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Applications of Critical Path Method in Project Management

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INTRODUCTION

The series of various activities arranged in suitable order for the accomplishment of a desired objective is known as project. In real world we encounter with endless projects daily. In some of them we get success but some projects turned into massive failure due to mismanagement of projects. The management of a project is essential to ensure the completion of desired activities in consensus with different expectations that have been set around regarding what should be delivered, by when, and for how much it must be made available. Project management is a process of defining, planning, organizing and controlling various activities to ensure timely delivery of project at reasonable cost.It assists in setting feasible targets rather than fixing over-ambitiousestimates based on the insight from similar projects handled previously.Project management is essential to schedule activities, design budget and ascertain delivery timelines. In practice, a project encounters with different constraints and restrictions that limit the completion of different activities involved in the project. To deal with such problems, we have few remarkable techniques for the suitable management of the project and Critical Path Method is one of them.

Critical Path Method is an algorithm that is used for the purpose of planning, managing, organising and analysing the total time involved in a project. It was developed by Morgan R. Walker of DuPont and James E. Kelley Jr. of Remington Rand.The DuPont is an American conglomerateand its stock price is a component of the Dow Jones Industrial Average (leading stock index of USA). The company was founded,as a gunpowder mill, by French-American chemist and industrialist EleuthereIrenee Du Pont in July 1802 in Wilmington, Delaware. During 19th century DuPont became the largest supplier of gunpowder to the United States military. In 2017, the company was merged with Dow Chemicals for being world's largest chemical company. Remington Rand established in 1927 was a result of mergerof Remington Typewriter Companyand Rand Kardex Corporation. The company has diversified conglomerate manufacturingpunched card calculator, typewriter, other office equipment, electric razors, etc. Morgan R. Walker (DuPont) and James E. Kelley Jr (Remington Rand) proposed critical path method for scheduling project. They analysed all activities and identified the longest path having least tolerant of slippage which was named as critical path.

CRITICAL PATH METHOD

The critical path method (CPM) has been a widely applied technique in large-scale industrial project planning and control. First time it was being used in 1966 for the construction of one of the major skyscrapers the former World Trade Centre Twin Towers in New York. CPM is activity oriented that schedules different activities of project through portraying a network of precedence relationships. It determines the dependencies among the activities and presents them using activity-on-node network construction.CPM is a deterministic model with well-known activity times based on the previous experiences. It is primarily used for such projects which are repetitive in nature and doesn't have uncertainty in time. The steps to be followed involved in CPM are as follows:

1. Preparation of work breakdown structure i.e. listing all the activities required to be done for the completion of project.
2. Estimation of time involved in each activity.
3. Ascertainment of the dependencies among the activities i.e. to deduce the precedence relationship among various activities
4. Construction of networkbased on theprecedent and succeeding relationship.

Determination of Earliest Time: It is concerned with the earliest occurrence time of an event i.e. the time at which an event can occur without disturbing the overall completion time of project. It has further been classified into two categories: earliest start time (EST) and earliest finish time (EFT). EST is the time at which the activity can start without affecting the total project time. EFT is the time at which the activity can finish without affecting the total project time. It can be determined through Forward Pass method. According to this method, computation begins from the start node and continues till end node. At the outset the occurrence time of initial even is assumed to be zero. Later the earliest start time for the activity

