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# Optimization of Factors that Critically Impact Time and Cost Overrun in Construction Projects

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***Abstract: The current study seeks to optimize the factors impacting the time and cost overrun in construction projects. The effect of widely identified factors of cost, time, quality, productivity, client satisfaction, environment, regulatory and community satisfaction and health and safety have been considered in this study. Data on the study variables were gathered from more than seventy construction projects stakeholders such as academia, engineers, contractors, real estate developers, architects, government official etc. using a standardized questionnaire. This paper focuses on use of relative importance index and statistical technique of ANOVA hypothesis to get an optimal solution of the factors that critically impact time and cost overrun in construction projects***
***Keywords: Relative Importance Index, Time and Cost overrun, ANOVA, Statistical Analysis, Optimization, and Construction***

## I. INTRODUCTION

The Indian construction industry is an essential indication of progress since it generates investment opportunities in a variety of connected sectors. In 1954, the National Industrial Development Corporation (NIDC) established the first professional advisory firm in the public sector. As a result, several architectural, design engineering and construction firms were established in public sector like NBBC, IRCON, RITES, HCC etc. The building sector is a vital component of any emerging country's economy growth. Its supplies the physical structure that is essential for the developers of the country. The Indian real estate sector is expected to reach a market size of $ 180 billion by 2020.

The construction industry expected to record a CAGR of15.7% to reach $ 738.5 billion by 2022 [11]. The government has laid out expansive plans in its National infrastructure plan to spend Rs. 111 Lakh corer in building infrastructure in the next five years, especially focusing on energy, road, urban infrastructure and railways [10]. Since the construction industry is volatile, every contractor needs an excellent money management, if they are to be capable to save money and time. But most of the time it is difficult. The major reason for the overrun in time and cost is inadequate planning at the outset of the project. When the project gets delayed, either the delivery time of the project gets extended or the progress of the project is accelerated heavily to deliver it in time [8]. The time required to complete the construction of public projects is infrequently greater than the time specified in the contract. These 'overruns' or time extensions are due to reasons such as cost, time and quality [8]. Overrun in time and expense occur in many construction projects and its magnitude varies from project to project. It is critical to establish the true reason of time and cost overrun in order to reduce and avoid delays and cost addition in any infrastructure project.

## II. OBJECTIVE

The main objective of study is to statistically analyse and optimize the factors that critically affect resource related detention of cost and time overrun in construction projects in India.

## III. RESEARCH METHODOLOGY

Based on extensive and thorough study of available literature, a questionnaire was designed to include factors that have been recognized to significantly contribute to the time and cost overrun in construction project. A total of forty seven resource related factors were identified and classified under eight broad categories i.e. cost (11 factors), time (8 factors), quality (6), productivity (5), client satisfaction (5), regulatory and community satisfaction (4), health and safety (5), and environment (3). further, a five point Likert Scale with values ranging from 1 (very low importance) to 5 (very high importance) was assigned to receive responses from construction industry stakeholders such as assistant engineers, S.O.D, sub engineers, site supervisors, academia, design engineers, project owners, green consultant, real estate developers, architects, contractors and industrialists.

### A. Data Collection

More than 100 stakeholders were approached to share their views on the subject based on their experience and expertise in this subject. A total of 71 responses were received from a variety of professional specialist across the country with some directly from government departments like PWD, PMGSY, MPRRDA, PHE, MPPWDNH, PEDA and from renowned local enterprises engaged in various public and private projects of infrastructure development such as high-rise buildings, water resources development, group housing, highway projects, real estate, etc.

### B. Analysis method

The various factors identified were prioritized and validated based on responses received from stakeholders. The data received for the purpose, was analysed by computing the mean and standard deviation and coefficient of variance. For which, the responses received on the Likert Scale value of 1 to 5 were converted to apply a factor of 0.2 to 1.0 respectively.

Based on the importance assigned by the respondent to each factors, a Relative Importance Index (RII) was computed for each factor using equation (1) [7].

$$\boldsymbol{RII} = \frac{n_5^5+n_4^4+n_3^3+n_2^2+n_1^1}{A\times N} * 100 \quad (1)$$

Where, $n_5$ is no. of respondents for very high importance, $n_4$ is no of respondents for high importance, $n_3$ is no. of respondents for medium importance, $n_2$ is no of respondents for low importance, $n_1$ is no. of respondents for very low importance, A is 5 (Highest value i.e. very high importance), N is total no of respondents (i.e. 71 in this case)

The index was further used for identify the most critical factors for the purpose of optimization, based on higher values obtained by the factors in the indexing.

