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Forecasting and Management of Triple Constraints in Construction Projects

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Abstract: *Scope, cost and time are the triple constraints which significantly impact project performance that ensure the effective flow of the project throughout its existence. Managing these constraints benefits the project completion in time with desired quality and within sanctioned budget. Rate variation is one of the extensive concerns in project affecting the total cost of project and is predominantly the consequence of escalation in rate of men, material and machinery. This study is to manage the triple constraints through forecasting the cost of resources namely men, material and machinery in construction project to attain enhanced project performance with preeminent efficacy. The structured questionnaire survey was framed based on 8 main factors together with corresponding 56 sub-factors and the survey was conducted with experts in various construction industry. The factor and forecasted resources have been mapped over the life cycle of the project to study their impact at each stage. The data gathered from survey and organization had been analyzed using statistical software such as SPSS for its reliability, frequency level, factor analysis & ranked using RII and Minitab have been used to measure the fluctuation of rate of resources using trend projection model. The outcome from these analyses revealed that design and documentation related factor rank at the top, sowing the seeds of delay & cost overrun in project and to persuade the most critical factor resources that effect the project progress. Proper proactive approach towards design and documentation related factors which ranks at the top will shade some light to constraints providing dualistic benefits of reaching the objectives of the project with enhanced performance. The appropriate suggestion for enhancing the project performance.*

KEYWORDS: - Triple constraints, Statistical package for social science (SPSS), Relative Important Index (RII), Minitab, Trend projection model.

1. INTRODUCTION

The Construction industry is an integral part of a country's economy; its growth plays a pivotal role in developing the country's infrastructure. The current status report published by the Indian Ministry of Statistics and Programme Implementation (MOSPI) highlighted that out of the 951 projects being monitored 309 projects have cost overruns and 474 projects are behind schedule [7]. Successful management of construction projects is based on three major factors i.e. time, cost and quality. The success or failure of any project depends largely on cost. India is the tenth largest country in the World and yet record of implementing major projects has been far from satisfactory. The figure 1 shows that current status of infrastructure project in India.

Figure 1: Status of Infrastructure project in India

Rate escalation is defined as fluctuations in the price of specific goods or services in a given economy, over a period. Medium to large construction projects takes over a year for completion and the cost of materials and labor often increase, which leads to major problems in administration of the contract. In construction project 80- 85% of cost is spend for resources. It has been observed that most of the projects in India ended with extra time, money and resources. It's a rare scenario in construction industry, that a project is completed within the estimated budget and time, with desired quality. According to Eleventh and Twelfth plan periods (2008 to 2017), India could suffer a GDP loss of US$ 200 billion around 10 per cent of its GDP in financial year 2017.

2. PROBLEM IDENTIFICATION

The construction industry is complex in nature due to large number of stakeholders. It has been facing several problems due to improper planning at the initial stages. The identified problems in construction projects had been grouped in to 8 major factors and corresponding 56 sub factors. Some of the severe challenges in construction projects are listed below:

- Around 37% of construction projects reconciled in downfall due to the inaccurate forecasting in the project, erroneous rate analysis and change of price in raw materials.
- Limited availability of skilled labors.

- Improper scheduling and inadequate monitoring at site during construction phase.
- Incomplete studies prior to project approval
- The change in materials specification modifying the requirements of stakeholders.
- Lack of communication between the owners and employee its lead to project failure
- Rate escalation outturn delays in construction projects, Reduction in scope of projects preferentially to cancellation of the projects.

2.1 Aim and Objectives

The aim of the study is to manage the triple constraints through forecasting the cost of resources namely men, material and machinery in construction project to attain enhanced project performance with preeminent efficacy.

The following are the objectives of the study:

- To identify the critical factors that influencing the triple constraints in construction projects.
- To prioritize and correlate the significant factor among various sub factors to enhance project performance.
- To map the factor and forecasted data related to men material and machinery over the life cycle of project to study their impact at each stage.
- To find the critical forecasted factor and their severity on the life cycle of project.
- To forecast the trends in rate of construction material, labor and equipment and to study their impact on performance of project.
- To suggest measures to enhance the project performance.

