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TIME – COST OPTIMIZATION (TCO) BY APPLICATION OF FUZZY LOGIC IN CONSTRUCTION PROJECTS

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Abstract: The optimal allocation of resources to different project tasks involving different and usually conflicting objectives is one of the recurring challenges for a project manager. The main aim of this research is to optimize the time and cost of a project by analyzing their trade-off. Time cost optimization is one of the main obstacles in project scheduling. This paper proposes a new approach for time cost optimization with fuzzy logic in MATLAB. The project direct cost is altered by difference in resource utilization and Activity duration. The proposed model is formulated using fuzzy theory combining CPM computations, time-cost trade off analysis. By adopting the MATLAB software for ranking process, for each case facilitates obtaining the optimum result. Therefore, through this process now the decision-maker can quite precisely estimate the effect of the project deadline on a total project cost before the submission of a tender. The advantages of the proposed approach are demonstrated through an application example and with an example of the time-cost trade-off analysis.

***Index Terms* - Time – Cost Optimization, Time – Cost trade off techniques, Fuzzy set and Fuzzy logic, Application of Fuzzy in Time – Cost Optimization**

1. INTRODUCTION

1.1 Time Cost Optimization in construction

The construction management is a critical part in the project because it contains the knowledge of controlling the cost, scheduling & resources. A construction contract is unit price, lump sum or cost plus; the construction cost is important factor in all projects. At the same time duration of completion of project is also important. Nowadays major construction projects are behind the schedule. The major factors that impact cost of construction is material, labour, equipment, overhead and profit (Kerzner, 2003). The deep-rooted culture of price competitiveness has slowly eroded the margins of construction firms, particularly in times of volatile economy. Contractors must try to reduce their costs to survive and one way to do this is by speeding up some of the construction activities.

Since the early 1960's, various analytical methods have been proposed for time–cost optimization (TCO), and examples of these include the heuristic (Siemens 1971; Moselhi 1993); linear programming; integer programming (Kelly 1961); and hybrid programming (Liu et al. 1995) models. Despite being easily comprehensible, these models only targeted minimizing the cost without due attention to reduce the time simultaneously. These TCO models are considered more suitable for smaller construction projects with relatively fewer activities, as it would be difficult to evaluate all possible combinations within a short period of time at a reasonable cost (Ng et al. 2000). So, the fuzzy based Time – cost optimization model for smaller construction projects is a sensible approach which can help to achieve an optimum duration and budget by evaluating all the possible case scenarios with lesser cost and quicker time.

1.2 Application of Fuzzy Logic in Time Cost Optimization

In the mid of 1960s, Professor Lofti Zadeh introduced fuzzy logic to mathematically represent the uncertainty and vagueness inherited in the real world (Zadeh 1965). Scholars have presented the use of fuzzy logic in construction projects such as duration management (Zielinski 2005; Chen, Hsueh 2007), cost estimation (Cheng et al. 2010; Idrus et al. 2011), risk management (Zhang, Zou 2007; Lee, Lin 2010), safety management (Dag˘deviren, Yu¨ ksel 2008), supply chain management (Chen, Huang 2006; Wei et al. 2007) and earned value management (Naeni et al. 2011). The extensive application of Fuzzy logic in the realm of construction demonstrated its easiness to be developed, understood and applied (Kasabov 1996).

Despite the fact that previous studies (Zheng et al. 2004) corroborated the practical values of Genetic Algorithms in construction TCO, most of the previous models were developed on the assumption that a precise (crisp) cost and duration for each activity can be defined beforehand by managers or planners. However, as construction projects are seldom entirely identical, and it would be unrealistic to determine the exact time and cost values until the activity in question is complete. Furthermore, in the absence of a mature tool for recording and retrieving the time/cost data, it would be costly to establish a series of possible time/cost for each activity. The incorporation of fuzzy sets (FSs) theory in TCO problems is therefore a sensible step to emulate the decision-making process of human experts based on a set of uncertain or incomplete data (Daisy X. M. et al. 2013). Fuzzy based time cost optimization model can be a better tool to deal with the uncertain time and cost data of a project.

