other resources such as men power, budget and so on.

As a further extended work, this system can add the calculation of critical path duration and Gantt chart for different calendar format. And as other extended work this system can use other scheduling method such as PERT method if estimation project has adequate knowledge about other resources.

### 10. References

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