Study on the Factors Causing Rework of Building Construction in Kerala using Interpretive Structural Modelling (ISM)

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ABSTRACT

The construction industry is one of India's most important and fastest-growing sectors. However, the construction industry is plagued with problems of cost and time overruns. Rework is one of the major causes of cost overrun and time overrun in the construction industry. This study investigates the factors causing the rework of building construction in Kerala. To compile a list of the factors that lead to rework, a thorough analysis of the literature was done. A questionnaire survey was conducted to collect the opinions from contractors, engineers, and design consultants and the factors were ranked using the relative importance index (RII). Lack of project funding, poor monitoring and control, and poor communication or coordination among stakeholders were identified as the significant causes of rework in building construction in Kerala. In order to establish an interrelationship between the top fourteen critical factors influencing rework, Interpretive Structural Modeling (ISM) method was used. Based on the ISM, a hierarchical structure was created, and it was found that the client's ignorance of the planning and construction processes was the primary cause of the rework in building construction. Matrice d' Impacts Croise's Multiplication Appliquee a Classement (MICMAC) analysis was done to classify the factors based on driving and dependence power and those factors with high driving power have to be given attention to control the rework of building construction in Kerala. The significance of each critical cause and its interrelationships can create a better awareness among the stakeholders involved and thereby reduce the extent of rework in building construction.

Keywords: Rework, Relative Importance Index (RII), Interpretive Structural Modelling (ISM), MICMAC analysis

1 Introduction

Rework is the work that must be done again after it has been completed due to an adjustment that had to be made while the project was being carried out. Rework results from needless redoing or rectification efforts of improperly implemented procedures or activities in construction projects [1]. Rework is a significant problem that affects the performance of projects in areas like cost, time, contractual claims and disputes, design team satisfaction, client satisfaction, contractor satisfaction, and quality. The cost of rework on residential, industrial, and commercial building projects ranged from 5% to 10% of their anticipated price, according to a study, and the cost of rework for a residential and industrial building was 3.15% and 2.40% of the contract value, respectively. Therefore, remodeling buildings may result in project cost overruns. Rework also contributes to delays in work, and studies estimate that it accounts for 20% to 30% of total project completion time [2]. Rework in construction projects was identified as a significant contributor to the cost and time overrun in construction projects in Kerala in a study by Sriram *et al.* [3]. Rework results in an unwanted and needless waste of effort, which is a hazard to the construction industry and a significant element affecting project performance.

2 Literature Survey

Alwi *et al.* [4] first investigated the causes of rework in Indonesian high-rise construction projects and

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reported that inadequate site supervision is a principal cause of rework. A case study on the rework of buildings due to the changes in the client preferences and government policies were undertaken by Patil and Jadhav in 2015. Raghuram and Nagavinothini [2] reported that low worker productivity resulted in the use of inferior materials, postponement of the project's completion date, and changes to the project's planning, design, or specification, thereby leading to rework of the project. According to Zeiter *et al.* [5], rushing to complete a task on schedule and skipping small construction process milestones results in errors and rework in the projects. Dash *et al.* [6] studied the main causes of rework for Egyptian construction projects, along with how they influenced the project's schedule and cost. Poor coordination or communication with contractors, lack of client involvement during the design and construction process, and lack of project funding are the main causes of rework in residential, commercial, and industrial projects [2], [7], [8]. Only limited studies on identification of causes of rework have been conducted in the Indian building construction sector and no studies were found in Kerala. Hence there is an urgency to understand the various causes of rework that can be ranked quantitatively and the major root driver for the problem can be identified and eliminated. Interpretive Structural Modelling (ISM) proves to be an effective tool in identifying root cause of a problem from the interrelationship between the critical factors and developing a hierarchical structure. The ISM Technique and the procedures involved in the identification of elements, the clarification of their interrelationships, and the significance of rank and direction to clarify complicated problems were explored by Attri *et al.* [9]. Zillante *et al.* [10] examined the ISM approach to investigate the interrelationships among barriers to OSC adoption in China, and the general structure among barriers was identified. Tokai *et al.* [11] discussed about the interaction of key drivers for a sustainable waste management system using ISM in Ethiopia and their interaction between key drivers were analyzed and ranked according to degree of influence to prioritize planning and intervention.

