Forecasting Delays and Budget overruns resulting from Material-Related Factors

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Abstract: The construction industry's success hinges on effective materials management, a complex process vital for timely and cost-effective material availability. Despite its significance, a notable gap exists in academic research on this critical aspect. This study addresses the gap by introducing a delay prediction model aimed at preempting project delays due to material-related challenges, offering a proactive project management strategy. Materials account for 60-70% of direct costs, and delays resulting from inefficiencies incur significant financial implications. The proposed algorithm, rooted in rigorous academic exploration, utilizes correlation matrices to predict time and cost overruns. The research concludes with a comprehensive analysis, validating the algorithm's utility by revealing average delays and cost overruns for diverse construction components. This study underscores the paramount importance of materials management in construction project success and offers a practical algorithm with potential real-time applications, suggesting avenues for future research expansion.

1. Introduction

Within the dynamic construction industry, the effective management of materials stands out as a pivotal factor for project success. The intricate process of material management coordinates the planning, execution, and regulation, ensuring a seamless availability of building materials precisely where and when they are needed. This discipline not only seeks to identify and procure materials of the right quality and quantity but also aims to do so in a timely and cost-effective manner [1], [2]. Serving as the backbone of project management, material efficiency in construction plays a crucial role in cost control and the timely completion of projects [3], [4].

Materials constitute a substantial portion of construction expenses, making them integral to the success of any project. The efficient coordination of various stages in materials management, including measurement, specification, procurement, delivery, and utilization, becomes paramount [5]. However, the construction landscape is fraught with challenges, and disruptions in this delicate process are common. Persistent issues such as delays stemming from late ordering, inaccurate delivery schedules, overordering, material errors, theft, and inefficient handling pose significant challenges on construction sites [2], [5], [6].

The critical role of materials management in influencing project outcomes underscores the necessity for heightened attention in this area. The seminal work of [5] delves into a broad spectrum of factors impacting construction delays, emphasizing the need for a granular exploration of material-related challenges, particularly in the unique context of the Indian construction milieu.

Despite the undeniable significance of materials management, there exists a disproportionate lack of academic scrutiny on this vital aspect. Rather than pursuing an exploratory research approach, this study proposes the development of a delay prediction model [7]. This model aims to leverage existing data and insights to forecast potential delays in construction projects, specifically focusing on material-related challenges. By adopting a predictive approach, this research seeks to provide proactive strategies for mitigating time and cost overruns in construction projects, offering a more targeted and practical contribution to the field [7], [8], [9], [10].

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2. Literature Review

2.1. Material Management

Material management is a critical organizational system overseeing the planning and regulation of material quality and quantity, ensuring timely equipment installation, fair pricing, and appropriate quantities as needed. It integrates supplier purchasing, shipping, and material control, defining a method for executing a cost-effective construction process by sourcing materials with precise quality at the right time and location [9],[11], [12]. Effective material cost control relies on seamless coordination, covering critical aspects such as materials purchase, consumption, and storage. Beyond cost considerations, materials management plays a pivotal role in optimizing manufacturing processes, encompassing correct usage, transportation, storage, handling, and distribution of materials. It also oversees personnel in marketing, buying, inventory control, retail management, and materials handling, highlighting the importance of a dedicated materials management department in businesses for effective manufacturing tasks and commodity management [8], [12], [13].

2.2. Delays in Construction Projects

In the construction industry, delays, defined as periods extending beyond the agreed completion date, pose significant challenges, leading to lost revenue for project owners and increased overhead expenses for contractors. On-time project completion signifies efficiency, but the construction process is susceptible to various unforeseen events stemming from factors such as parties' performance, resource availability, environmental conditions, engagement of other parties, and contractual relationships [14], [15], [16]. Despite these challenges, projects are rarely completed within the initially stated time frame. Material management in construction is a systematic process coordinating planning, demand analysis, sourcing, purchasing, transporting, storing, and regulation of materials, aiming to reduce waste and increase profitability by lowering material costs, where materials contribute 60-70% of the direct cost in construction projects, with labor accounting for the remaining 30-40% [9], [17]. Researchers have highlighted the use of fly ash-based blocks for load-bearing structures, particularly in the Indian setting [18]. The usefulness of construction mechanization in reducing delays and enhancing building performance has been the subject of numerous studies [19].