Next, statistical technique of two-way Analysis of Variance (ANOVA) was applied to calculate the relevance of the group factors based on the importance assigned by the respondent to the particular factor.

The ANOVA statistical technique compare over a variable over two or more groups (factors and respondent in this case) controlling each other.

The strength of hypothesis depending on problem categories and classification of the survey is investigated.

The hypothesis adopted in this study was based on the assumption that construction company problem increase with classification. Based on this, the value F is compared with F critical ($F_C$) which depends upon the degree of freedom of number of respondents and factors [9].

The confidence level for this analysis was taken as 95% implying level of significance of 5% [2]. The value F less than $F_C$ implies that null hypothesis of the group under consideration, fails to reject ($H_0$) and vice-versa. The null hypothesis failing to reject implies that the particular group of factors under consideration has impact on time and cost overrun.

Selection of sample size is an important part of the ANOVA technique, a small sample is to be selected for the analysis. For the present study, sample selection was done randomly from the seventy one responses.

As a start, to understand the sensitivity of the sample size to the hypothesis, all 71, 50, 20, 11, 8 and 3 samples were analysed randomly. It was found that the higher value of 71 and 50 have values different than the values obtained at 20 and lesser. Hence the sample size of twenty was finally chosen for the results commensurate with its ANOVA method compatibility in relation to the number of factors to be evaluated in each groups.

Result of RII and ANOVA were then finally used for optimization of the factors that are more critical to time and cost overrun in construction projects.

## IV. RESULT & DISCUSSION

The data obtained from the survey has normal distribution. Some have been shown in fig.1 for Material & equipment's cost, time needed to rectify defects, Number of rework and project complexity. Mean values, standard deviation and coefficient of variance of the study data were obtained in the range of 0.62 to 0.83, 0.14 to 0.23 and 0.19 to 0.34 respectively. These values indicate a low scatter of the importance assigned to factor chosen, hence validating their importance in time and cost overrun in construction project. Relative Importance Index (RII) values obtained in the range 60 to 100, higher value indicates higher importance of the factors.

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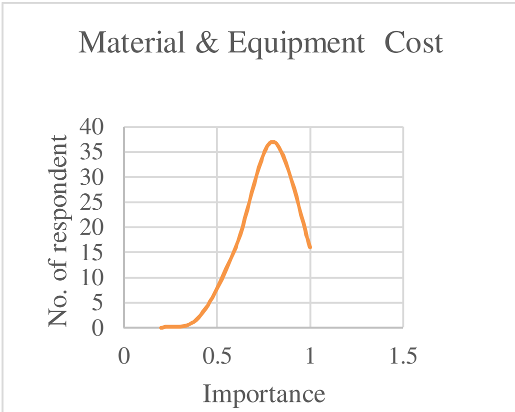
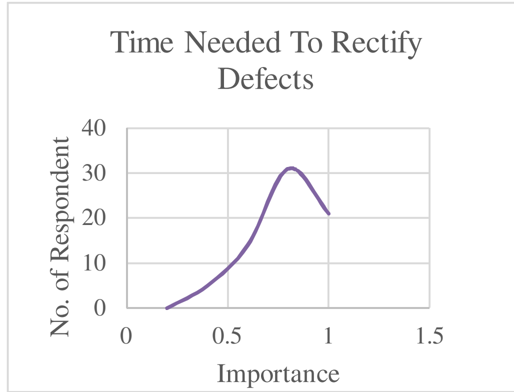



(a)

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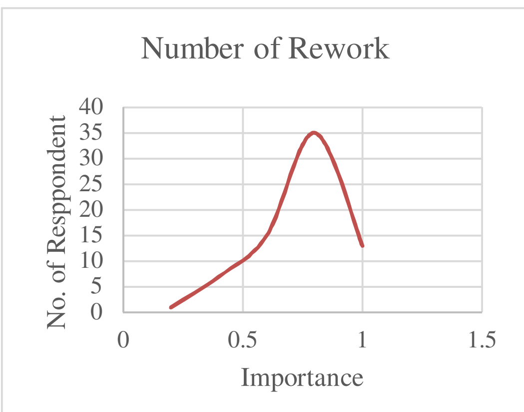