3 Research Method

An extensive study of the literature review was carried out to identify the provisional list of factors causing rework. A provisional list of 37 factors was identified from previous studies and then a pilot study was conducted to confirm whether the list of provisional factors identified from the different literature contains all possible factors in the context of building construction in Kerala. Based on the comments and suggestions from the respondents a list of 28 factors was finalized for the study, thereby constructing an effective questionnaire. Table 1 shows the final list of factors considered for the study. A formal questionnaire survey was conducted to collect the opinions from Contractors,Engineers and Design consultants working in construction industry on the factors influencing rework and the respondents were also asked to rate the factors in five-point Likert Scale (1-5).

A snowball sampling technique was used and a total of 50 responses were received. The Relative Importance Index (RII) technique, employed in rework studies of building construction projects [5], [12], was used to rank these issues. Equation 1 was used to calculate the relative importance index (RII) for each cause, where "w" represents the weight given to each member by respondents, "N" represents the total respondents, "A" represents the highest weight (5 in this study), and ni, (where i =1 to 5) represents the number of respondents who assigned the i^{th} rank to the given element. Thus, RII will range from 0 to 1, with the greatest RII denoting the most critical and the lowest one the least critical item. IBM SPSS Statistics26 and Microsoft excel were used in the analysis of data.

$$RII = \frac{\Sigma w}{A \times N} = \frac{\Sigma_{i=1to5} i \times n_i}{A \times N} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \quad (1)$$

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Table 1: *Final List of Factors Causing Rework of Building Construction*

Sl.no	Factors
1.	Poor communication or coordination with contractor and design consultant by the clients
2.	Lack of funding for the project (PS)
3.	Lack of knowledge of design and construction process of client
4.	Changing the designs or specifications as per the client (PS)
5.	Inadequate time and money spent on briefing the process
6.	Poor coordination among design team members
7.	Incomplete details of design at time of tender
8.	Insufficient experience of design consultant
9.	Lack of quality practices and control (PS)
10.	Unclear design or error in design during preparation of design
11.	Poor usage of modern technology by design teams
12.	Poor coordination and communication with consultant
13.	Poor quality of the construction material and techniques
14.	Inappropriate or errors in construction methods
15.	Noncompliance with specifications or unclear specifications
16.	Due to schedule pressure
17.	Lack of experience or unqualified contractors and subcontractors
18.	Insufficient knowledge of workers to complete the task
19.	Lack of training and skill development to workers
20.	Poor communication to workers
21.	Poor monitoring and control
22.	Excessive overtime to workers
23.	Lack of understanding of specifications and design given by supervisor
24.	Poor site conditions
25.	Adverse natural conditions
26.	Lack of safety
27.	Change in government regulations
28.	Effect of social and cultural factors

3.1 Interpretive Structural Modelling

Interpretive structural modelling (ISM) is used to determine how the important variables interact. Attri *et*

al. [9] described ISM as a qualitative research methodology and an interactive learning process. The first step in constructing an ISM is to identify the components that need to be taken into account. Next, create a structural self-interaction matrix to show how the factors relate to one another in context (SSIM). Based on the opinions of the experts, the V, A, X, and O symbols are placed in each cell of the SSIM matrix. SSIM is transformed into an Initial Reachability Matrix (IRM) utilising a transformation rule and binary values (0 or 1). The transitivity assumption needs to be verified before creating the final reachability matrix (Ahamed *et al.* [13]).

Level partitioning is the process of assigning variables to hierarchical levels after discovering a contextual relationship between them. To assign levels to each factor, reachability sets, antecedent sets, and interaction sets must be found. To depict the levels obtained through level partitioning, an ISM diagram is constructed. The top of the graphic is taken up by the first level driver, followed by the second level driver, and the bottom by the last level. The variables are presented depending on the driving and dependence power of each driver in the final stage, known as the MICMAC analysis (Matrice d' Impacts Croise's Multiplication Appliquee a Classement). The drivers are divided into four groups based on the graph of dependence power versus driving power.

4 Results and Discussions

4.1 General Information of the Respondents

All of the responses were gathered from the southern districts of Kerala, specifically Kollam, Ernakulum, Pathanamthitta, and Alappuzha. The majority of the respondents were engineers, and 40% of their working experience was greater than five years. 64% of the total respondents had experience with reworking building construction projects, which was sufficient for our study.

4.2 Perceptions on Rework of Building Construction in Kerala

The view of the respondents on the frequency of rework in building construction in Kerala revealed that it happens sporadically, and it was evident that rework in building construction makes the research crucial. When it comes to cost overrun issues, this rework issue in building construction results in large costs, as seen in figure 1. This shows unequivocally that the need to address the core source of cost overruns, which is the reworking of building construction.

