# Application of Critical Path Method for Project Scheduling – A Case Study

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## *Abstract*

*Conventional techniques like Critical Path Method (CPM), are being constantly refined to cope up with the changing trends in Project Scheduling. Distributed resource constrained multi-project scheduling problem has been taken up recently. It primarily focusses on handling resource conflicts. A method has been developed to distinguish between resource dependent and logic dependent activities. The following case study concentrates on the time constraint and involves implementation of CPM in the optimization of the manufacturing procedure of an All-Terrain Vehicle (ATV). The analysis is based on the data collected from the club of College of Engineering, Pune, that manufactures ATVs and the aim of the study is to minimize the total project duration using CPM, considering the limited time and resources available at hand.*

**Keywords**: CPM, All-Terrain Vehicle, Project Scheduling, Activities, ATVs, Optimization, Time constraint.

**Introduction**

Planning and scheduling in today's time has become a very essential tool for Project management which is done through several highly effective methods. One such method being the CRITICAL PATH METHOD (CPM). Project Management has three main objectives, namely

1. Reduction of the duration of the project
2. Lowering of the cost associated with the project
3. Scaling down the resources required for the project.

The aim of this case study is to attain the three objectives mentioned above using MS Project Software.

The critical path method (CPM) is a step-by-step project management technique for process planning that defines critical and non-critical tasks with the goal of preventing time-frame problems and process bottlenecks. CPM is ideally suited to projects consisting of numerous activities that interact in a complex manner.

CPM was developed in the 1950s by DuPont, and was first used in missile-defence construction projects. Since that time, CPM has been adapted to other fields including hardware and software product research and development. Various computer programs are available to help project managers use CPM.

In applying CPM, there are several steps that can be summarized as follows:

- Define the required tasks and put them down in an ordered (sequenced) list.
- Create a flowchart or other diagram showing each task in relation to the others.
- Identify the critical and non-critical relationships (paths) among tasks.
- Determine the expected completion or execution time for each task.
- Locate or devise alternatives (backups) for the most critical paths.

Microsoft Project is designed to assist a project manager in developing a plan, assigning resources to tasks, tracking progress, managing the budget, and analysing workloads.

Project creates budgets based on assignment work and resource rates. As resources are assigned to tasks and assignment work estimated, the program calculates the cost, equal to the work times the rate, which rolls up to the task level and then to any summary tasks and finally to the project level. Resource definitions (people, equipment and materials) can be shared between projects using a shared resource pool. Each resource can have its own calendar, which defines what days and shifts a resource is available. Resource rates are used to calculate resource assignment costs which are rolled up and summarized at the resource level. Each resource can be assigned to multiple tasks in multiple plans and each task can be assigned multiple resources, and the application schedules task work based on the resource availability as defined in the resource calendars.

