Analyzing the interactions among delay factors in construction projects: A multi criteria decision analysis

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Article Info

Article history:

Received July 12, 2023
Revised November 13, 2023
Accepted November 17, 2023

Keywords:

Construction,
Projects,
Site Management,
Delay Factors,
TISM,
MICMAC.

ABSTRACT

The construction industry is a crucial sector that drives economic growth and facilitates socio-economic development. However, construction projects often get delayed due to multiple controllable and uncontrollable circumstances. In this scenario, the construction industry is striving for potential solutions to resolve project delays. Thus, the present study objectives to analyze the delay factors that affect the timely accomplishment of construction projects in the context of emerging economies. The study adopts a mixed methodology comprising of Delphi, Total Interpretive Structural Modelling (TISM) and Matrice d' Impacts Croises Multiplication Applique a Classement (MICMAC) method to model the identified delay factors. A Delphi analysis was conducted to finalize the most crucial delay factors to the on-time completion of building projects. The causal relationships and expert interpretations for each identified delay factor were then determined using multi-criteria decision analysis, TISM and MICMAC analysis. The study results highlight that lack of knowledge of newer construction methodologies and lack of project monitoring tools and techniques are positioned at the bottom level of model, which suggests that this delay factor influences others. The study results will help managers resolve the issues of project delays by selecting the most suitable approach. The findings from the study suggest adopting advanced technologies for effective communication, use of analytical tools for resource allocation and waste-scrapping approaches for eliminating delays in construction projects.

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1. Introduction

The construction of complex structures like water treatment plants, dams, buildings, sewage plants, bridges, and roads are examples of the construction industry. However, the construction industry is indispensable for the progress of the economy. It facilitates socio-economic development and fosters the development of other industries. In construction projects, numerous reasons account for losses in productivity, and the major contributor is Project Delays (PDs) (Anibire et al., 2022). Delay is defined as the amount of time a project exceeds the planned end date of a contract (Anibire et al., 2022; Goers & Horton, 2023). According to Rivera et al. (2016), 63% of projects encountered cost overruns with a 24% rise in the original planned cost, and 72% of projects experienced delays with a 38% increase in the scheduled initial duration. Rework is another element that influences performance and may contribute to a 12.4% increase in overall project costs (Love et al., 1999). Construction delays have troubled the world's building sector for many years (Mahamid & Bruland, 2012). Delays in Construction Projects (CPs) have a variety of detrimental implications on both the project's stakeholders and its overall performance. Construction delays harm clients, contractors, and consultants and may trigger arguments or legal disputes. In addition to litigation, delays can lead to budget and schedule overruns, reduced output and income, and even contract termination (Tumi et al., 2009). According to Sanni-Anibire et al. (2022), delays may result in losses for the owner and the contractor, expenses associated with inefficiency or lost output, and other losses. Every type of delay results in economic loss for the customer and increased overhead costs for the contractor. Sometimes, delays result in material waste and obsolescence. According to Ratajczak et al. (2019), if the PD issue is managed, it may increase productivity. All types of CPs are susceptible to delays. The likelihood of delays in CPs is significantly higher since the work is done on open sites contrary to controlled environments of the manufacturing or Information Technology (IT) sector.

The organizations are required to handle the delay issue before it gets out of hand and impacts costs along with a shortage of resources and relationships and communication with internal and external stakeholders, which may lead to conflicts (Senesi et al., 2015; Dağıstanlı et al., 2023). The organizations have been trying to reduce construction delays, and the topic has been a forerunner for researchers and academicians. Despite several efforts, projects in developing countries such as India are experiencing delays due to time overruns. Several studies have reported incidences of disagreements due to construction PDs and time and expense overruns (Padroth et al., 2017). Project abandonments are also correlated to building PDs (Musa et al. 2018). According to Chipulu et al. (2019), the success or failure of a project is proportioned and directly related to PDs. Previous researchers assert that multiple PD studies clearly demonstrate the limits. The notion that each PD factor is not an independent occurrence and is instead connected to other direct and indirect variables has not been adequately addressed (Chipulu et al. 2019). With the expanding volume, performance in terms of project completion on time in the Indian construction industry is unquestionably an important area for research. Many studies have already been done to find the causes and variables or factors influencing schedule and cost performance (Annamalaisami & Kuppuswamy, 2022; Zheng, 2023). Apart from the studies that identify and rank the individual factors that cause construction delays, there is a requirement for studies that determine the interrelationship between them. It is highly important to research the factors that cause delays in CPs and to learn their effects or impacts and how these factors interact with each other. However, limited studies have focused on understanding the dynamics of these delay-causing factors.