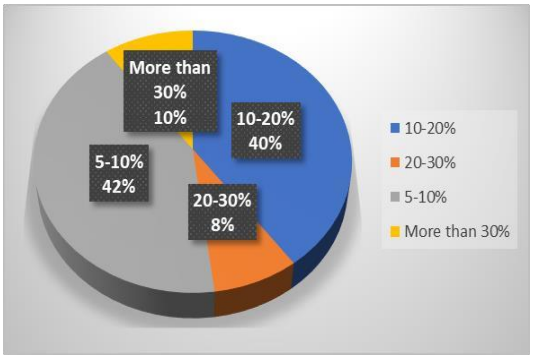

Figure 1: *Cost overrun in Rework projects.*

4.3 Ranking of the Factors

The ranking of factors was done using RII and the table 2 shows the factors ranked according to the RII value. Lack of funding for the project was found to be the topmost cause for rework and it can be eliminated by proper planning at the design stage [7]. Poor monitoring and control of work, and coordination issues between the stakeholders were found to be the next serious issues. These can be eliminated by

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implementing proper supervision panels and a workable mechanism to bring together the three stakeholders to minimize change orders and introduction of additional works at site.

Table 2: *Ranking of Factors Causing Rework of building Construction.*

Description of Factor	RII	Ra
Lack of funding for the project	0.776	1
Poor monitoring and control	0.74	2
Poor communication or coordination with contractor and design	0.724	3
Inappropriate or errors in construction methods	0.704	4
Changing the specifications as per the client	0.696	5
Lack of experience or unqualified contractors and subcontractors	0.684	6
Lack of training and skill development to workers	0.682	7
Unclear design or error in design during preparation of design	0.672	8
Lack of quality practices and control	0.668	9
Lack of understanding of specifications and design given by supervisor	0.648	10
Poor quality of the construction material and techniques	0.64	11
Lack of knowledge of design and construction process of client	0.62	12
Non-compliance with specifications or unclear specifications	0.612	13
Insufficient knowledge of workers to complete the task	0.608	14
Poor usage of modern technology by design teams	0.596	15
Poor communication to workers	0.584	16
Poor coordination among design team members	0.576	17
Change in government regulations	0.572	18
Poor coordination and communication with consultant	0.568	19
Incomplete details of design at time of tender	0.532	20
Inadequate time and money spent on briefing the process	0.524	21
Poor site conditions	0.512	22
Lack of safety	0.510	23
Due to schedule pressure	0.508	24
Adverse natural conditions	0.504	25
Lack of motivation	0.472	26
Effect of social and cultural factors	0.426	27
Excessive overtime to workers	0.428	28

4.4 Interpretive Structural Modelling

For the Interpretive structural modelling (ISM) analysis, the top fourteen crucial elements were selected, and their interrelationships were investigated. The SSIM was based on the opinions of the ISM respondents, who were highly qualified and experienced engineers with more than 10 years of work experience in the construction industry. The matrix was replaced with binary values (0 or 1) to determine the initial RM, and the transformation algorithm is applied to obtain the final RM. In order to determine the indirect relationship between the elements, the transitivity check was performed by changing the zeros to one*. The driving power (DR) and dependence power (DP) of each factor were derived from this final RM. The final RM created is displayed in Table 3.

In level partitioning, levels were assigned to the factors, and reachability sets, antecedent sets, and intersection sets were identified based on the final RM. Figure 2 depicts the hierarchical ISM diagram, made up of six levels in total. Table 4 shows how the main elements were level partitioned. The lowest level of the hierarchy, level 6, which is the root cause driver. Lack of understanding on the planning and

construction processes by the client is identified to be the root cause for rework. This lack of information by the client influences the choice of inexperienced contractors and untrained staff, which results in supervisors lacking comprehension of the design process. Unexperienced contractors and untrained workers will result in a poor communication of the design and construction process. As a result, the specifications will get changed by the client which drives into unclear specifications, funding problem, lack of quality and error in work.

The driving and dependent factors for the reworking of building construction in Kerala were discovered through MICMAC analysis. The elements were divided into four categories based on the driving force and dependence power: linkage, autonomous, dependent, and independent factors. In Figure 3 shows the MICMAC analysis. Results of the MICMAC analysis indicated that there were 11 linkage factors and 3 independent variables. However autonomous or dependent variables were not obtained. Linkage factors are challenging to control from causing rework as it is driving more factors and driven by more factors towards rework problem. Independent factors are those that have a significant driving force but little reliance. Therefore, it is crucial to manage the independent variables in order to manage Kerala's difficulty with building construction rework. Here, the client's ignorance has a dependence power of 1 because it is independent of the other 13 elements, but it also has a driving strength of 14, which motivates the other 13 factors to cause rework in building construction.