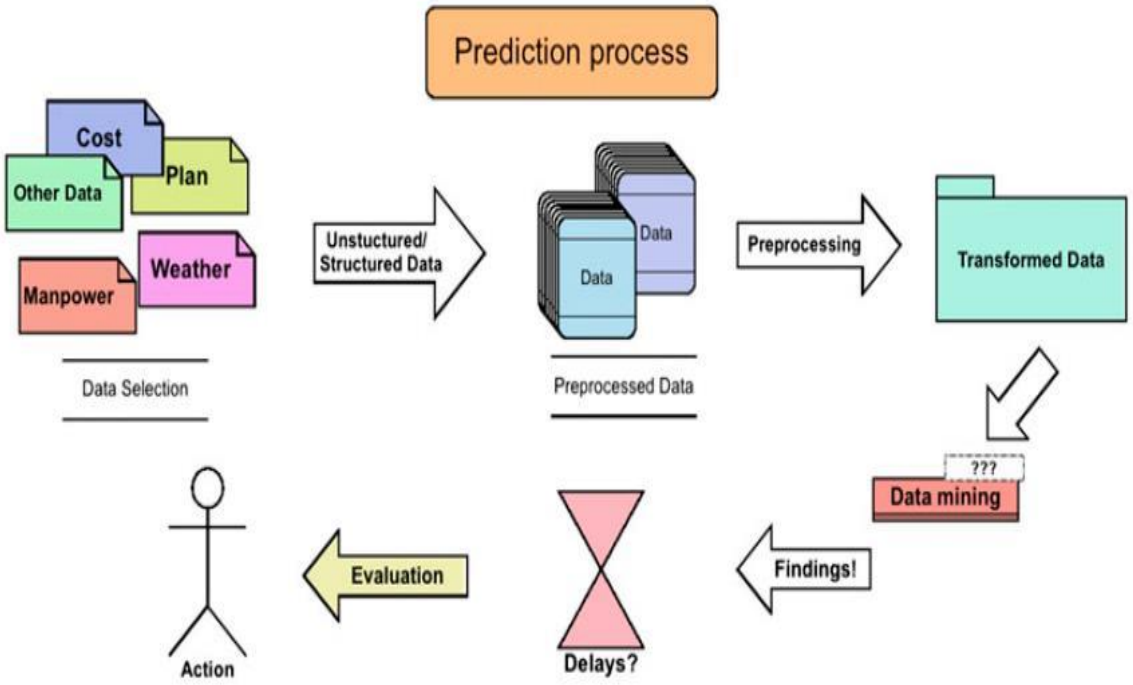

Fig. 1. Delay Prediction Process.

In Table 1 [20] very categorically and comprehensively listed out the issues with Material management that may further lead to delays.

Table 1. Factors related to materials causing Time and Cost Overrun.

S.no.	Main Factor	Sub Heads
1	MF1 - Inadequate Planning of Materials	F1 - Delay in approval of material by client
		F2 - Shortage of material in market
		F3 - Changes in material prices during construction
		F4 - Incorrect material take-off from drawings and design documents at time of placing order of material
		F5 - Incorrect order quantity of material
		F6 - Non integration of material planning with construction schedule
		F7 - Ambiguity in scope of work discovered at time of placing order of material
		F8 - Lack of knowledge with respect to lead time of materials from a specific supplier
		F9 - Availability of limited numbers of suppliers for procurement of material
		F10 - Not receiving materials at time of requirement
2	MF2 - Lack of Information and Communication	F11 - Lack of tracking of material (inadequate information on material delivery status and material usage in site)
		F12 - Lack of effective communication
		F13 - Lack of effective coordination and management of surplus materials, usable at other sites
		F14 - Improper handling of materials at site
		F15 - Low usage of information technology (IT) system in material management
		F16 - Difference in actual physical stock at site and commensurate data on computer-based system used for material management
		F17 - Non integration of updated material planning in computer-based system (EIP, SAP, etc.) used for material management
3	MF3 - Improper delivery of materials	F18 - Receiving incorrect type of material (materials do not match with purchase order)
		F19 - Lack of inspection and testing of materials by buyer department prior to delivery of material from suppliers' storage
		F20 - Receiving poor quality of material (material do not meet specifications)
		F21 - Damage and loss of material during transportation to site
4	MF4 - Difficulty in transportation of materials	F22 - Weather conditions like heavy rain, flood, snow, etc. during transportation of material
		F23 - On-site delivery difficulties (site access problem)
5	MF5 - Changes in scope of materials	F24 - Design changes during construction
		F25 - Changes in material specification during construction
6	MF6 - Financial issues in procurement	F26 - Delay in payment (payment not released within stipulated time) to supplier
		F27 - Shortage of fund to procure material