Considering the research gap, the current study aims to model the delay factors behind construction PDs in the context of developing nations. The study adopts an integrated methodology of Total Interpretive Structural Modelling (TISM) and Matrice d' Impacts Croises Multiplication Applique a Classement (MICMAC) to discover the relationship among the delay factors and also identify the driving-dependent delay factors among them. The study focuses on the Indian construction sector, majorly in the context of water authority and public department work in one of the Indian states - Kerala.

The remaining of the manuscript is structured as follows. The literature review is performed in Section 2. Section 3 describes the integrated methodology adopted to model the project delays. Section 4 presents the results, discusses the essential findings and proposes interventions to resolve the PDs. Section 5 concludes the study and suggests future research extensions.

2. Literature Review

CPs around the world continue to get critically hampered on account of prolonged delays. To resolve the issues of PDs, many authors conducted studies to understand the reason behind these delays in CPs. Sambasivan & Soon (2007) examined the reasons and consequences of delays in the Malaysian construction sector. The research focused on three stakeholders: consultants, clients, and contractors. Their results highlight that PDs were caused by inadequate planning, inexperienced contractors, delayed payments, lack of materials and labour, equipment availability, subcontractor issues, machinery failure, communication delays among stakeholders, and construction errors. The research also highlighted six critical consequences of delay: overrun of time and money, litigation, disagreements, arbitration, and outright abandonment. According to the study by Doloi et al. (2011), the absence of commitment was identified as the leading cause of building delays. El-Razek et al. (2008) stated that a contractor's financial insecurities or difficulties are the primary cause. Another essential element affecting the timeliness of most building projects is ineffective site management. This may result from the site expert's lack of formal training as they often acquire their supervisory abilities via. experience. Another important cause of building delays is a scarcity of materials.

Bashir et al. (2019). adopted the "Integrated Social Network-Fuzzy Integrated Network-Fuzzy Cross-Impact Matrix Multiplication Analysis" (MICMAC) method and considered many PD variables, their interrelationships, and analyzed the relationship between the various PD drivers. The study reflected that delay factors are both directly and indirectly connected. Muneeswaran et al. (2020) highlight that the nature of CPs is exceptionally complicated and dynamic. However, because of its dynamic nature, it is subject to several hazards and delays before the start, during the ongoing process of the project, and after the completion of construction. The study evaluated and prioritized delays and hazards using a literature survey and the perspective of construction experts in the Indian construction industry. In the context of the Indian construction sector, statistical analysis was performed to discover, evaluate, and prioritize delays and hazards using fuzzy ranking and the relative significance index. The most significant risk was determined to be an inadequate schedule, which is a persistent issue with all building projects. Anibire et al. (2022) proved that delays are one of the prime reasons for performance in the construction sector. The study identifies the top reasons for delays as contractor's financial problems, delay in material delivery, delay in the approval of finished work, poor site organization, planning and coordination.

Bagrecha & Bais (2017) discussed the importance of the construction sector for developing the economy and the dichotomy it presents. They highlight that the construction sector is extensive, unstable, and expensive to invest in; however, it is a supporting sector for the growth of many other businesses as it provides the infrastructure for the growth of others. Almost all CPs experience delays, and the severity of these delays varies significantly from project to project. It is possible to define a delay in construction as extending over the delivery date or the completion date stated in the pre-agreed contract. Due to a scarcity of leasing space and manufacturing facilities and reliance on existing facilities, a delay results in a loss of income. The overall cost of the project is closely correlated with PDs. Only after determining the cause can the delay be reduced.