Table 3: *Development of Final Reachability Matrix*

Factors	F14	F13	F12	F11	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1	DR
F1	*1	1	0	1	*1	1	*1	1	0	1	*1	0	1	1	11
F2	*1	1	0	1	*1	1	*1	0	0	0	1	0	1	*1	9
F3	*1	1	0	*1	0	*1	1	*1	1	1	*1	*1	*1	1	12
F4	1	1	0	*1	1	*1	*1	*1	0	*1	1	*1	*1	1	12
F5	0	1	0	*1	0	*1	1	*1	0	1	*1	0	*1	1	9
F6	*1	1	0	1	*1	1	*1	0	1	*1	1	1	1	*1	12
F7	1	1	0	1	1	1	*1	1	0	*1	*1	*1	*1	*1	12
F8	*1	1	0	*1	*1	*1	1	*1	0	*1	1	0	*1	1	11
F9	*1	*1	0	1	*1	1	0	*1	0	*1	1	0	*1	1	10
F10	1	1	0	1	1	1	1	*1	*1	1	*1	1	1	1	13
F11	*1	1	0	1	*1	*1	*1	*1	0	*1	*1	0	*1	1	11
F12	*1	1	1	*1	1	*1	1	*1	*1	1	*1	1	*1	1	14
F13	0	1	0	*1	0	1	1	*1	0	*1	*1	0	*1	1	9
F14	1	1	0	1	1	1	*1	0	0	*1	*1	*1	1	*1	11
DP	12	14	1	14	11	14	13	11	4	13	14	7	14	14	

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Table 4: *Level partitioning of factors*

Factors	Antecedent sets	Reachability sets	Intersection sets	Levels
F1	1 2 3 4 5 6 7 8 9 10 11 12 13 14	1 2 4 5 7 8 9 10 11 13 14	1 2 4 5 7 8 9 10 11 13 14	1
F2	1 2 3 4 5 6 7 8 9 10 11 12 13 14	1 2 4 8 9 10 11 13 14	1 2 4 8 9 10 11 13 14	1
F3	3 4 6 7 10 12 14	1 2 3 4 5 6 7 8 9 11 13 14	3 4 6 7 14	3
F4	1 2 3 4 5 6 7 8 9 10 11 12 13 14	1 2 3 4 5 7 8 9 10 11 13 14	1 2 3 4 5 7 8 9 10 11 13 14	1
F5	1 3 4 5 6 7 8 9 10 11 12 13 14	1 2 4 5 7 8 9 11 13	1 4 5 7 8 9 11 13	2
F6	3 6 10 12	1 2 3 4 5 6 8 9 10 11 13 14	3 6 10	5
F7	1 3 4 5 7 8 9 10 11 12 13	1 2 3 4 5 7 8 9 10 11 13 14	1 3 4 5 7 8 9 10 11 13	5
F8	1 2 3 4 5 6 7 8 10 11 12 13 14	1 2 4 5 7 8 9 10 11 13 14	1 2 4 5 7 8 10 11 13 14	1
F9	1 2 3 4 5 6 7 8 9 10 11 12 13 14	1 2 4 5 7 9 10 11 13 14	1 2 4 5 7 9 10 11 13 14	1
F10	1 2 4 6 7 8 9 10 11 12 14	1 2 3 4 5 6 7 8 9 10 11 13 14	1 2 4 6 7 8 9 10 11 14	4
F11	1 2 3 4 5 6 7 8 9 10 11 12 13 14	1 2 4 5 7 8 9 10 11 13 14	1 2 4 5 7 8 9 10 11 13 14	1
F12	12	1 2 3 4 5 6 7 8 9 10 11 12 13 14	12	6
F13	1 2 3 4 5 6 7 8 9 10 11 12 13 14	1 2 4 5 7 8 9 11 13	1 2 4 5 7 8 9 11 13	1
F14	1 2 3 4 6 7 8 9 10 11 12 14	1 2 3 4 5 8 9 10 11 13 14	1 2 3 4 8 9 10 11 14	4