3. RESEARCH METHODOLOGY

Researched methodology had been framed for Factors impact on triple constraints in construction project. The aim and objectives of the study was formulated after the identification of problems in the construction industry. The questionnaire survey had been framed based on the case studies & expert opinion under 8 main factors and corresponding 56 sub factors. The influencing factors were identified through discussion with various construction companies involving stakeholders such as project managers, project engineers, quantity surveyor and so on. Respondents from various construction firm were requested to rate the 4-point scale 1-4, for each factor which was considered to be the major reason that influence the triple constraints in construction projects with their experience in the firm. The data were procured from construction companies for the analysis of future rate. The acquired data have been analyzed to forecast the future rate for the next five years by comparing the rate of resources of men, material and machinery for past 6 year. The forecasting data were mapped over the life cycle of project to study their impact at each stage. Outcome of percentage increase in rate variation portrays the most critical resources that impacts the project progress. The appropriate suggestion for enhancing the project performance has been catered.

3.1 Factor Identification

The following factors have been identified and categorized in to different groups and subgroups with their dependency through expert opinion and case studies.

MAIN FACTOR	SUB FACTOR
Design And Documentation Related Factor	Mistakes and discrepancies in design documents
	Delay in producing design documents
	Unclear and inadequate details in drawing
	Complexity of project design
	Insufficient data collection and survey before design
	Misunderstanding of owners requirements by design Engineer
Financial Management Related Factors	Poor financial control on site
	Financial difficulties of owner
	Delay in progress payment by owners
	Delay payment to supplier/subcontractors
	Contractual claims such as extension of time with cost claims
	Difficulties in financial project by contractor
Information And Communication Related Factor	Lack of coordination
	Slow information flow
	Lack of communication
Material and Machinery Related Factor	Fluctuation of prices of materials
	Shortage of materials
	Late delivery of material and equipment
	Change in material type and specification during construction
	Damages in sorted material while they are needed urgently
	Low level of equipment operator skills

Human Resource Related Factors	Equipment shortage
	Poor quality of equipment spares
	Labour absenteeism
	High cost of labour
	Accident and injury during construction work at site
	Change in the scope of the project
	Delays in decision making
	Inaccurate quantity take-off
	Legal disputes between parties
Project Management Related Factors	Underestimate of project time and duration
	Lack of experience in some type of project
	Risk and uncertainty associated with projects
	Lack of proper training and experience of PM
	Poor project management
	Lack of appropriate software
Contractor site management factor	Poor site management and supervision
	Incompetent subcontractors
	Schedule delay
	Inadequate planning and scheduling
	Lack of experience
	Mistake during construction phase
	Inadequate monitoring and control of cost
	Inadequate time and cost estimates
External Factors	Effect of social and cultural factors
	Traffic control and restriction at job site
	Changesin government regulation and laws
	Delay in providing services and utilities
	Natural disasters
	Catastrophe effect on construction activities
	Unavailability of utilities in site (eg: water, electricity)

4. DATA COLLECTION AND ANALYSIS

4.1 Respondent Profile

The data were collected from experts in various construction industries. The questionnaires were distributed to the various construction industries and the respondents involved in the study had several years of experience in handling various types of projects. The respondent's designation and experience are shown in the figure 2 & 3