2.3. Algorithm for Analysis

The application of a classification-based data mining (machine learning) approach is employed to predict specific outcomes for data instances based on given inputs. This methodology utilizes a training set containing a set of attributes and the desired output, often referred to as the prediction attribute, to anticipate the outcome. By discerning potential connections between attributes, the algorithm attempts to predict the outcome [5], [20], [21]. Subsequently, a new data set, termed the prediction set, mirrors the attributes of the training set except for the prediction attribute. The algorithm analyzes this data to make predictions. In the context of this study, the construction database serves as the training set, housing essential project information, and the prediction attribute pertains to whether or not development was delayed. In an effort to enhance the performance of the construction sector for comparable projects, a survey is designed to address specific queries, and a data-mining prediction model is assessed using WEKA software. Delays significantly impact both the cost and timeliness of completing construction projects [22], [23], [24]. Identifying the reasons behind delays is crucial for mitigation, as understanding the causes can aid in prevention. Numerous studies have investigated factors influencing delay causes; however, due to the contextual nature of these issues, research must be tailored to specific geographical locations, nations, or regions to yield relevant insights [5], [25], [26].

3. Methodology

The questionnaire is a research tool that contains a series of questions for the purpose of collecting information from respondents. Questions can be considered as a written interview. They can be done face-to-face, by telephone, by computer, or by mail. Questionnaires provide a cheap, quick and effective way to get more information from a large sample of people. This is helpful for most people when conversations are not working. Questionnaires can be an effective way to measure performance, attitudes, preferences, ideas and objectives for large numbers of courses that are cheaper and faster than alternatives. Often a questionnaire uses open and closed questions to gather information. This is beneficial because it means that quantity and quantity information can be obtained.

Table 2. Mean RII and Weightage of Factors (Source: Author)

S. no.	Factors	RII (Frequency of Occurrence)	RII (Impact on Time Overrun)	RII (Impact on Cost Overrun)	Weightage for Factors
1	F1	0.56	0.67	0.65	0.63
2	F2	0.51	0.71	0.61	0.61
3	F3	0.63	0.71	0.64	0.66
4	F4	0.56	0.65	0.63	0.62
5	F5	0.61	0.66	0.64	0.63
6	F6	0.69	0.68	0.67	0.68
7	F7	0.60	0.61	0.64	0.62
8	F8	0.69	0.67	0.68	0.68
9	F9	0.74	0.65	0.67	0.69
10	F10	0.73	0.71	0.73	0.72
11	F11	0.62	0.66	0.66	0.64
12	F12	0.68	0.69	0.71	0.69
13	F13	0.61	0.61	0.64	0.62
14	F14	0.66	0.71	0.67	0.68
15	F15	0.74	0.62	0.65	0.67
16	F16	0.64	0.63	0.62	0.63
17	F17	0.70	0.67	0.64	0.67
18	F18	0.57	0.70	0.63	0.63
19	F19	0.62	0.66	0.63	0.64
20	F20	0.67	0.65	0.70	0.67
21	F21	0.62	0.61	0.64	0.62
22	F22	0.53	0.63	0.63	0.59
23	F23	0.57	0.59	0.62	0.59
24	F24	0.64	0.69	0.68	0.67
25	F25	0.66	0.69	0.71	0.69
26	F26	0.69	0.73	0.66	0.69
27	F27	0.66	0.73	0.65	0.68

In this study, data were collected through a systematic questionnaire designed to assess respondents' views on asset management in the construction of construction sites. Respondents were asked to rate their views on the frequency of occurrence of the factors identified for delays in a project pertaining to material and their impact on the project period and the cost on a five-point scale where, Very High = 5, High = 4, Medium = 3, Low = 2 and Very Low = 1.
The study was conducted in North India and a questionnaire is provided to contractors, clients and other representatives of the site or head office. A total of 39 respondents have given their responses on the floated questionnaire survey.