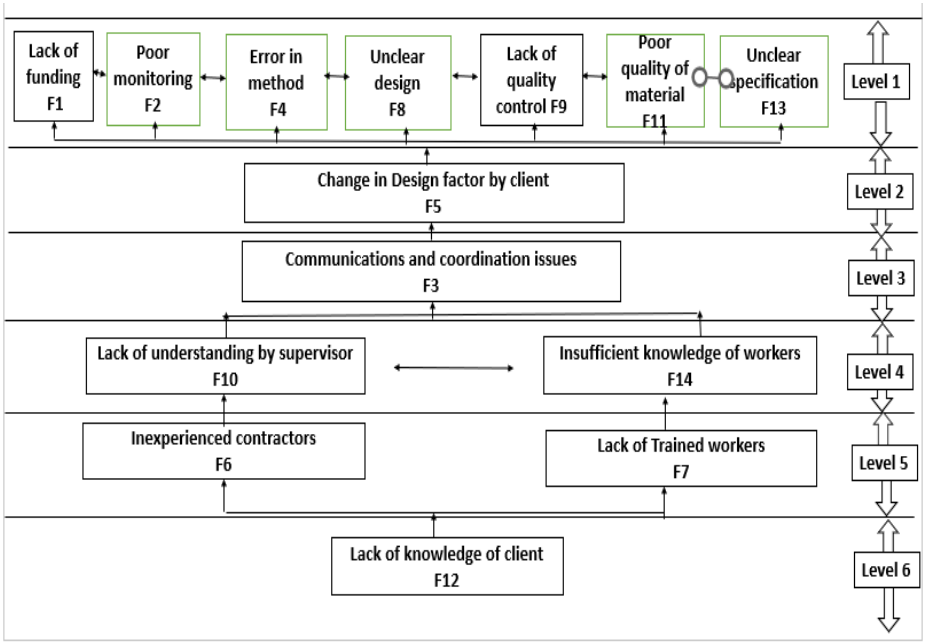

Figure 2: *ISM diagram*

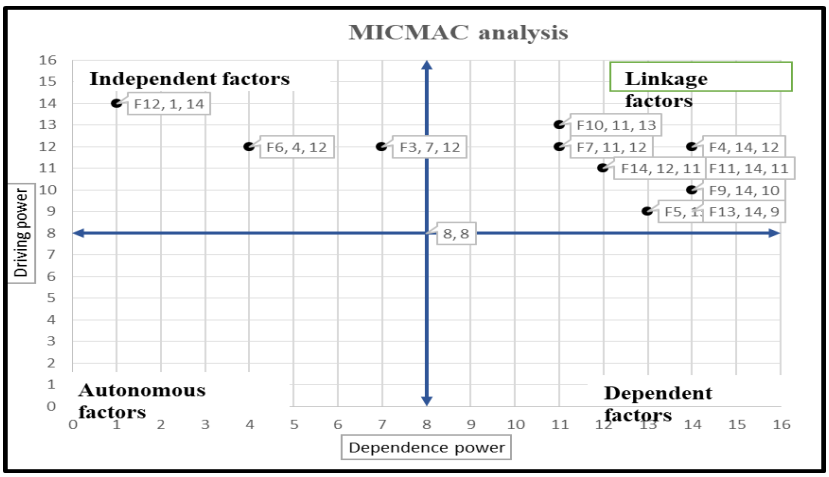

Figure 3: *MICMAC analysis*

5 Conclusions

The construction sector is among one of the India's most significant and rapidly expanding sectors. Projects undertaken in Kerala are suffering from cost overruns and delays in completion of work. One of the primary sources of the aforementioned issues in Kerala has been shown to be rework in building construction.

Lack of financing for the contract documentation was found to be the topmost factor influencing rework in building construction, and it can be eliminated with proper preparation of the contract documents at the design stage. Other critical causes influencing rework were found to be inadequate monitoring and control of the activity, and problems with stakeholder cooperation. These can be avoided by setting up suitable supervisory panels and creating a platform to bring together different stakeholders to reduce the change orders.

The interrelationships between the critical factors and the independent elements were established using interpretative structural modelling. Lack of understanding on the design and building processes by the clients were found to be the driving cause for rework. It changes the scope of the work and thus the designs

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will be changed. It can be that the customer is having a hard time picturing the project from 2D designs or that they have a vague understanding of how the facility will be used. By providing a standard structure for capturing their demands, customers might be encouraged to write down their intentions before meeting with the designer. The client must be certain of his requirements and cannot alter them.

6 Publisher's Note

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