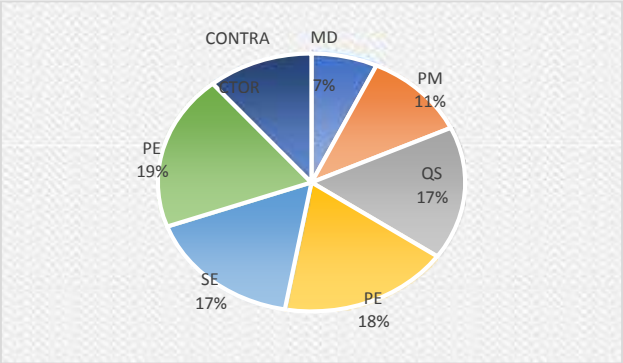


Figure 2: Percentage of respondent

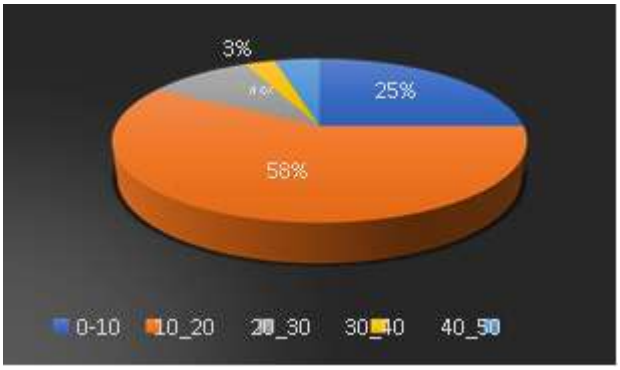


Figure 3: Year of experience for respondent

4.1 Reliability Test

The data collected from the questionnaire must be reliable and consistent, so the acquired data through Delphi method from experts have been checked for its reliability. For such analysis, Cronbach alpha for reliability is calculated using statistical tool SPSS version 20 as shown in table II. When the Cronbach alpha value of reliability for the data is less than 0.3, the data collected is not reliable and cannot be adopted. Reliability will be at high level, only when the Cronbach alpha is more than 0.6-0.9.

Figure 4: Factor and sub factors entered into SPSS Version 2.0 tool

Table II- Ranking for the factors

S.NO	FACTORS	CRONBACH ALPHA VALUE
1	Design and Documentation Related Factors	0.846
2	Financial Management Related Factors	0.756
3	Information and communication Related Factors	0.754
4	Material and Machinery Related Factors	0.768
5	Human Resources Related Factors	0.770
6	Project Management Related Factors	0.767
7	Contractor Site Management Related Factors	0.823
8	External Factors	0.762
OVER ALL CRONBACH ALPHA VALUE		**0.781**

4.2 Relative Importance Index

The RII is used to rank the different causes. These rankings make it possible to cross-compare the relative importance of the factors as perceived by the groups of respondents. Each individual cause's RII perceived by all respondents should be used to assess the general and overall rankings

$$RII = \frac{\sum W}{A \times N}$$

W = Weighting given to each factor by the respondents and ranges from 1 to 4

A = Highest weight

N = Total number of respondents

Table III – Ranking Criteria

Very important	Important	Somewhat important	Not important
N4	N3	N2	N1
4	3	2	1

Table IV- Ranking for the factors

Human Resources Related Factors	0.704	3
Project Management Related Factors	0.698	4
Contractor Site Management Related Factors	0.731	2
External Factors	0.557	8
Human Resources Related Factors	0.704	3
Project Management Related Factors	0.698	4
Contractor Site Management Related Factors	0.731	2
External Factors	0.557	8

4.4 Factor Analysis

It is a technique used to reduce a large number of variables or factors into fewer number of factors. It is part of General linear model (GLM), which includes relevant variables into analysis and there is true correlation between factors. Among different type of methods to extract the factor from the data set, **principal component model** has been used in the analysis to Identify the most critical factors that influencing the triple constraints in construction project impacting project progress. From this analysis, **eight critical factors** are identified using PSPP, the factors are listed below:

- Inadequate planning and scheduling
- Insufficient data collection and survey before the design part
- Shortage of workers and
- Misunderstanding of owner's requirement by design engineer
- Lack of experience
- Unavailability of skilled labor
- Mistake and discrepancies in design documents

4.5 Forecast the Future Rate

The process of estimating a future event by casting forward past data. The past data are systematically combined in a predetermined way to obtain the estimate of the future. Trend projection model was used to predict the future rate of resources in construction project. straight line trend is represented by the equation:

$$Y=a + bX$$

Y= Forecast rate of resources X= Year

a= Intercept (base level) b= Slope (trend)

The rates of resources namely material, men and machinery are collected from construction industry. The rates of material for past 6 years and cumulative of hike in each material are listed below:

Table V- Rates of construction Material

ITEM NO	ITEM DESCRIPTION	UNIT	RATES OF CONSTRUCTION LABOUR						CUMMULATIVE % OF HIKE
			2012	2013	2014	2015	2016	2017	
1	Cement	Bag	280	300	320	330	350	380	26.31
2	Reinforcement steel	kg	39	43	44	46	59	53	26.41
3	Structural steel	Kg	38	42	43	45	58	52	26.92
4	River sand	Cft	16	20	25	33	40	60	56.67
5	40mm aggregate	Cft	12	14	16	20	24	31	61.29
6	20mm aggregate	Cft	13	15	17	23	26	28	53.57
7	12mm aggregate	Cft	10	12	14	16	18	23	56.52
8	Quarry dust	Cft	5	7	9	10	18	25	80
9	Bricks	No	4	4.5	5	5	5.5	6	33.33
10	Fly ash bricks 9"x4"x3"	No	5.5	6	6.5	6.5	7	7.5	26.67
11	Fly ash bricks 9"x9"x4"	No	6	6.5	7	7	7.5	8	25
12	RR Stone	No	9	10	11	12	15	18	50
13	Soling Stone	Cft	9.5	11	12.5	17	21	28	66.07
14	Solid Block, 200mm thick	No	12	13	14	15	15	16	25
15	Solid Block, 150mm thick	No	9	10	11	12	12	13	30.77
16	Gravel	Ctf	6	9	10	11	12	13	53.85
17	Brick aggregate	Cft	32.5	35	40	42.5	45	50	35
18	Plasticizer	Kg	3	3.5	4	4.5	4	5	40
19	Bitumen 80/100	Kg	41	45	48	49	52	53	22.64
20	Solid Block, 100mm thick	No	7	8	9	10	10	11	36.36
21	Kerosene oil	Litre	36	39	42	45	48	50	28

The sample calculation in Minitab for trend rate of cement for next five years in construction projects.

Figure 5- Sample trend rate in Minitab

Trend projection model has been used to measure the cost trends in the construction industry. Table 5 shows the forecasted price of the various material in the construction industry for the periods 2018to 2022. Likewise, the cost can be forecasted for all the resources considered for this study.

Table VI- Forecast rate for materials (2018-2022)

ITEM NO	ITEM DESCRIPTION	UNIT	RATES OF MATERIALS				
			2018	2019	2020	2021	2022
1	Cement	Bag	398.48	417.34	436.2	455.06	473.92
2	Reinforcement steel	kg	59.91	63.34	66.77	70.2	73.63
3	Structural steel	Kg	60.74	64.17	67.6	71.03	74.46
4	River sand	Cft	64.14	72.37	80.6	88.83	97.06
5	40mm aggregate	Cft	41.42	45.11	48.8	52.49	56.18
6	20mm aggregate	Cft	37.68	40.94	44.2	47.46	50.72
7	12mm aggregate	Cft	27.74	30.17	32.6	35.03	37.46
8	Quarry dust	Cft	28.94	32.77	36.6	40.43	44.26
9	Bricks	No	6.85	7.50	8.15	8.8	9.45
10	Fly ash bricks 9"x4"x3"	No	8.40	9.05	9.7	10.35	11
11	Fly ash bricks 9"x9"x4"	No	29.42	31.4	33.37	35.34	40
12	RR Stone	No	19.74	21.48	23.22	24.96	26.7
13	Soling Stone	Cft	32.34	35.97	39.61	43.23	46.86
14	Solid Block, 200mm thick	No	36.14	37.28	38.42	39.56	40.7
15	Solid Block, 150mm thick	No	34	35	36	37	38
16	Gravel	Ctf	16.48	17.77	19.06	20.35	21.645
17	Brick aggregate	Cft	52.31	55.74	59.17	62.6	66.03
18	Plasticizer	Kg	87.48	90.51	93.54	96.57	99.6
19	Bitumen 80/100	Kg	54.0	57.14	59.48	61.82	64.16
20	Solid Block, 100mm thick	No	37.96	40.02	42.08	44.14	46.2
21	Kerosene oil	Litre	53.76	56.62	59.48	62.34	65.34

5. RESULT AND DISCUSSION

5.1 Mapping the Factors Over Life Cycle of Project

The factor influencing the triple constraints has been identified and mapped over the life cycle of the project.

1. Initiation and Planning Phase

- Delay in decision making by owner
- Land acquisition
- Delay in obtaining approvals from cooperation
- Mistake and discrepancies in design
- Inadequate planning and scheduling
- Delay in producing design document
- Improper site investigation

- Frequent changes in design by owners

2. Execution Phase

- Poor site management and supervision
- Poor financial control at site
- Late procurement of material
- Fluctuation of material prices
- Delay in payment by owners
- Shortage of skilled labors and site workers
- Mistake and discrepancies in design
- Lack of communication
- Catastrophe effects at site
- Poor selection of technology equipment.