According to Mali and Warudkar (2019), workforce shortages, lack of advanced mechanical equipment, and site mobilization are the leading causes of delays. Most consultant-related issues are brought on by failure to comprehend the customer's needs, a lack of sufficient project information, a lack of specific drawing details, etc. Project circumstances include supplying services from utilities (water and electricity) and difficulty in work due to weather causing delays. External factors like changes in administration, law or location, and an untrained workforce can also cause delays. The contractor and the employer often care about how rapidly and economically a project will be finished (Salunkhe and Patil, 2014). Time overruns impact over 57% of building projects in India (Arantes, A. and Ferreira, L.M.D., 2020). These delays in schedules generally cost all the stakeholders significantly. Local contractors, being unaware of the importance of a proper management plan, fail to develop a realistic and viable plan at the first planning stage. The consultants use only expertise and instincts to verify and evaluate the work program that the contractors have supplied. PDs are caused by a lack of risk recording, ignoring risks that could adversely affect project implementation, lack of risk management, and lack of specificity in the project manager's scheduling of project activities (Mardiani, 2018). As per Haseeb et al. (2011), natural disasters like floods and earthquakes are thought to be the leading cause of delays. However, other factors like "financial and payment problems," "improper planning," "poor site monitoring", "insufficient experience", and "shortage of materials and equipment" were also found to be important in a study conducted in Pakistan.

Alinaitwe et al. (2013) investigated the reasons behind cost overruns and construction delays in Uganda's public projects. The emphasis of the research was on aviation-related initiatives. Out of the five variables, poor monitoring and control were determined to be among the most important of the study's 20 determinants of delay. Similarly, Venkatesh et al. (2012) identified poor monitoring of projects as one of the main factors that cause delays. Accidents, poor planning, or a breakdown in communication between the parties can all contribute to mistakes made during the building phase (Lingard et al. 2021). Whatever the cause, faults can hinder the project's advancement. Whenever there are delays, there are disagreements over who should be held accountable and how much it should cost. When these disagreements cannot be resolved through arbitration, third parties will often file a lawsuit, and the court will decide. In the worst-case scenarios, many projects were found to be abandoned in between. Client, relationship, contract, and other external variables also affect the disputes that emerge throughout the project. The conflicts between different parties are sometimes caused by late payments for finished construction. If the disagreements are not settled peacefully, they may result in arbitration or legal action (Sambasivan & Soon, 2007). Koushki et al. (2005) proposed that order changes, the owner's financial limitations, and the owners' lack of industry knowledge all contributed to time delays. Concerning cost overruns, the three primary causes were issues with the contractors, problems with the materials, and, once more, the owner's financial limitations.

It is apparent from the above discussion that construction PDs are an active area of research and have attracted attention from researchers all over the world. An inclusive review of the previous literature has been carried out to explore the reason for the delays. The recent articles indicate that researchers have overlooked on the interactions or relations between the delay factors. Further, Arantes and Ferreira (2020) highlight the need to explore delay factors from the perspective of different geographies. In this context, they report that delay factors vary and can depend on the type of project, place of the project, its nature and other factors. Many studies have prioritized the delay factors, but there has yet to be a consensus on the ranking. A critical research gap emerges in terms of a limited understanding of delay factors and how they affect each other. Knowing the interrelations among the delay-causing factors in CPs is necessary to resolve the impacts and effects of PDs. Thus, modelling the interrelationship among the factors of PDs can be seen as a critical research gap.

3. Research Methodology

The study is conducted in two stages. In the first stage, the delay factors of the project have been identified. In the second stage, the proposed integrated methodology has been adopted to model these delay factors. Figure 1 represents the flow diagram of the research methodology adopted for this study.

The well-known approach of "Total Interpretive Structural Modelling" (TISM) identifies and summarises correlations among variables (Sushil 2012). The TISM method is best suited to define the contextual relationship among a set of elements with complex relationships (Patil et al. 2023). The method is preferred to develop a refined understanding of the system's multiple co-dependencies and make a well-informed decision (Sahoo & Goswami, 2023). This study selected TISM as it helps answer the "what", "how" and "why" of theory development exercises by showing the interlink among elements.

Initially, based on a literature survey, the delay factors which usually affect the timely completion of projects were identified. Initially, 25 plus potential delay factors were identified using the previous literature. The most pertinent delay factors were determined utilizing Delphi approach with the help of five specialists. A purposive sampling technique was considered to choose the experts for this examination. Therefore, the specialists were decided based on their experience (at least five years) and expertise in CPs. The expert panel provided insights on the identified significant delay factors and helped finalize the delay factors considered for further analysis.

