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Time, Cost, and Quality Trade-off Analysis in Construction Projects

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Abstract – Time, cost and quality are the three important objectives in construction project. Trade-off between these constraints is very important. Time and cost are quantitative parameters, but quality is a qualitative parameter. In this paper it is to create a Time Cost Quality Trade off, TCQT model is being analysed. The assumptions and conditions are taken based on an industrial survey. The survey data is thoroughly analysed using SPSS software. Finally, a case study of a building construction, which is scheduled using primavera is done in this project.

Key Words: TCQT, Construction, Trade-off, SPSS

1. INTRODUCTION

The foremost objective of construction comes is to complete the project within time, within budget and as per the scope demands. These attributes of every activity place confidence within the execution chance by that the activity's work completed. It is required to develop an approach that can find an optimum or about to optimum set of execution selection for the project's activities therefore on attenuate the project's total worth and total amount whereas its overall quality is maximized.
In order to get the optimal decision result, an effective algorithm based on the improved particle swarm optimization algorithm and critical path method (CPM) are used according to the characteristic of optimization problem. At last, a case study on heavy repair of instrument control system for hot blast stove is given to verify the feasibility and practicability of the model. But when we approach project schedules where resource plays a major role, CPM has lot of limitation. Apart from when we are focusing in another major dimension as Quality, it is not meet our all requirements.

A construction project is mainly facing different constraints like time constraints, budget constraints and scope constraints. Both dependencies and constraints are important elements of any project. Projects essentially are a series of interrelated tasks that will have a priority order and relationship with each other, which will cause dependencies. On the other hand, constraints happen when you have a set of requirements from a project, a deadline for completion, and other characteristics that put a limit on how you can approach the project. Simply, anything that stops or puts a limit on your implementation strategies is considered a project constraint. All these constraints will affect the **Quality** of the project.
The time, quality, and cost are three important but contradictive objectives in a building construction project. It is a tough challenge for project managers to optimize them since they are different parameters.
The linear relationship shown in between these two points implies that any intermediate duration could also be chosen. It is possible that some intermediate point may represent the ideal or optimal trade-off between time and cost for this activity. The slope of the line connecting the normal point (lower point) and the crash point (upper point) is called the cost slope of the activity. The slope of this line can be calculated mathematically by knowing the coordinates of the normal and crash points.

Project Time-Cost Relationship:

Project Time-Cost Relationship Total project costs include both direct costs and indirect costs of performing the activities of the project. Direct costs for the project include the costs of materials, labor, equipment, and subcontractors. Indirect costs, on the other hand, are the necessary costs of doing work which cannot be related to a particular activity, and in some cases cannot be related to a specific project.

SCOPE OF THE PROJECT

- Identifying and assessing various factors affecting Time, Cost and Quality Trade-off in Construction Projects
- Understanding the limitations of conventional or present methodologies and introduce new industry updates.
- Further to develop a methodology to implement in construction projects and verify the results in a case study.

OBJECTIVE:

- To identify common and relevant factors causing Time, Cost and Quality in Construction projects.
- To conduct a questionnaire survey among consultants, contractors and engineers.
- To develop statistical models using multiple analysis techniques using standard tools.
- To validate the results obtained from the statistical models.

2. Methodology

Generally, Time-cost trade-off analysis involves accelerated activity durations that are obtained by allocating more resources, and lead to shorter project duration and lower indirect cost at the expense of higher direct cost. But whether it may affect the quality or not there is no such measurements. For shut down work like projects it may effective. But in construction like projects special care should be taken. So, the project is observing in an angle of Time –Cost and Quality trade-off. The methodology adopted is shown as below:

- **Literature survey: A** detailed literature survey is conducted through the various journals regarding this subject. Literature review which helps to identify the main strategies affects the project nature. Literature review conducted based on the journals, textbook, conferences papers. Blogs etc.
- **Questionnaire preparation:** The questionnaire which includes the questions related
  With the fast-track construction, Delay management. Resource management and
  Choice of technology.
- **Company identification:** Find out the suitable construction projects for the data
  Collection and questionnaire survey. Most prefer the ongoing fast track projects in
  Kerala.
- **Questionnaire survey:** The questionnaire survey which includes the most relevant
  Questions for the data collection. The questions related with the strategies are also
  Included in the questionnaire survey.
- **Data collection:** The Data collected through the questionnaire survey, field visit, data from the other sources and their sorting.