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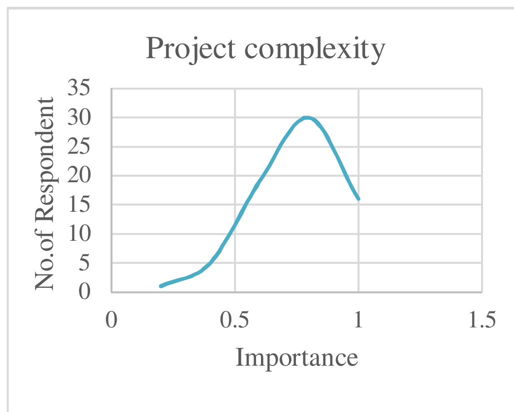


(d)

Figure- 1 Normal Distribution of Data
(a) Material and equipment Cost (b) Time needed to rectify defects (c) Number of rework (d) Project Complexity

Table 1: Relative Importance Index (RII) of factors identified fro Time and Cost Overrun in construction Project

| Factors | RII |
|---|---|
| Cost control system, Leadership skills for project manager, Quality of equipment's and raw materials in project, Easiness to reach to the site (location of project), Information coordination between owner and project parties, Participation of managerial levels with decision making, Average delay because of closures and materials shortage, Quality assessment system in organization, Sequencing of work according to schedule, Time needed to rectify defects. | 80-100 |

| | |
|---|---|
| Material and equipment cost, Application of Health and safety factors in organization, Learning from own experience and past history, Project overtime cost, Reportable accidents rate in project, Number of disputes between owner and project parties, Planned time for project construction, Wastes around the site, Project labor cost, Regular project budget update, Speed and reliability of service to owner, Quality and availability of regulator documentation, Availability of resources as planned through project duration, Site preparation time, Project complexity, Absenteeism rate through project, Cost of rework, Assurance rate of project, Management-labor relationship, Cost of variation orders, Number of reworks, Conformance to specification, Availability of personals with high experience and qualification, Number of new projects / year, Average delay in payment from owner to contractor, Neighbours and site conditions problems, Quality training/meeting, Time needed to implement variation orders, Cost of compliance to regulators requirements, Number of non-compliance to regulation, Cash flow of project, Average delay in claim approval, Air quality. | 70-80 |
| Noise level, Liquidity of organization, Market share of organization | 60-70 |

Tables 2 to 9 show the results of two way ANOVA analysis for the eight groups of factors.

Table: 2 ANOVA Analysis of Cost Factors

| *Source of variation* | *Sum of Square (SS)* | *Degree of freedom (df)* | *Mean Square (MS)* | *F* | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| *Factors* | 0.41 | 10 | 0.041 | 1.08 | 1.88 | Accepted |
| *Respondent* | 1.16 | 19 | 0.061 | 1.60 | 1.64 | Accepted |
| *Error* | 2.27 | 190 | 0.038 | | | |
| *Total* | | 219 | | | | |

Since $F<F_C$, therefore we fail to reject null hypothesis. In other words, we conclude that all the respondents agree on the ranking of cost factors and thus factor group contributes significantly to time and cost overrun.

Table: 3 ANOVA Analysis of Time Factors

| SOURCE OF VARIATION | SUM OF SQUARE (SS) | DEGREE OF FREEDOM (DF) | MEAN SQUARE (MS) | F | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| FACTORS | 0.132 | 7 | 0.014 | 0.5 | 2.08 | Accepted |
| RESPONDENT | 0.086 | 19 | 0.046 | 1.64 | 1.67 | Accepted |
| ERROR | 3.65 | 133 | 0.28 | | | |
| TOTAL | 3.86 | 159 | | | | |

Since $F<F_C$, therefore we fail to reject null hypothesis. In other words, we conclude that all the respondents agree on the ranking of time factors and thus factor group contributes significantly to time and cost overrun.

Table: 4 ANOVA Analysis of Quality Factors

| Source of variation | Sum of Square (SS) | Degree of freedom (df) | Mean Square (MS) | F | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| Factors | 0.015 | 5 | 0.030 | 1.1 | 2.31 | Accepted |
| Respondent | 1.06 | 19 | 0.055 | 0.6 | 1.69 | Accepted |
| Error | 3.19 | 95 | 0.033 | | | |
| Total | 4.26 | 119 | | | | |

Since $F<F_C$, therefore we fail to reject null hypothesis. In other words, we conclude that all the respondents agree on the ranking of quality factors and thus factor group contributes significantly to time and cost overrun.