1.3 Need of the study

In project it is necessary to decide which optimization is required and amount of detail that will be in used into the construction stage. The optimization of time and cost is necessary as it could minimize both the time and total cost of project. This optimization in time and cost helps to achieve the greatest benefit *(Mali P. A et al. 2017).* In project management, the fundamental project concepts of time, cost, and risk are conflicting terms which should be appropriately assigned to project activities to achieve the desired objectives of project stakeholders *(M. A. Alzarrad et al.2017).* There are many occasions where the owner informs the contractor that the schedule must be shortened. This action could lead to increases in total cost as well as risk. To accelerate the execution of a project, project managers need to reduce the scheduled execution time by hiring additional labour or using productive equipment. But this idea will increase cost and risk, hence shortening the completion time of jobs on critical path network is needed. Time-cost trade-off (TCT) is a common approach applied by project managers to reach the required completion time of the projects with the least extra cost *(J. H. Dahooie et al.2018).*

The major constraints in a construction projects are time, cost and resources of the project. Generally, the construction projects are complex in nature it will get affected by time-cost overruns. The major reasons for the delay are inaccurate estimation, design faults, land problems, poor bidding and delay in financial flow, payment delays, inexperience, lack of coordination, change in scope of work *(Agyei, W., 2015) (Khang, D.B. and Myint, Y.M., 1999)* So, the management will face time-cost trade-off problems. The main reasons for reducing the duration of the project are imposed project duration, unforeseen delays and to avoid high overhead cost. The time-cost trade-off majorly focus on reducing critical path *(Huang, J. W et al. 2008).*

1.4 Aim

The main aim of this research is to develop a model for Time – Cost Optimization by application of fuzzy logic in construction projects.

1.5 Objectives

The main objectives of this research are

1. To study and analyze Time – Cost Optimization and various techniques used in construction.
2. To develop a model based on fuzzy logic for Time – Cost Optimization in construction.
3. To apply the developed model on a case study project for time – cost optimization**.**

1.6 Scope of Work

1. The scope of this study includes study of various available literature to understand the basic concepts of time cost optimization and fuzzy theory.
2. The study will be using Fuzzy Inference System (FIS) in MATLAB for Optimization.

1.7 Hypothesis

Based on the understanding gained from Literature review, the following hypothesis has been made:

1. Introducing fuzzy logic in Time cost optimization can help to decide on the case scenarios
2. Fuzzy based time cost optimization model will be less complex and efficient than any other optimization model.

2. PROPOSED FUZZY LOGIC BASED MODEL FOR TIME – COST OPTIMIZATION

2.1 Introduction

In this chapter proposed fuzzy logic-based model for time – cost optimization will be developed. The time and cost of the project activities, as well as the project itself, may be expressed using a range of values rather than exact numbers. This fact makes the theory of Fuzzy logic applicable in such cases to represent the uncertainty in time and cost of construction project.

The value for time – cost optimization cannot have a crisp value like yes or no. There is always an uncertainty attached to the input variable or values like experience of team, method used for calculation. The fuzzy environment deals with the fuzzy inputs and gives a crisp output. The proposed fuzzy logic-based model for Time – Cost optimization is explained with the help of applying on Case study project.

2.2 Steps for Proposed Time Cost Optimization Model

Before the application the proposed model first a mathematical model is prepared. To prepare a mathematical model for project scheduling using Fuzzy theory the following proposed algorithm will be applied:

2.2.1 Steps for developing possible Case Scenarios

Step 1- Define the project activities

Step 2- Define the logical relationship between activities

Step 3- Estimate the activities time and cost this includes both direct and indirect cost.

Step 4- Specify, the crash time and cost for crashing the activity

Step 5- Calculate the cost slope for the project.

Step 6 – Establish possible case scenarios of completing the project using the cost slope.

Step 7 – Develop a mathematical model for each scenario and solve it by using fuzzy logic toolbox presented in the commercial program (MATLAB). Evaluate the Case scenarios in MATLAB program and identify the optimum time and cost for the project.

2.2.2 Steps to solve the mathematical problem in MATLAB

Step 1: To open the fuzzy logic designer

Step 2: Defining input and output variables

Step 3: Defining the membership functions for both input and output.

Step 4: Defining rules in rule editor and checking the rules in rule viewer

Step 5: Writing the codes for operation and run

Step 6: Evaluating each Case Scenario and obtaining the Fuzzy Score.

Step 7: Ranking all the Case Scenario based on the obtained Fuzzy Score and identifying the optimum duration and cost for the project. These steps are explained in detail with the use of Case study project in the following sections.

3. APPLICATION ON CASE STUDY PROJECT

3.1 Case Study Project Data

The data of Activity, Normal duration, Normal cost, Crash duration and Crash cost data of the case study project are listed below.