3. Closure Phase

- Additional work by owner requirement.
- Legal dispute between parties.
- Contractual claims such as extension of time and cost claim.
- Delay in performing final inspection and certification.
- Payment issue between parties

5.2 Mapped Resources Over Life Cycle

Forecasting parameters (men, material and machinery) were mapped over the life cycle of project and their severity level of influence and critical parameters were identified. The below table VII shows the severity level in the life cycle of project.

Figure 6 – Mapping forecasted data

Table VII - Severity of parameters in life cycle of project

PARAMETERS	HIGH	MEDIUM	LOW
MATERIALS	4	2	3
LABOURS	4	3	2
MACHINERY	2	3	4

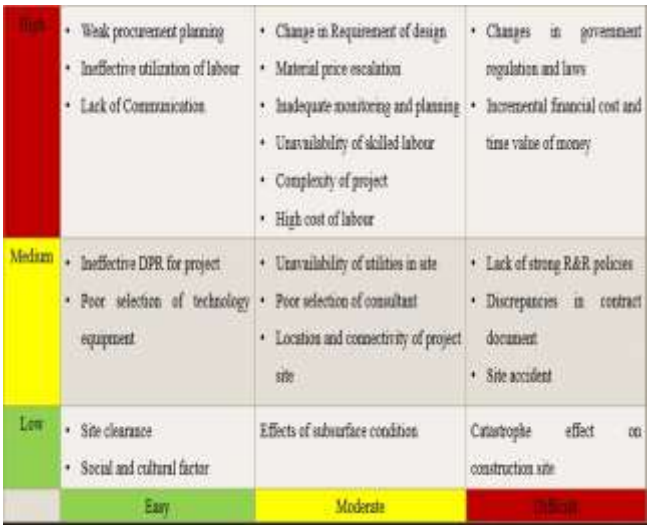
5.3 Rate of Escalated Resources

The cumulative percentage of hike in each resource has been identified and the top five critical resources in the projects are given below:

Table VIII- Top five highly cumulative escalated rate of various resources

TOP FIVE HIGH RATE OF ESCALATED RESOURCES					
MATERIAL RATE		LABOUR RATE		EQUIPMENT RATE	
Name of material	% of increases	Name of labour	% of increases	Name of equipment	% of increases
Quarry dust	80%	Tile layer	58.33%	Bob cats	50.91%
Soling Stone	66.07%	Mixer operator	58.33%	Road Roller	50.48%
12mm aggregate	56.52%	Female helper	55.55%	Excavator	48.57%
Gravel	53.85%	Stone Cutter	54.45%	Crawler Crane	40%
20mm aggregate	53.57%	Plumber	50%	Grinding Machine	34.51%

5.4 Model for Enhancing Project Performance



6. CONCLUSION

Construction industry has been twined with costoverrun and delays, making a obligation to manage these triple constraints from impacting project performance over the life cycle of the project. The outcome from these analysis Shades the light to the constraints (SCOPE, TIME, COST) in construction industry enhancing performance of the project by implementing the following suggestions arrived from the results of analysis.

- Expert opinion through questionnaire survey envisages the "Impact level of various factors on construction projects". (Considerations of the critical factors with the impact over the life cycle of the projects to attain the objectives).
- Forecasting the rate of various resources with the past trend rate using trend projection model (Identification of the critical resources with high price escalation to be incorporated in planning stage of the project)
- Suggestions over the life cycle of the projects sustaining dualistic benefits of reaching the objectives of the project with enhanced performance.

6.1 SUGGESTION

- Institutionalize project management training for professionals
- Responsibilities must be shared with all stake holders in construction such as engineers, planning managers.
- Select design and engineering consultant on the basis of quality –cum-cost assessment
- Documentation of change to avoid discrepancies or mistake in future
- Ensuring subcontractor with capability to deal with project
- Having a stringent process in place for selecting subcontractors into the supply chain
- Quality of work of activities at every stage must be implemented to reduce the mistakes that lead to rework of activities.

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