3.1. Relative Importance Index (RII)

Responses from respondents analyzed using the Microsoft Excel application. In terms of the content of the questionnaires, the analysis was divided into two parts: the statistical analysis of population significance and relative importance index. Analysis of related indicators was selected in this study to quantify the process according to its relative significance. The following formula is used to specify a relative reference.

$$RII = \sum \frac{W}{(A*N)} \quad 1)$$

W is the weight determined by each respondent on a scale of one to five, one being the lowest and five being the maximum. A is the maximum weight and N is the total number of specimens. Based on the ranking (R) of relative indices (RII), the weighted average for the two groups will be determined.
According to [27], five important levels are transformed from RII values as shown in Table 3.

Table 3. RII Values.

S.no.	Level	Range (RII Values)
1.	High (H)	0.8 – 1.0
2.	High-Medium (H-M)	0.6 – 0.8
3.	Medium (M)	0.4 – 0.6
4.	Medium – Low (M-L)	0.2 – 0.4
5.	Low (L)	0.0 – 0.2

Table 4. Average Time and Cost Overruns (Civil Works) (Source: Author)

Civil works			
S.no.	**Factors ID**	**Average Time over run (In weeks)**	**Average Cost Over Run (In Lakhs)**
1	F1	3.33	35.00
2	F2	3.33	45.83
3	F3	3.67	45.83
4	F4	3.33	35.83
5	F5	3.33	0.83
6	F6	3.00	38.33
7	F7	3.67	7.50
8	F8	3.67	15.00
9	F9	3.67	22.50
10	F10	3.67	15.00
11	F11	2.67	15.00
12	F12	2.67	1.67
13	F13	2.00	5.83
14	F14	1.00	4.17
15	F15	1.33	5.00
16	F16	2.33	10.83
17	F17	1.33	2.50
18	F18	2.00	3.33
19	F19	1.67	5.00
20	F20	2.00	5.83
21	F21	3.33	3.33
22	F22	3.67	44.17
23	F23	2.67	36.67
24	F24	3.67	45.83
25	F25	3.00	37.50
26	F26	2.67	15.00
27	F27	2.00	15.00

shows the weightage for individual factor has been calculated on the basis of RII for the three-criterion decided namely, the likeliness or Frequency of occurrence of the factor, the Impact on Time over run and the impact of Cost over run. Case studies have been analyzed to collect a range of data for the impact of each factor in ongoing construction project on the Time and cost overrun. After analyzing multiple case studies, a matrix of the impact of the factors pertaining to Management of materials that lead to Time and Cost overruns.

4. Data Analysis

A variety of data regarding the influence of each factor in an ongoing construction project on time and expense overruns has been gathered through the analysis of case studies. A matrix showing the effects of the materials management-related elements that cause time and cost overruns was created after examining several case studies. Average time over runs (in weeks) and Average cost overrun (in lakhs) analyzed from the data collected from the primary cases studies are given below in the table. The average values given in the **Error! Reference source not found.** below are for Civil works.**Error! Reference source not found.** provides a comprehensive analysis of 27 factors (F1 to F27) related to civil works, highlighting average time overruns ranging from 1 to 3.67 weeks and average cost overruns from minimal amounts to 45.83 lakhs. Most factors show a significant time overrun of 3.33 weeks, with some reaching up to 3.67 weeks. Concurrently, certain factors, including F2, F3, and F24, exhibit substantial cost overruns of 45.83 lakhs, emphasizing critical areas requiring immediate attention and remedial actions. These findings underscore the imperative for vigilant monitoring, strategic intervention, and efficient management to mitigate risks, optimize project outcomes, and ensure timely and budget-conscious completion of civil works projects.