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5. i, j is computed on the basis of event time i..e$EST_{ij} = E_i$. The earliest finish time of activity i, j is the EST of the concerned activity added by the duration of the activity i.e. $EFT_{ij} = EST_{ij} + t_{ij}$. Here t stands for the time involved in the activity. Earliest occurrence time for the event j is the maximum of the EFT of all activities completing into event j i.e. E_i = Maximum ($EST_{ii} + t_{ii}$).
6. Determination of Latest Time: The latest occurrence time for an event denotes the time by which all activities involved in the event should be completed without delaying the project. Latest time estimates are calculated through backward pass method. According to this method the latest time and earliest time for the last event are similar and then backward calculations are made till one reach to the first event. Latest start time (LST) is determined by subtracting activity time from the latest finish time (LFT) for activity i, j i.e. $LST_{ij} = LFT_{ij} - t_{ij}$. Latest event time for event i is the minimum of the LST of all activities originating form that event i.e. L_i = Minimum (LST_{ij}) or Minimum (($LFT_{ij} - t_{ij}$).
7. Estimation of Floats: The term float represents the amount of time by which activity completion could be delayed beyond expected EFT without affecting the overall completion time of the project. It can be calculating through subtracting EST from the LST. The difference between latest start time and earliest start time is known as total float which may be free float as well as independent float. Critical activities always have zero floats. The activities with non-zero total floats may be positive or negative depending upon the availability of resources. If the resources are in surplus, float will be positive. If resources are inadequate, float will be negative. In such a situation crashing is required to be done to reduce the negative value.
8. Identification of Critical activities: The completion of critical activities can't be delayed therefore no float is available for such activities. Thus, the activity with zero float may be a critical activity. In case of such activity, the resources are assumed to be neither in surplus nor inadequate to complete them. The resources are believed to be just sufficient to complete the activity.

The path formed through combining critical activities is known as critical path. The critical path is the longest path which is discerned by the measuring the completion time after the longest stretch of dependent activities. It is a sequence of project activities that add up to the maximum duration of the project completion. It has a zero-run-time reserve and depicts the prolonged route of planned activities towards the end of the project. After ascertaining the critical path, project manager has to set up the deliverable i.e. the logical end points of the project.

REVIEW OF RELATED LITERATURE

CPM is one of the most popular techniques used particularly by big industries for scheduling and managing big projects. But in-spite of its immense use, the same hasn't been much explored by the researchers. However, in recent few years it allured the attention of researchers. Some of the studies undertaken in this context are as follows: Hegazy (2002) observed that CPM algorithm is based on two assumptions viz., unlimited resources and unrestricted project completion deadline. Since both of these assumptions are difficult to be possible in practical world, CPM must be supplemented by other techniques like time & cost trade-off, resource allocation and resource levelling which can be applied to project one by one. Lu and Li (2003) found that in most practical situations, the resources required for activities are limited particularly when they have to be used for multiple activities and projects. They suggested the use of resource-activity CPM to synchronize activity planning and resource planning. Gould (2005) remarked that CPM analysis is an important tool for project management. The project manager can monitor the completion of day-to-day activities as against the time schedule specified by CPM. Further, CPM can be used as an indicator to anticipate possible problems that may occur in near future.

Farughi et., al. (2012) proposed heuristic that uses CPM for improving the scheduling flexible job shop with overlapping operations. The method was developed to solve the scheduling problems and to reduce the total span. The experimental results of CPM and algorithm suggested the near optimal solution for medium and large size problems in reasonable time. Boushaala (2013) critically appraise PERT / CPM techniques. The paper reported that the two techniques can be used to give information regarding slack time, earliest start and end time. But PERT/CPMhas an inherent assumption of infinite resources. Further study found that CPM doesn't specify any formal way to confirm that all the activities are well connected in the project network. The study proposed the application of Petri Net model.Rautelaet., al. (2015) highlighted the advantages and applications of CPM as a tool for meeting the commitment of the delivery to other related departments. They study found that CPM can be applied byevery department to honour the contracts by assuring timely delivery. The study reported that internal delays are major cause for the

delay in delivery of the final product and CPM proved to be useful for resolving the issues concerning internal delays.

Tudor et., al. (2015) used critical path method for understanding the technological process of repairing tractor engines with low power. CPM has been applied to schedule the time involved in activities and also to manage them. Razdan et., al. (2017) applied Critical Path Method technique for scheduling of projects and manufacturing of an All-Terrain Vehicle. The study applied critical path method to tackle the limitations of time and available resources for minimize the overall duration taken in project completion. The study sorted the over-allocation of resources and reduced the project duration by 32 days and led to the saving of the planned initial time by 9.1%. CPM is believed to be a powerful tool that enables the organisation to meet the project deadline at a reasonable cost. In this context, the present paper makes an attempt to highlight some of the common application of CPM for the project scheduling and management.