To determine the connections between relevant factors, engineers (9), supervisors (6), project managers (4), and contractors (3) were interviewed in this process. The total sample size for the study was 22. A questionnaire was established under the framework of TISM methodology (Sushil 2017). To prevent potential conflict between their responses, the practitioners' opinions were collected independently. A Yes/No-based list of obtained delay factors was presented as a questionnaire, and their inputs were taken to choose the most appropriate ones. The delay factor was preferred if at least 50% of the experts answered affirmatively. Additionally, any additional potential delay factor that was not included was requested from the experts. Following that, a final list of delay factors was developed. The methods used are comparable to that of El-Razek et al. (2008). Semi-structured questions were used to interview the experts on the panel. The questions asked to the experts included, "Do you think this factor contributes to delays in CPs in Kerala? Do you want to add any other delay-causing factor? Do you want to group together any delay factors etc.? Finally, these delay-causing factors were narrowed down to eight. The list of final factors responsible for significant construction delays are presented in Table 1.

The next step was to develop a conceptual hierarchy model adopting an integrated method of TISM and MICMAC. The expert opinion was used to establish the relationships among the various delay factors identified after the preliminary analysis and study (Bhanot et al., 2017). The study adopted the modification of the ISM method to model these delay factors. The main problem with the ISM is that it struggles with incorrect interpretations of the relations or dependence of these factors. Thus, this study adopts a modification of ISM named TISM.