**Literature Review**

In the recent past many authors, have successfully used CPM to calculate the time, resources and cost required for various projects and events. Wallace Agyei, 2015 in his case study applied CPM for investigating time-cost trade-offs by crashing the activities using linear programming and concluded with a shorter duration and an acceptable cost for the building construction project at Angel Estates and Construction Ltd [1]. Adel Issa Elsosan 2014 in his case study Optimized the time and cost using Critical Path Method on Parlur fly over Surakarta. He successfully reduced duration of the project by 10 days with acceptable cost [4]. M.S. Rautela 2015 in her paper concluded that CPM can be used by every department as a tool for meeting the commitment of the delivery to other related departments and thereby reducing the problem of internal delays which in turn causes the delay in delivery of the final product of the company, in her case the company being a Shoe Production plant [9]. Mohammad Saiedur Rahaman 2016 in his paper introduced a new contour based path planning system called CAPRA [8] which not only found the shortest path i.e. reduce the time for travel but gave other paths taking into consideration the various kinds of people travelling. Earl B. Anderson in his paper describes the critical path method, explains the mathematical concepts behind it, and--using the Fire Economics System (FEES) [2] project as an example--illustrates how a computerized CPM approach can be applied to a resource management or other research project. Nafkha, R., Wiliński, A. (2016) paper [6] discusses about the optimal project duration is designated after solving human resource deficiencies or conflicts occurring in the generated schedule. Okmen, Ö (2013) presents a procedure for critical path method-based (CPM) scheduling in linear construction projects that have repeating activities [7]. The procedure concurrently provides the utilisation of resources without interruption and preservation of network relationships between successive units. With this procedure it is possible to represent activities by variable production rates through consecutive units and assign any kind of relationship type with lag time. Biswanath Chakraborty, Santanu Das (2015) proposes a new metaheuristic model [3] which is based on the integration of Group Technology (GT), CPM and Line of Balance (LOB) technologies. This new technology is named as GCL for optimization of the production schedule through serialized utilization of resources of a large project. This model is applied to a case of an industry to obtain good line balance efficiency. Tudor, P; Voicu, Gh; David, O; Manole, B; Dinca, N. presents the technological process of repairing some low-power tractor engines, with the main characteristic activities, the ordering in time and the manner of managing them, by applying the critical path method (CPM)[10]. It were determined the activities duration, the starting and ending times, time margins and reserves calculated on the basis of mathematical model characteristic of the method, the activities graph and the time grading, so that there are no major risks in the running process. Hiwa Farughi, Babak Yousefi Yegane Mohammad Fathian (2012) presents a memetic algorithm (MA) for flexible job shop scheduling with overlapping operations [5] proposed that solves the flexible job shop scheduling problem (FJSP) to minimize make span. It also proposed a heuristic that uses the critical path method (CPM) in order to improve the results of MA and reduce the objective function.

Baja SAE is an intercollegiate design competition run by the Society of Automotive Engineers (SAE). Teams of students from universities all over the world design and build All-terrain vehicles (ATVs). The cars all have engines of the same specifications. The teams are judged based on certain dynamic events. These include Acceleration, Manoeuvrability, Suspension and finally an endurance race. This paper deals with a case study of the Baja Team of College of Engineering, Pune (Team Nemeses) and aims in reducing the duration of their project.

**Simulation using MS Project Software**

The manufacturing of an ATV for the BAJA SAE competition involves several phases – Team Formation, Design Phase, Sponsorship Generation, Manufacturing etc. to name a few. Each of the phases are further divided into sub-processes. All the sub-processes do not follow a chronological pattern and two or more tasks may be independent of each other and carried out simultaneously, for example, the manufacturing of sub-systems (steering, transmission, brakes etc.). All these tasks, their duration, resources and the corresponding costs are entered into MS Project software along with the constraints for each task (if applicable). These constraints include “as soon as possible”, “start no earlier than”, “finish no later than” etc. The task dependency is also specified so as to start a particular task only after the completion of certain task(s). Such detailing of the data provides a tool for better analysis of the process-flow and the discrepancies that may be found in the completion of the project. The image shows the data entered into MS Project according to BAJA’s schedule and after modification.

The College Club, whose data has been used in this study has a list of the activities that need to be completed and the time taken by each activity. The date of the final competition before which the ATV needs to be ready is also known in advance. In this case study, the data was first entered according to the team’s initial schedule. The date of the competition was known to be February 15, 2017. So, considering 349 days of work required, the project had to be started on March 15, 2016. In addition to the duration, out of the 25 work resources at hand, 21 of them were over-allocated for two tasks, i.e., 21 work resources were scheduled to be present for the completion of two different tasks at the same time.