Table 5. Summary output for Regression Statistics (Civil Works) (Source: Author)

Regression Statistics	
Multiple R	0.570717
R Square	0.325717
Adjusted R Square	0.298746
Standard Error	0.705205
Observations	27

The regression statistics in Table 5 offer insights into the relationship between variables under study, with a Multiple R value of 0.570717 indicating a moderate positive correlation. The R Square value of 0.325717 suggests that approximately 32.57% of the variability in the dependent variable can be explained by the independent variables. The Adjusted R Square, slightly lower at 0.298746, accounts for the impact of the number of predictors in the model, reflecting a slightly adjusted explanation of the variability. The Standard Error, measured at 0.705205, represents the average deviation of observed values from the predicted values, providing a measure of the model's accuracy. With 27 observations, these regression statistics provide a foundational understanding of the relationship dynamics and the predictive capability of the model, indicating areas for further exploration and refinement to enhance model reliability and effectiveness.

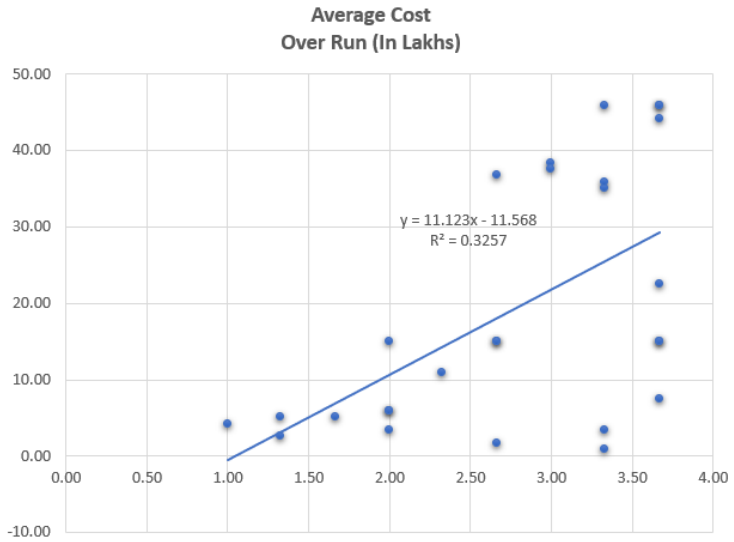

Fig. 2. Average Cost overrun (Civil Works) (Source: Author)

Average time over runs (in weeks) and Average cost over runs (in lakhs) analyzed from the data collected from the primary cases studies are given below in the table. The average values given in the

Table **6** below are for MEP works.

Table 6. Average Time and Cost Overruns (MEP Works)

MEP works			
S.no.	**Factors ID**	**Average Time Over Run (In weeks)**	**Average Cost Over Run (In Lakhs)**
1	F1	3.50	16.25
2	F2	2.00	41.25
3	F3	0.50	30.00
4	F4	2.50	18.75
5	F5	2.00	30.00
6	F6	2.50	16.25
7	F7	1.00	18.75
8	F8	2.00	18.75
9	F9	2.00	16.25
10	F10	2.00	30.00
11	F11	0.50	30.00
12	F12	1.00	16.25
13	F13	2.00	41.25
14	F14	2.50	75.00
15	F15	2.00	41.25
16	F16	2.50	52.50
17	F17	2.00	41.25
18	F18	3.50	52.50
19	F19	3.50	52.50
20	F20	3.50	38.75
21	F21	4.00	87.50
22	F22	3.50	52.50
23	F23	2.00	87.50
24	F24	2.00	52.50
25	F25	1.00	41.25
26	F26	3.00	52.50
27	F27	2.00	52.50

Table **6** presents an analysis of various factors (F1 to F27) associated with MEP (Mechanical, Electrical, and Plumbing) works, detailing the average time overruns in weeks and the average cost overruns in lakhs. Notably, there is a wide range of time overruns observed, varying from 0.50 weeks for F3 and F11 to 4.00 weeks for F21. Similarly, the average cost overruns also exhibit significant variability, ranging from 16.25 lakhs for multiple factors like F1, F6, F9, and F12 to as high as 87.50 lakhs for F21 and F23. Several factors, such as F2, F13, F14, F16, F18, and F19, have cost overruns exceeding 40 lakhs, emphasizing potential budgetary challenges and financial discrepancies in certain MEP work areas. The findings underscore the importance of meticulous planning, effective cost management, and proactive monitoring to mitigate risks, optimize project outcomes, and ensure the successful and timely completion of MEP works within stipulated budgets.