Table 1 Case Study project data

Case study project information					
S. No	Activity	Time (Days)		Cost (Rupees)	
		Normal	Crash	Normal	Crash
1	Site Mobilization	30	23	5,91,801.00	7,10,161.00
2	Demolition of existing structure	105	90	7,99,550.00	9,19,482.00
3	Excavation and foundation work	165	150	10,78,582.00	12,61,942.00
4	RCC level 1	120	105	35,54,266.00	43,00,662.00
5	RCC level 2	150	135	37,27,617.00	45,10,416.00
6	RCC level 3	90	78	28,90,211.00	34,97,156.00
7	Steel structure level 2	75	75	5,71,256.00	5,71,256.00
8	Steel structure level 3	90	90	5,71,256.00	5,71,256.00
9	Steel structure level 4	60	60	5,71,256.00	5,71,256.00
10	Site Development works	270	270	8,59,200.00	8,59,200.00
11	Brickwork	225	195	51,46,762.00	58,67,308.00
12	Electrical work	225	225	29,32,986.00	29,32,986.00
13	Plumbing work	225	225	21,11,750.00	21,11,750.00
14	Plastering	255	225	7,71,833.00	9,10,763.00
15	Flooring	210	210	31,14,297.00	31,14,297.00
16	Painting	180	150	5,67,004.00	7,20,096.00
17	Landscaping	120	105	3,22,200.00	3,83,418.00
	Total	**720**	**660**	**3,01,81,826.00**	**3,38,13,403.00**

3.2 Cost Slope

Cost slope = (Crash cost – Normal cost) / (Normal time – Crash time)
Cost slope = (3,38,13,403 - 3,01,81,826) / (720 – 660)
= 18,15,788.50 per month

3.3 Case Scenarios for Case Study Project

There are 4 case scenarios for this case study project which are listed below

Table 2 Case Scenario for Case Study Project

	Project Duration (days)	Project Cost (rupees)
Case 1	660	3,38,13,403
Case 2	680	3,26,02,877
Case 3	700	3,13,92,351
Case 4	720	3,01,81,826

3.4 Defining Input and Output Variables for Case Study Project

After calculating the case scenarios to evaluate and rank them fuzzy score is calculated in MATLAB. To define the inputs and output for the case study project use the fuzzy command in MATLAB command window. The two inputs will be Time and Cost. The output will be Fuzzy Score.