Reliability check using SPSS software

SPSS is a widely used program for statistical analysis in social science. It is also used by Market researchers, health researchers, survey companies, government, and education Researchers, marketing organizations, data miners, and others. The original SPSS Manual (Nie, Bent & Hull, 1970) has been described as one of "sociology's most Influential books" for allowing ordinary researchers to do their own statistical Analysis.] In addition to statistical analysis, data management (case selection, file Reshaping, creating derived data) and data documentation are the features of the base Software.
The data were analyzed on the basis Relative Rank Index (RRI) technique. The RRI Technique is used for comparison between the importance levels of variables and derived from the Liker scales which represent the level of importance of variables Chosen by respondents which need to be transformed into a Relative Rank Index that has a value of one or less. The RRI can be calculated using the following equation:

$$RRI = 1\ (\Sigma lixini = 1)$$

Where,
RRI refers to Relative Rank Index, n- Maximum Likert scale value (here 5)
N-Total number of responses, i- 1, 2....n
Li = Likert scale (*l*1 is the least important and *in* is the most important)
xi = the frequency of the I th response.

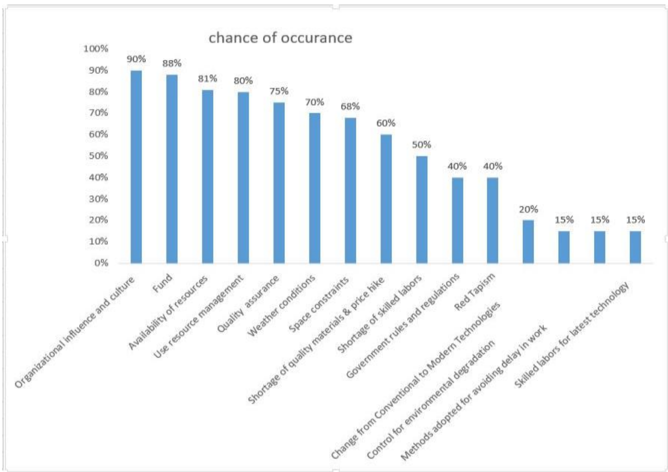

Fig 1

The overall performance of a project regarding time, cost, and quality is decided by the amount, cost, and quality of its activities. These attributes of every activity place confidence within the execution chance by that the activity's work is completed. It's required to develop an approach that's capable of finding an optimum or about to optimum set of execution selections for the project's activities therefore on attenuate the project's total worth and total amount, whereas its overall quality is maximized. So, we need a Time Cost Quality Trade off **(TCQT**) model.

IMPLIMENTING TCQ MODEL

Already we have discussed about the TCQT models' elements to apply in each area like project time duration, budget of the project and quality criteria. We can further move to the time cost trade of analytical model.

Activity Time-Cost Relationship

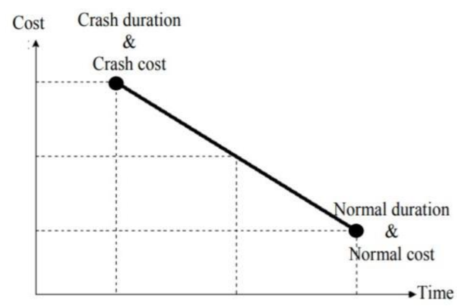

Fig 2

Cost slope = (crash cost – normal cost) / (normal duration – crash duration)

OBSERVATIONS FROM THE TIME COST TRADE OFF ANALYSIS

As we are doing the problem in a Critical Path Method, we can summarize it as:

- It is difficult to estimate the completion time of an activity.
- The critical path is not always clear in CPM.
- For bigger projects, CPM networks can be complicated too.

And in the case of Cost Analysis, the highlighted columns, we can observe that same cost of the networks are completed in different time. It points out that normal critical path method may not be suited for such type of analysis. Here we can use CCPM to reduce cycling time and efficiency in cost analysis.

CASE STUDY ANALYSIS USING ORACLE PRIMAVERA

Oracle's Primavera P6 EPPM is a cloud-based, software-as-a-service solution backed by a global network of Oracle Project Portfolio Management professionals and the assured security, scalability, performance, and support from one of the world's largest cloud vendors. It provides a 100% web- based solution for managing projects of any size, adapts to varying levels of complexity across projects and intelligently scales to meet the needs of all roles, functions, or skill levels in your organization and on your project team.