Using MS Project, the over-allocation of resources could be sorted out. The over allocation primarily happens because of dynamic allocation of resources, i.e., although it may be specified that the completion of certain task requires, say X days, it does not imply the work resource needs to spend complete X days on the given task. The same resource can also work on other tasks simultaneously. Considering such dynamic allocations, the over allocation of the work resource can be avoided. Also, certain resources which were free at a particular time were assigned tasks by rearranging the workload. This also helped in avoiding the over-allocation of resources. The duration of the project was also brought down to 317 days. This was done by sequential ordering of the tasks. The independent tasks that required a separate set of work resources could be started/ completed simultaneously. The task(s) which did not have any preceding task were scheduled to be completed whenever the resource was free or there was float duration available in completion of some other task. The number of critical tasks were increased from 1 to 36, implying that instead of a single task, 36 tasks needed to be completed within the stipulated duration without any available float.

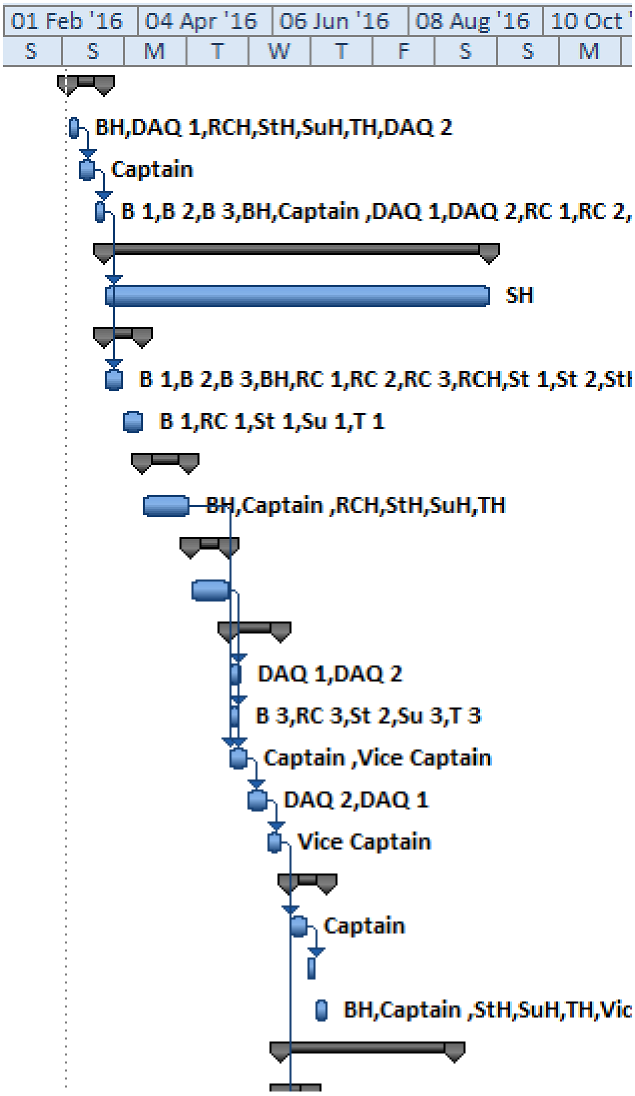


Figure 1

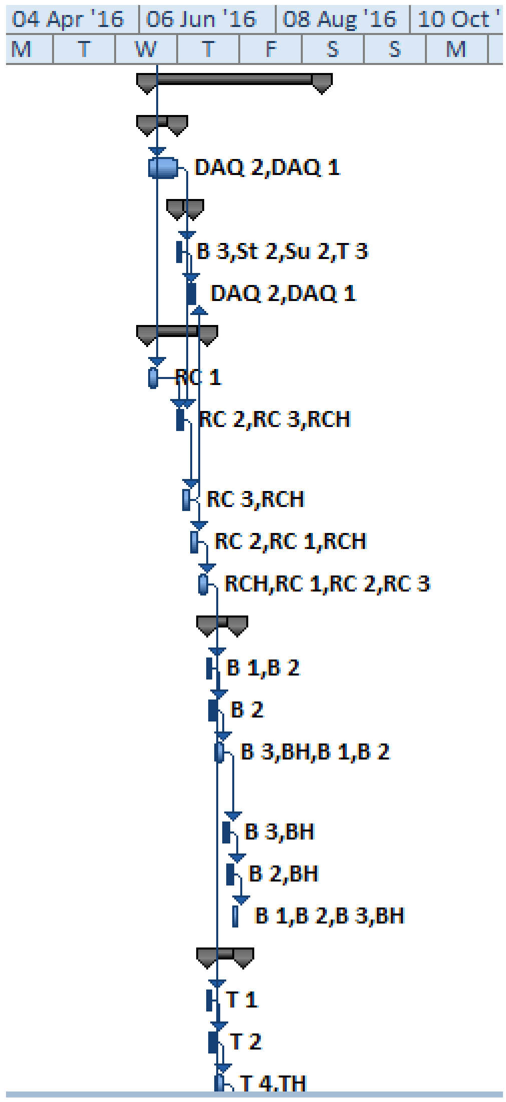


Figure 2

Figure 1, 2, 3 and 4 show a schematic Gantt chart of the tasks associated in the manufacturing of the ATV in the club. The important tasks include the design phase, manufacturing phase and the testing phase. These phases need to be given utmost importance because maximum cost and resources are incurred in these phases. In manufacturing phase, all the sub-systems are manufactured simultaneously i.e. there is overlap of tasks, hence adding to the complexity. Also, assembly of the vehicle starts only after the manufacturing of all sub-systems is completed as well as the bolts are procured. Thus, the tasks are shifted so that less float is available and the duration of the project can be effectively reduced,