Table: 5 ANOVA Analysis of Productivity Factors

| Source of variation | Sum of Square (SS) | Degree of freedom (df) | Mean Square (MS) | F | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| Factors | 0.038 | 4 | 0.0094 | 0.32 | 2.50 | Accepted |
| Respondent | 0.89 | 19 | 0.0468 | 1.59 | 1.72 | Accepted |
| Error | 2.23 | 76 | 0.030 | | | |
| Total | 3.15 | 99 | | | | |

Since $F<F_C$, therefore we fail to reject null hypothesis. In other words, we conclude that all the respondents agree on the ranking of productivity factors and thus factor group contributes significantly to time and cost overrun.

Table: 6 ANOVA Analysis of Client Satisfaction Factors

| Source of variation | Sum of Square (SS) | Degree of freedom (df) | Mean Square (MS) | F | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| Factors | 0.20 | 4 | 0.05 | 2 | 2.49 | Accepted |
| Respondent | 0.81 | 19 | 0.042 | 1.68 | 1.72 | Accepted |
| Error | 1.90 | 76 | 0.025 | | | |
| Total | 3.15 | 99 | | | | |

Since $F<F_C$, therefore we fail to reject null hypothesis. In other words, we conclude that all the respondents agree on the ranking of client satisfaction factors and thus factor group contributes significantly to time and cost overrun.

Table: 7 ANOVA Analysis of Regulatory and Community satisfaction Factors

| Source of variation | Sum of Square (SS) | Degree of freedom (df) | Mean Square (MS) | F | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| Factors | 0.135 | 3 | 0.045 | 2.81 | 2.76 | Rejected |
| Respondent | 1.23 | 19 | 0.064 | 4.0 | 1.77 | Rejected |
| Error | 0.905 | 57 | 0.016 | | | |
| Total | 2.27 | 79 | | | | |

Since $F > F_C$, therefore we reject null hypothesis. In another words, we conclude that all the respondents do not agree on the ranking of regulatory and community satisfaction factors and thus factor group does not contribute significantly to time and cost overrun.

Table: 8 ANOVA Analysis of Health and Safety Factors

| Source of variation | Sum of Square (SS) | Degree of freedom (df) | Mean Square (MS) | F7 | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| Factors | 0.19 | 4 | 0.048 | 1.54 | 2.49 | Accepted |
| Respondent | 1.02 | 19 | 0.053 | 1.70 | 1.72 | Accepted |
| Error | 2.40 | 76 | 0.031 | | | |
| Total | 3.60 | 99 | | | | |

Since $F < F_C$, therefore we fail to reject null hypothesis. In other words, we conclude that all the respondents agree on the ranking of health and safety factors and thus factor group contributes significantly to time and cost overrun.

Table: 9 ANOVA Analysis of Environment Factors

| Source of variation | Sum of Square (SS) | Degree of freedom (df) | Mean Square (MS) | F | $F_C$ | $H_0$ |
|---|---|---|---|---|---|---|
| Factors | 0.08 | 2 | 0.040 | 4.154 | 3.244 | Rejected |
| Respondent | 2.73 | 19 | 0.144 | 14.70 | 1.86 | Rejected |
| Error | 0.37 | 38 | 0.007 | | | |
| Total | 3.18 | 59 | | | | |

Since $F > F_C$, therefore we reject null hypothesis. In another words, we conclude that all the respondents do not agree on the ranking of environment factors and thus factor group does not contribute significantly to time and cost overrun.

Based on the analysis it has been found that out of the eight groups selected, six groups (40 factors) are more significant. The 6$^{th}$ and 8$^{th}$ factor groups of Environment, Regulatory and Community Satisfaction factors are not as significant as the above six groups to time and cost overrun.

As final step these forty factors found as significant, they are further analysed in lieu of the ranking assigned to them based on their Relative Importance Index (RII) for optimization of factors to obtain the factors that are most critical to time and cost overrun.

10 factors with RII of 80 and above amongst these were finally found as critical factors are Cost control system, Leadership skills for project manager, Quality of equipment's and raw materials in project, Easiness to reach to the site (location of project), Information coordination between owner and project parties, Participation of managerial levels with decision making, Average delay because of closures and materials shortage, Quality assessment system in organization

## V. CONCLUSIONS

The objective of the present study was to explore the critical factors affecting the time and cost overrun in construction projects. 47 factors related to cost, time, quality client, and productivity, regularity community, health-safety and environment were identify for the study. Data variables of importance of these factors were collected through standard questionnaire from Assistant Engineer, S.D.O, sub engineer, site supervisor, academia, design engineer, project owner, green consultant, real estate developers, architectures, contractors and industrialist. Various statistical tools such as ANOVA hypothesis test, relative importance indexing, coefficient of variance, computation of means and standard deviation were used for optimization the factors that are most critical. The results of the study reveal that the factors related to cost factors, time factors, quality factors, client satisfaction factors, & Health and safety factors in construction projects are most critical. The study recommends that the above factors should be considered by the stakeholders of construction projects for avoided time and cost overruns. Control over these factors right from project inception to construction stage can help completing the project in time and within the planned budget.