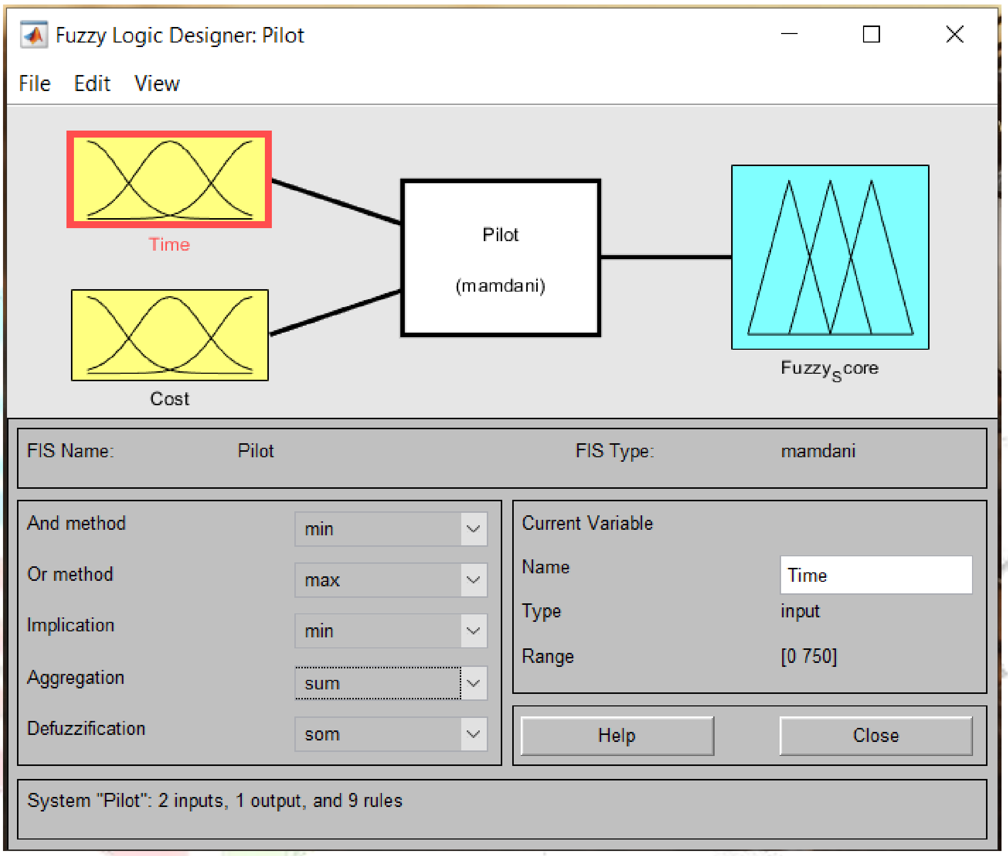

Figure 1 Input and Output for the Case study Project

3.5 Defining Membership function for Input and Output Variables

The next step is to define the membership function for both input and output of case study project. The membership function for the inputs – Time and cost will be Trapezoidal membership function. The range of Time and Cost are to be entered in the membership function where it decides the parameters by itself. This range is depended on the project duration and cost.

The range for time in case study project is given as 0 to 750. This 750 days is the upper range limit which is selected by adding a month of buffer time to the normal duration 720 days. The cost for the case study project is given in lakhs so the range selected for the cost is 0 to 340 Lakhs. This upper limit 340 lakhs is calculated from the crash cost which means that the project cost will fall between 0 to 3.4 Crores.