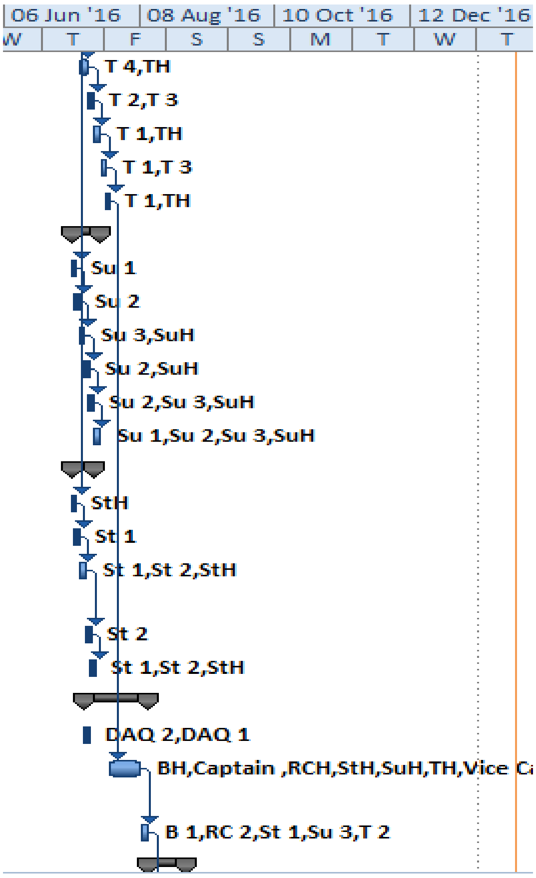


Figure 3

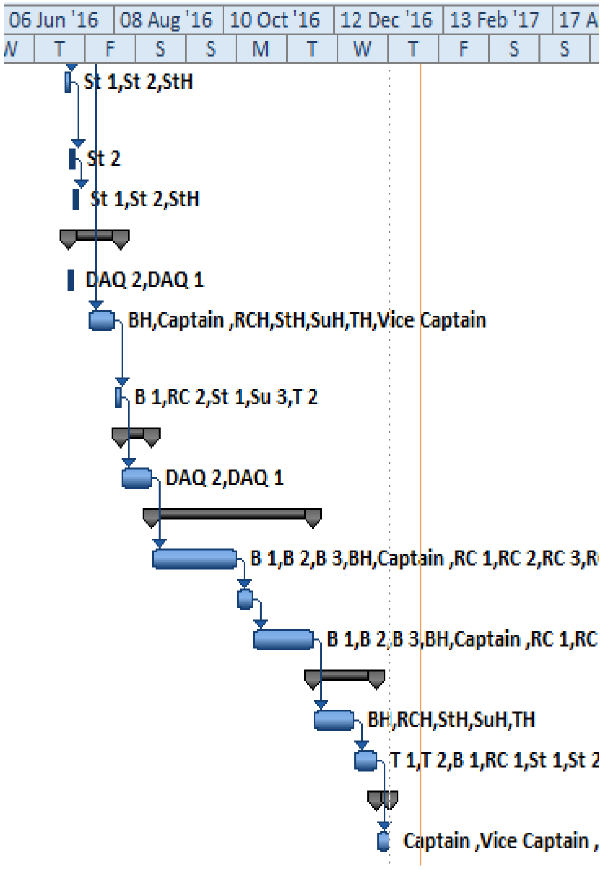


Figure 4

Figure 5 illustrates that in addition to reducing the total duration, the workload on various resources was also distributed almost equally.

Initially the workload which was distributed unequally (depicted in blue) was rearranged so that it would be distributed almost equally.

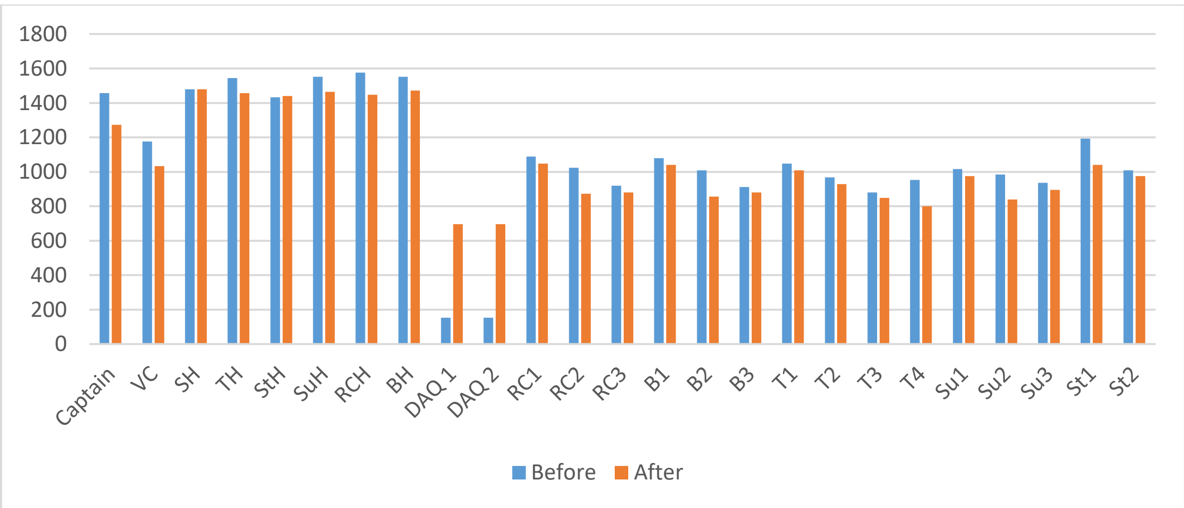


Figure 5: Distribution of Resources

Table 1: MS Project Report analysis

| Particulars | Initial schedule | After modifications |
|---|---|---|
| Duration | 349 days | 317 days |
| Cost | Rs. 13,00,532 | Rs. 13,00,532 |
| Over-allocated resources | 21 | 0 |

Table 1 gives the summary of the duration, cost and over-allocated work resources before and after the modifications using MS Project.

**Conclusion**

The case study shows that the Critical Path Method (CPM) technique can be used effectively in scheduling of projects, manufacturing of an ATV in this case. With the use of MS Project Software, in this paper duration of the project was reduced by 32 days, saving 9.1% of the initial time planned. Also, the workload on resources was evenly distributed increasing the resource utilization of the team.

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