The case study is a Multi- storied building Project. The Schedule is prepared using Oracle Primavera and the project divided into Work Breakdown Structure (WBS) and activities are entered with duration. Activity relations are provided as Predecessor Diagramming method (PDM). Resources are assigned to activities with Direct and Indirect cost. The Scheduling is done by CPM method. Into the same schedule we are applying our topic Time Cost Trade off analysis and observe the variation. How the cost is making the changes from the defined scope (i.e., Quality) is calculated in terms of time and money. All the Techniques like Resource analysis, resource levelling such process applied on the new CCPM based schedule. As we know CPM Schedule has limitations to manage resource and share resource based on skills (it is called as ROLES), like all procedures done and find the variations.

BASELINE FOR PROJECTS

A baseline in project management is a clearly defined starting point for your project plan. It is a fixed reference point to measure and compare your project's progress against. This allows you to assess the performance of your project's changes, duration changes, and cost changes like all. So, Baseline will help to track activity graphically and tabular changes like date, duration, cost etc. will get as table form.

We have set a baseline for our schedule and attach with the schedule. After we can apply our changes like avoiding parallel activities. We can track the present stage of applying CCPM on CPM schedule.

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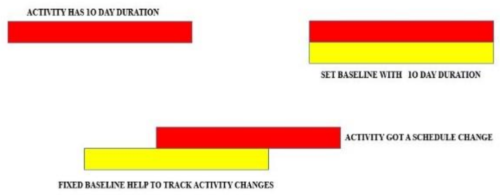

Fig 3

So, Baseline will help to track activity graphically and tabular changes like date, duration, cost etc. will get as table form.

CPM BASE PROJECT	CCPM NEW PROJECT
Total duration of the project: 426. Days	Total duration of the project: 396 Days
Project Start & End Date: 01 March 2021 & 17 October 2022	Project Start & End Date: 01 March 2021 & 05-09-2022
Budgeted Labour Cost: Rs: 8,503,800.0 /-	Budgeted Labour Cost: Rs: 8,503,800.0 /-
Budgeted Indirect Cost: Rs: 94,500 /- (Rs: 100/- for activity per day)	Budgeted Indirect Cost: Rs: 94,500 /- (Rs: 100/- for activity per day)
Budgeted Total Cost: Rs: 8,598,300/-	Budgeted Total Cost: Rs: 8,598,300/-

By apply CCPM we can reduce total duration 30 days and we get ahead schedule. It never means that we reduce the duration of activity and the cost.

CRASHING

Now we can apply the crashing on the new project means CCPM project and want to calculate the changes. We set CCPM project itself as Baseline.

- Applying crashing will suddenly reduce the duration of activity and projects.
- Change in cost will also track.

Set a baseline for schedule and attach with the schedule. We can track the present stage of applying crash and cost trade-off on the CCPM schedule.

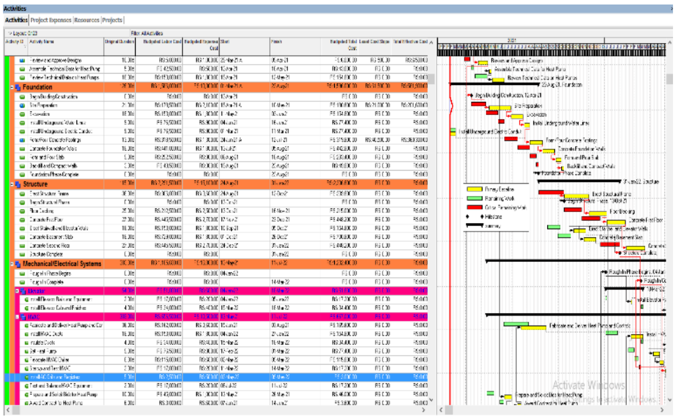

Fig 4

The time cost trade-off occurred as per the equations that had discussed. We can separately check the costing.