Table 7. Summary output for Regression Statistics (MEP Works)

Regression Statistics	
Multiple R	0.390198661
R Square	0.152254995
Adjusted R Square	0.118345195
Standard Error	0.886682016
Observations	27

Table 7 regression statistics offer insights into the relationship between variables within a given dataset. With a Multiple R value of 0.390198661, there exists a modest positive correlation among the variables. The R Square value of 0.152254995 indicates that approximately 15.23% of the variability in the dependent variable can be explained by the independent variables. The Adjusted R Square, slightly lower at 0.118345195, accounts for the influence of the number of predictors in the model, reflecting a more conservative estimate of the variability explained. The Standard Error,

quantified at 0.886682016, represents the average discrepancy between observed values and predicted values, serving as a measure of the model's predictive accuracy. With 27 observations, these regression statistics provide a foundational understanding of the data relationships and predictive capability of the model, highlighting opportunities for further exploration and refinement to enhance the model's reliability and effectiveness.

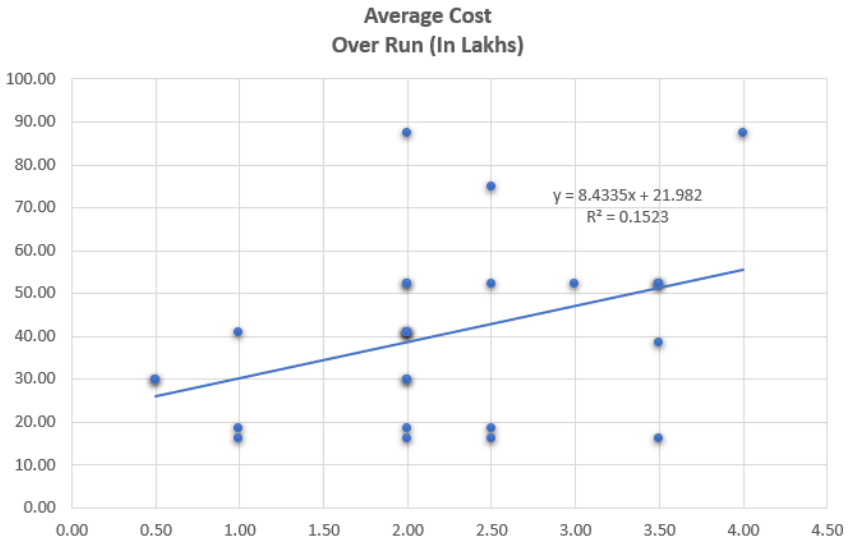

Fig 3. Average Cost overrun (MEP Works) (Source: Author)

The correlation between average cost over runs and average time over runs as determined by analysis of the key case studies is shown in the graph above. The graph displays all of the values for the 27 materials-related criteria. The resultant R value is 0.3258. For the identified parameters related to Material causing time overruns and cost overruns, a correlation matrix has been created as shown in Fig. **2** & Fig 3. The Excel data analysis tool was used to create the correlation matrix for time and cost overruns, which is shown below. To examine the effects of the factors on one another, a correlation matrix connecting the identified factors F1 to F27 has been created. Strong relationships between these elements can be seen in the Time and Cost overruns Heat Map that is shown below. The high correlation suggests that there may be multicollinearity among the variables. Strong correlations, or components with absolute correlation values more than 0.5, may be dropped from consideration while developing the algorithm for estimating the projected time and cost overruns.