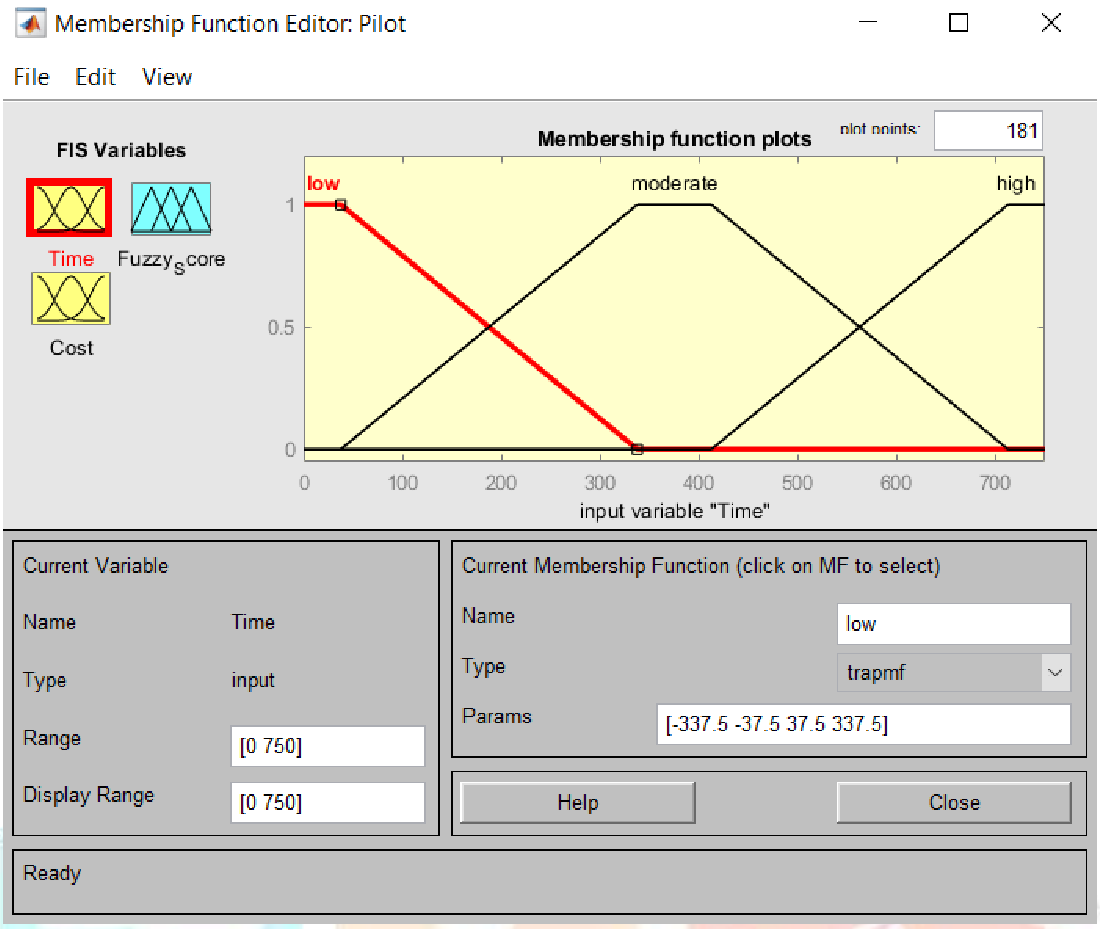

Figure 2 Membership function for Input and Output variables

3.6 Defining rules for Case study project

The Rule Viewer is a MATLAB-based display of fuzzy inference program: it is used as diagnostic tool and can show which rules are active or how individual membership function shapes are influencing the results. As shown in figures, one give inputs through the input edit window and directly obtained the output. The rules for the case study project are tabulated below

Table 3 Set of Rules for Time - Cost Optimization

FUZZY SCORE		TIME		
		Low	Moderate	High
COST	Low	L	L	M
	Moderate	L	M	M
	High	M	H	H

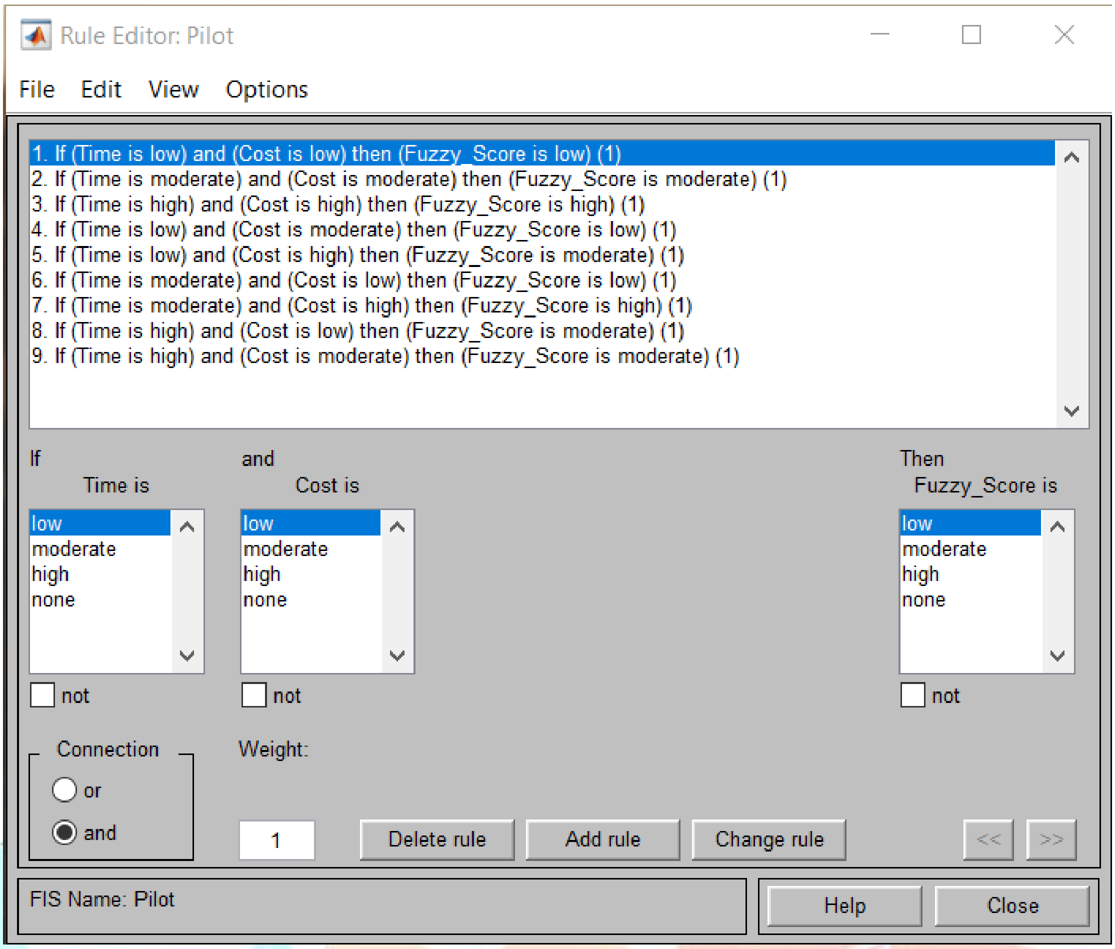

Figure 3 Rules for Case Study Project

3.7 Evaluation of Each Case Scenarios

Evaluating each case scenario in developed MATLAB program for Time - Cost optimization