Activity ID	Activity Name	Original Duration	Budgeted Labor Cost	Budgeted Expense Cost	Budgeted Total Cost	Least Cost Slope	Total Effective Cost
B1000	Design Building Addition	20.00d	RS:170,000.00	RS:2,000.00	RS:172,000.00	RS:17,000.00	RS:189,000.00
B1010	Review and Approve Designs	10.00d	RS:5,000.00	RS:1,000.00	RS:6,000.00	RS:500.00	RS:6,500.00
B1020	Assemble Technical Data for Heat Pump	5.00d	RS:42,500.00	RS:500.00	RS:43,000.00	RS:0.00	RS:0.00
B1030	Review Technical Data on Heat Pumps	18.00d	RS:153,000.00	RS:1,800.00	RS:154,800.00	RS:0.00	RS:0.00
B1040	Begin Building Construction	0.00d	RS:0.00	RS:0.00	RS:0.00	RS:0.00	RS:0.00
B1050	Site Preparation	21.00d	RS:178,500.00	RS:2,100.00	RS:180,600.00	RS:21,000.00	RS:201,600.00
B1060	Excavation	18.00d	RS:153,000.00	RS:1,800.00	RS:154,800.00	RS:0.00	RS:0.00
B1070	Install Underground Water Lines	9.00d	RS:76,500.00	RS:900.00	RS:77,400.00	RS:0.00	RS:0.00
B1080	Install Underground Electric Conduit	9.00d	RS:76,500.00	RS:900.00	RS:77,400.00	RS:0.00	RS:0.00
B1090	Form/Pour Concrete Footings	13.00d	RS:318,500.00	RS:1,300.00	RS:319,800.00	RS:40,500.00	RS:360,300.00
B1100	Concrete Foundation Walls	18.00d	RS:441,000.00	RS:1,800.00	RS:442,800.00	RS:0.00	RS:0.00
B1110	Form and Pour Slab	9.00d	RS:292,500.00	RS:900.00	RS:293,400.00	RS:0.00	RS:0.00
B1120	Backfill and Compact Walls	3.00d	RS:49,500.00	RS:300.00	RS:49,800.00	RS:0.00	RS:0.00
B1130	Foundation Phase Complete	0.00d	RS:0.00	RS:0.00	RS:0.00	RS:0.00	RS:0.00
B1140	Erect Structural Frame	36.00d	RS:306,000.00	RS:3,600.00	RS:309,600.00	RS:0.00	RS:0.00
B1150	Begin Structural Phase	0.00d	RS:0.00	RS:0.00	RS:0.00	RS:0.00	RS:0.00
B1160	Floor Decking	25.00d	RS:212,500.00	RS:2,500.00	RS:215,000.00	RS:0.00	RS:0.00
B1170	Concrete First Floor	27.00d	RS:445,500.00	RS:2,700.00	RS:448,200.00	RS:0.00	RS:0.00
B1180	Erect Stairwell and Elevator Walls	18.00d	RS:153,000.00	RS:1,800.00	RS:154,800.00	RS:0.00	RS:0.00
B1190	Concrete Basement Slab	18.00d	RS:729,000.00	RS:1,800.00	RS:730,800.00	RS:0.00	RS:0.00
B1200	Concrete Second Floor	27.00d	RS:445,500.00	RS:2,700.00	RS:448,200.00	RS:0.00	RS:0.00
B1210	Structure Complete	0.00d	RS:0.00	RS:0.00	RS:0.00	RS:0.00	RS:0.00
B1220	Rough-In Phase Begins	0.00d	RS:0.00	RS:0.00	RS:0.00	RS:0.00	RS:0.00
B1230	Rough In Complete	0.00d	RS:0.00	RS:0.00	RS:0.00	RS:0.00	RS:0.00

Fig 5

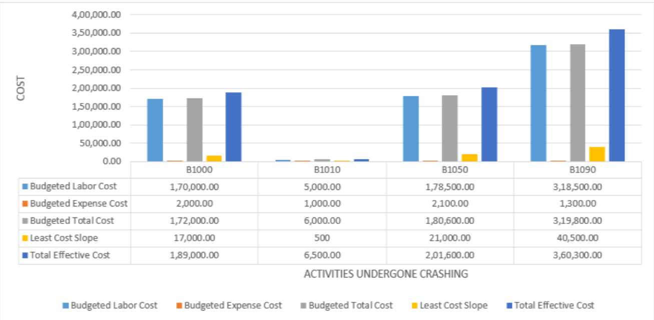

Fig 6

CONCLUSIONS

The principal plan of TCQT is to strike a balance among the conflicting objectives of time, cost and quality. That is depends on the organizations approach towards the nature of the project. The principal objective of such models is to find an optimal or near optimal set of execution options for a project's activities in order to minimize the project's total price, minimize its total duration, and maximize its overall quality. To validate the developed models and demonstrate their efficiency, they were applied to case studies introduced by literature. Compared to results obtained by literature, satisfactory results were obtained by the developed models. The applicability of the procedure presented here is not limited to the construction project planning problems. It may be useful for various types of problems in which uncertain outcomes are compared. It can be also applied. For example, in inventory models, evaluation of investment projects, production process control and many other industries.

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