APPLICATIONS OF CPM

CPM lays emphasis on the trade-off between project cost and overall completion time. It argues for putting additional human as well as capital inputs, which may increase the cost burden, to reduce the duration of designated jobs in a project. It provides the best way of planning and scheduling large projects. It identifies critical and non-critical path to enable top management to concentrate on critical activities for assuring the project completion by deadline.CPM can be applied in every project with deterministic time estimates of interdependent activities. The method attempts to establish the trade-off between the overall cost of the project and the total time for the completion of desired activities. It assesses whether the estimated time could be reduced through compromising with cost (i.e. allowing the escalation of cost) or the same is not sound from financial perspective. CPM allows minimizing the project duration within certain limits by deploying additional resources at an optimal cost. If the project has some activities with negative floats, extra resources are inducted to reduce the negative float value. The process to reduce the time involved through allowing the increase in cost in known as crashing. The cost for reducing the time of an activity can be calculated through the following formula:

$$Costperunitofreducedtime = \frac{Crashcost - Normalcost}{Normaltime - Crashtime}$$

Initially the normal time estimates for each activity are taken to calculate project duration. To reduce the project duration, we need to reduce the time of critical activities because reduction in time of any non-critical activity will not help in minimizing the project duration. The cheapest activity is selected for the crashing and the process remains continue till there remains any critical activity.

CPM can also be used for resource leveling. Resource leveling allows the inclusion of resources with respect to the concern activity i.e. it permits the activity-based resource assignments. The term resource levelling refers to such a technique that balances the demand and supply of available resources. It allows adjustments in time deadlines to meet the constraints of resources. Resource levelling is primarily done when the restriction is on the availability of manpower. Levelling assists in adjustment of resources as against the possible floats available in the activity. It is helpful to reduce the burden on the limited resource and establish the trade-off between overall duration of the project and cost involved in it.

Critical Path Analysis is commonly used in large industrial houses where the time involved in completion of an activity can be predicted with reasonable certainty owing to the previous experiences. Few examples of industries where CPM has wide applications areconstruction, defense, installation of complex equipment, engineering, aerospace, maintenance and shifting of plant, launching space programmes, traffic flow pattern and other large projects etc.CPM has wide applications that are essential for the successful completion of a project. But at the same time, the method has been criticized on few grounds.

It has been argued that CPM is a static planning model and cannot be used for controlling real situations. It is unable to accommodate the dynamism because in case of any changes in the network, the entire evaluation procedure has to be repeated to determine the new critical path. To resolve the problem, CPM is needed to be supplemented by some heuristic and mathematical models. In addition to this the method is required to be supported by high-end software that could tackle the problems of logical constraints but sophisticated programmes are very limited which poses a serious threat to managers. In practice, MS project software system is used but it has certain limitations concerning with resource constrained schedules. Kim and de la Garza (2003) found that under resource constraint schedules the system may

provide inaccurate calculations of total floats. Similarly,Korman and Daniels (2003) also noted that logic abuses in this context can result into delayed projects and consequent lawsuits.

CONCLUSION

CPM is a widely used and powerful technique of project management. It assists in scheduling different activities, ascertaining their various time slots (like earliest start time, latest start time, earliest finish time and latest finish time), estimation of free, independent and total floats to determine the critical and non-critical path. CPM is of great help to optimize the project time at reasonable cost. The present paper discusses the applications of CPM as a project management technique.However, the method is based on the assumption that manager has precise information about the duration, size and performance of different activities, which may not be true in real life scenario. Further the present study submits that CPM is needed to be augmented and supplemented by advanced mathematical dynamic models that can handle logical constraints.

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