The data gathered from the various case studies for the civil works shows an average delay of three weeks and an average cost overrun of 19.20 lakhs. Regarding MEP works, there is a noticeable 2.5-week average delay and an average cost overrun of 40 lakhs. Strong correlation between several variables is evident in the correlation matrix, and both the time and cost overrun correlation matrices show an absolute value larger than 0.5. The matrix's heat map highlights the multi-collinearity among the parameters under consideration, and the study's suggested algorithm takes this into consideration. The suggested technique computes the anticipated time and cost overruns while eliminating one of the two collinear variables to adjust for multi-collinearity. The method takes into account various combinations of the elements and accounts for the components' correlation and collinearity. There is a moderate to significant association between time and cost overruns, according to the regression model created between the average cost overruns and time overruns in the case studies, with an R-value of 0.57.

5. Algorithm

The correlation matrix clearly indicates the negative values. Certain factors have negative correlation with each other. To amount for these negative correlations and collinearity of factors, this study proposes the following algorithm given in Fig 4.

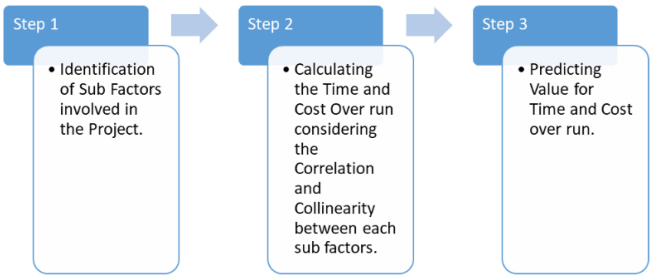

Fig 4. Proposed Algorithm Steps (Source: Author)

Assumptions:

• Max. Value for Time and Cost overrun shall be taken as the average Time and Cost Overrun values as derived from the case studies.

• Overlapping of Activities have not been considered.

• For each Main Factor Component combinations of all the possible values shall be considered to provide the final output range.

• Max value for DF or CF will be the computed average value of Time overrun of the factor and Min value shall be the average of the Lower Range value for the recognized factor.

• For factors with absolute value of correlation greater than 0.5 only one factor shall be considered for the prediction of Main factor component.

Step 1: Recognition of Any of the 27 sub-Factors in the project. These sub factors shall be renamed as F1 to F27. The main factors are Named as MF1 to MF6.

Step 2: Calculating the Time and Cost Overrun considering the Correlation and Collinearity Matrix between each sub factors.

Step 3: Predict Time and Cost Overrun using,

Predicted Time overrun = RII of MF1 X (DF1+DF2+DF3……DF10) + RII of MF2 X (DF11+DF12+DF13……DF17) +……. (RII of MF6) X (DF26+DF27)

Predicted Cost overrun = RII of MF1 X (CF1+CF2+CF3……CF10) + RII of MF2 X (CF11+CF12+CF13……CF17) +……. (RII of MF6) X (CF26+CF27)

Example: Suppose in Project A, the sub factors recognized are F3, F7, F11 and F18 for Civil works. Now to Predict the Time over run as per the above algorithm.

Step 1: Recognition of the Sub Factors: F3, F7, F11 and F18.

Step 2: Calculating main factor components for time and cost overrun:

The correlation matrix for time over run for the identified factors is as shown.

	F3	F7	F11	F18
F3	1			
F7	0.97	1		
F11	0.97	0.94	1	
F18	-0.08	0.06	0.06	1

The cells marked in Orange indicate the presence of collinearity between the variables since the correlation is strong and is above the threshold value of 0.5. Thus, the presence of collinearity allows us to drop factors during combination formation. Now as per the proposed Algorithm:

Predicted Time over run = RII of MF1 X (DF1+DF2+DF3……DF10) + RII of MF2 X (DF11+DF12+DF13……DF17) + ……. (RII of MF6) X (DF26+DF27)

Predicted Cost overrun = RII of MF1 X (CF1+CF2+CF3……CF10) + RII of MF2 X (CF11+CF12+CF13……CF17) + ……. (RII of MF6) X (CF26+CF27)

Calculating for Time over run, Since, F3 and F7 have a strong positive correlation. For calculating the Main factor component for MF1, the following combinations are possible: {DF3} or {DF7)} (3.67) or (3.67)

Since in both the cases, by dropping one variable we still get a time over run of 3.67 weeks.