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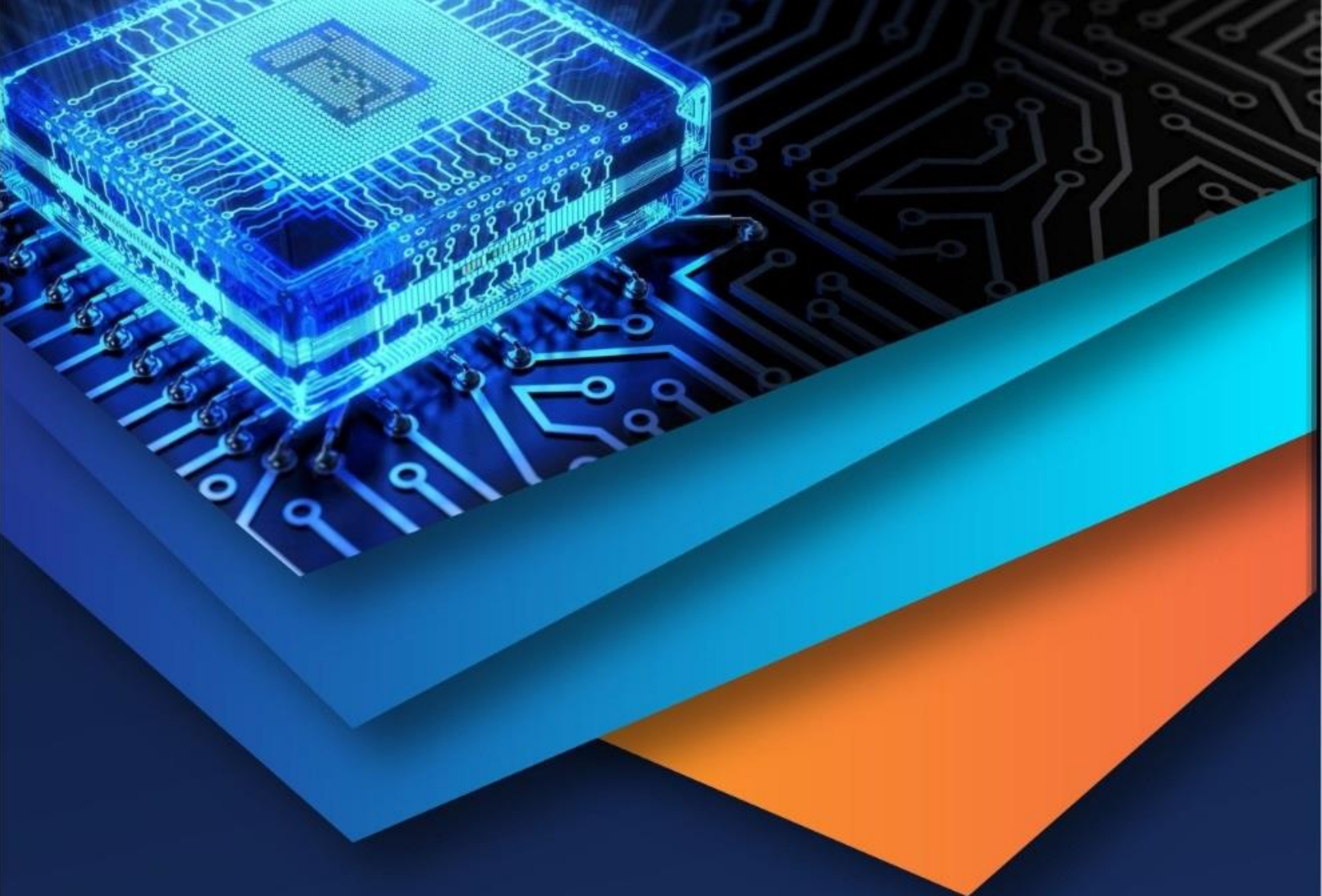


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