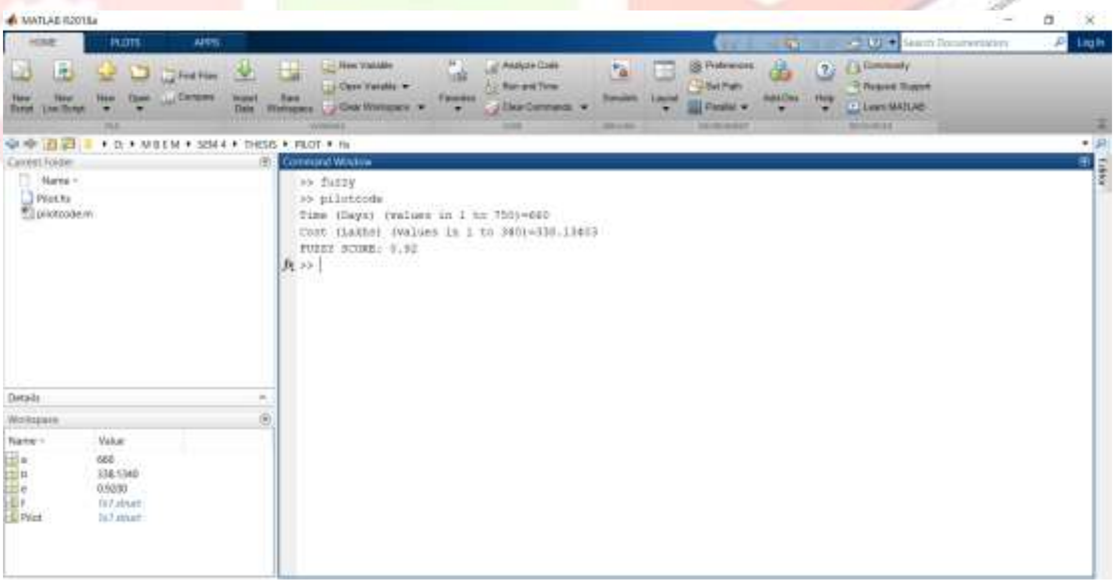

Figure 4 Evaluation of Scenario showing Fuzzy score in MATLAB

The above image shows the Fuzzy Score calculations for the first case scenario. The same process is repeated and Fuzzy Score for all the other scenario is calculated and tabulated below:

Table 4 Fuzzy Score and Rank for Case Study Project

	Project Duration	Total Cost	Fuzzy Score	Rank
Case 1	660	₹ 3,38,13,403.00	0.92	1
Case 2	680	₹ 3,26,02,877.33	0.95	3
Case 3	700	₹ 3,13,92,351.67	0.97	4
Case 4	720	₹ 3,01,81,826.00	0.93	2

3.8 Results and Inference

From the application of developed model on the Case Study project it is found that the case scenario 1 has obtained Rank 1 with the Fuzzy Score 0.92. If the deciding authority of the project is unable to choose this option due to any constraints like not within the budget etc then the case scenario 4 can be preferred since it has obtained Rank 2 with the fuzzy Score 0.93. Hence the Optimum solution for the Case Study project is:

Table 5 Results for Case Study project application

	Optimum Duration	Optimum Cost
Case Study Project	660 days	₹ 3,38,13,403.00

4. CONCLUSION

1. Fuzzy mathematical model has the capability to determine the optimum solution for time-cost trade off analysis. The presented solution is identical to manual solution in which time-cost trade off analysis and resource allocation are performed in succession, and requires no effort of network rescheduling as it is performed manually.
2. Fuzzy mathematical model provides accurate results and that the optimization model is performed correctly. In addition, optimization model finds the minimum completion time for projects while fuzzy model provides a range of time that is between the normal time and the maximum crash time.
3. The model allows the decision maker to examine different scenarios for project execution, and their impact on total time and cost, done by changing the order of performing activities which causes automatic change in project duration and cost.
4. This model could be used for examining the possibility of material or technical shortages. The analysis could be done by comparing other alternatives such as using a more costly material that could be delivered at the right time.
5. This model can be used for the projects which have the right required information for project scheduling such as normal and crash time and cost, the expected resource shortage and the cost of the available alternatives.

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