S.no.	Main Factors	Weightage for Factors
1	MF1	0.65
2	MF2	0.66

3	MF3	0.64
4	MF4	0.59
5	MF5	0.68
6	MF6	0.59

The value for MF1 Component for Time over run comes out to be 3.67 weeks.
Similarly, MF2 and MF3 component the values as taken from the Average time overrun table, these values come out to be 2.67 week and 3.5 week.
Now as per the proposed Algorithm:
Predicted Time over run = RII of MF1 X (DF1+DF2+DF3……DF10) + RII of MF2 X (DF11+DF12+DF13……DF17) + ……. (RII of MF6) X (DF26+DF27)
= 0.65 X (3.67) + 0.66 X (2.67) + 0.64 X (2) = 2.38 + 1.76 + 1.28 = 5.42 Weeks.
The correlation matrix for cost overrun for the identified factors is as shown.

	F3	F7	F11	F18
F3	1			
F7	-0.15	1		
F11	-0.36	0.40	1	
F18	-0.12	0.92	0.55	1

Predicted Cost overrun = RII of MF1 X (CF1+CF2+CF3……CF10) + RII of MF2 X (CF11+CF12+CF13……CF17) + ……. (RII of MF6) X (CF26+CF27)
Since, F3 and F7 have a negative correlation. For calculating the Main factor component for MF1, the following combinations are possible: {CF3(max) + CF7(min.)} or {CF3(min) + CF7(max.)} (50 + 10) or (10+ 50)
The value for MF1 Component for Time over run comes out to be 60 lakhs.
Similarly, MF2 and MF3 component the values as taken from the Average time overrun table, these values come out to be 15 lakhs and 3.3 lakhs.
Predicted Cost overrun = RII of MF1 X (CF1+CF2+CF3……CF10) + RII of MF2 X (CF11+CF12+CF13……CF17) + ……. (RII of MF6) X (CF26+CF27)
= 0.65 X (60) + 0.65 X (15) + 0.64 X (3.3) = 39 + 9.75 + 2.11
Predicted Cost Overrun = 50.86 Lakhs
The above example demonstrates a situation where 4 sub factors can be observed at a project site and using the data collected from the case studies and the existing correlation between the factors, we are able to compute a ballpark or predicted values for the time and cost over runs that may occur if the Factors F3, F7, F11 and F18 occur simultaneously at the same time during the ongoing project. The predicted values as per the algorithm proposed give values for time over run as 5.42 weeks and a predicted value for cost overrun as 50.86 lakhs.

6. Conclusion

The significance of material-based drivers in assessing time and cost overruns in construction projects is illustrated by this study. The average values of time and cost overruns were determined through three distinct case studies as a function of the 27 elements linked to material-related concerns that may arise on site and cause schedule and cost deviations.
A questionnaire survey was floated to find out the weightage for each factor and main factors to be adopted in the final algorithm. With 85 respondents the relative importance indices were calculated. The following conclusions may be drawn from the study:

- An average delay of 3 weeks can be found from the collected data from the various case studies for the civil works with an average cost overrun of 19.20 lakhs for civil works.
- An average delay of 2.5 weeks can be clearly found for MEP works and average cost overrun of 40 Lakhs can be observed for MEP works.
- The correlation matrix clearly indicates strong correlation between multiple variables and an absolute value of greater than 0.5 can be observed in both the correlation matrix for time and cost overruns.
- The heat map created for the matrix indicates the multi-collinearity between the considered factors and the same has been accounted for in the algorithm proposed in the study. The proposed algorithm accounts for multi-collinearity by dropping one of the two collinear variables while computing the predicted time and cost overruns.

- The algorithm considers multiple combinations of the factors and caters for the correlation and collinearity between the considered factors.
- The regression model generated between the average cost overruns and time overruns in the case studies with a R value of 0.57 indicates a moderate to strong correlation between the time and cost overruns.

7. Future Scope

The creation of a mathematical algorithm has been the exclusive focus of the investigation. The suggested algorithm might be investigated further, and a Python digital program could be created to be appropriately utilized on project sites for the prediction of time and expense overruns caused by material-related issues. This study might be expanded to include all the variables that contribute to schedule and budget overruns in building projects.

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