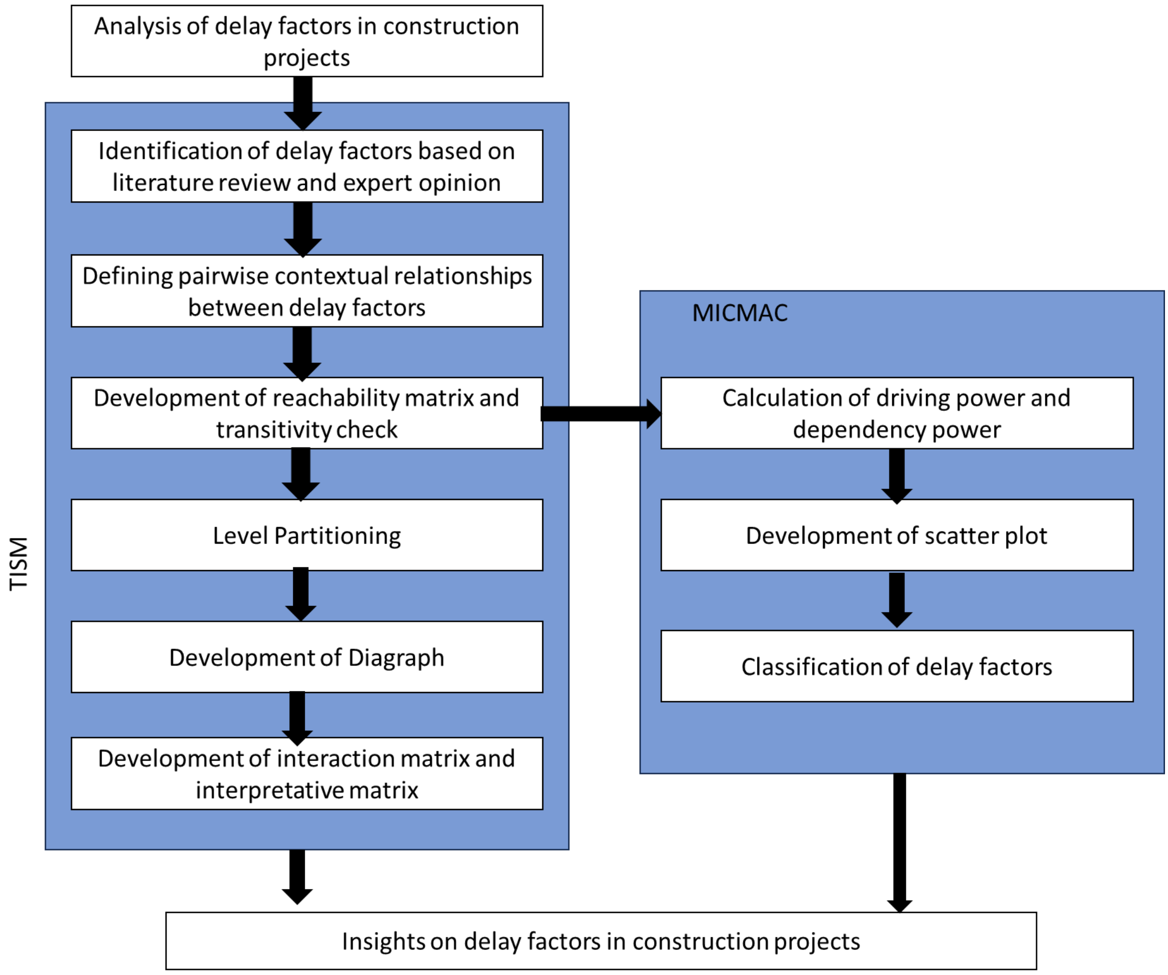

Figure 1. Flow diagram for research

Table 1. Delay factors in construction projects

Code	Delay factors in construction project	References
C1	Poor proper project management plan	Shrivas, A., & Singla, H. K. (2022); Edison, J. C., & Singla, H. K. (2020)
C2	Lack of knowledge of newer construction methodologies	Khan, R. A., & Gul, W. (2017); Bhatti et al., (2022)
C3	Shortage of labour and material	Khahro, et al., (2018); Umar, et al., (2020); Pamucar et al., (2023)
C4	Lack of project monitoring tools and techniques	Aregay, H. (2022); Dwivedi et al. (2023)
C5	Extra work due to bad quality or errors	Głuszak, M., & Leśniak, A. (2015); Tafazzoli, M., & Shrestha, P. P. (2017)
C6	Inefficient site management, communication, and supervision	Aregay, H. (2022); Arantes, A. and Ferreira, L.M.D., (2020)
C7	Conflict between top management, unions, contractors, etc.	Razia et al. (2017); Islam, M. S., & Trigunarsyah, B. (2017)

C8	Unrealistic cost and time estimates	GIZAW, Y. (2021); Yousri, et al. (2023); Singh et al. (2023)

TISM is a more professional assessment of the critical connections presented in ISM (Choudhury et al., 2021). Researchers have employed the TISM approach in a wide variety of areas (Patil et al., 2020; Sushil and Dinesh, 2022). Next, we discuss the key steps of TISM methodology after the finalization of delay factors.

Step 1: Pairwise comparison and Development of structural self-interaction matrix

A questionnaire has been prepared under the framework of TISM methodology that helps pairwise compare the delay factors influence on each other. Although there is no set standard for the number of experts to be interviewed or included in TISM analysis, past researchers have employed five to eight experts to perform the analysis (Patil et al., 2022; Tripathi, M., & Hasan, Z. 2022) . The present study consulted 22 experts, including contractors (8), consultants (1), supervisors (8) and project managers/engineers (20) to conduct TISM analysis. Using pairwise association/relationships between delay factors in CPs, the initial reachability matrix was developed as reflected in Table 2.

Table 2. Initial Reachability Matrix

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	0	1	0	1	0	0	1
C2	1	1	0	1	0	0	0	0
C3	0	0	1	0	1	0	0	0
C4	1	1	0	1	1	1	0	0
C5	0	0	1	0	1	0	1	0
C6	0	0	1	0	1	1	0	0
C7	0	0	0	0	0	0	1	0
C8	1	0	1	0	0	1	0	1

The reachability matrix with transitivity is formed by taking transitivity into account. The TISM method's definition of transitivity asserts that if a variable i is connected to j and j is linked to k, it is possible to assume that i is also linked to k. If there is no correlation between i and j, there is no transitivity. Table 3 shows the reachability matrix with transitivity. The one (1*) indicates the transitive relationship, one (1) indicates the direct relationship and zero (0) indicates no relationship among the pairs. This matrix is used for level partitioning.

Step 2: Development of Reachability Matrix with transitivity

Table 3. Reachability Matrix with transitivity

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	0	1	0	1	1*	1*	1
C2	1	1	1*	1	1*	1*	0	1*
C3	0	0	1	0	1	0	1*	0
C4	1	1	1*	1	1	1	1*	1*
C5	0	0	1	0	1	0	1	0
C6	0	0	1	0	1	1	1*	0
C7	0	0	0	0	0	0	1	0
C8	1	0	1	0	1*	1	0	1

Step 3: Level partitioning

The level of each delay factor needs to be identified to understand which delay factor affects the most, and this is done in the level partitioning stage. The level partitioning stages are shown in Appendix A. This step helps determine the level of each delay factor, which is done using the reachability and antecedent set for each delay factor. The delay factors which influence the other delay factor are included in the antecedent set.

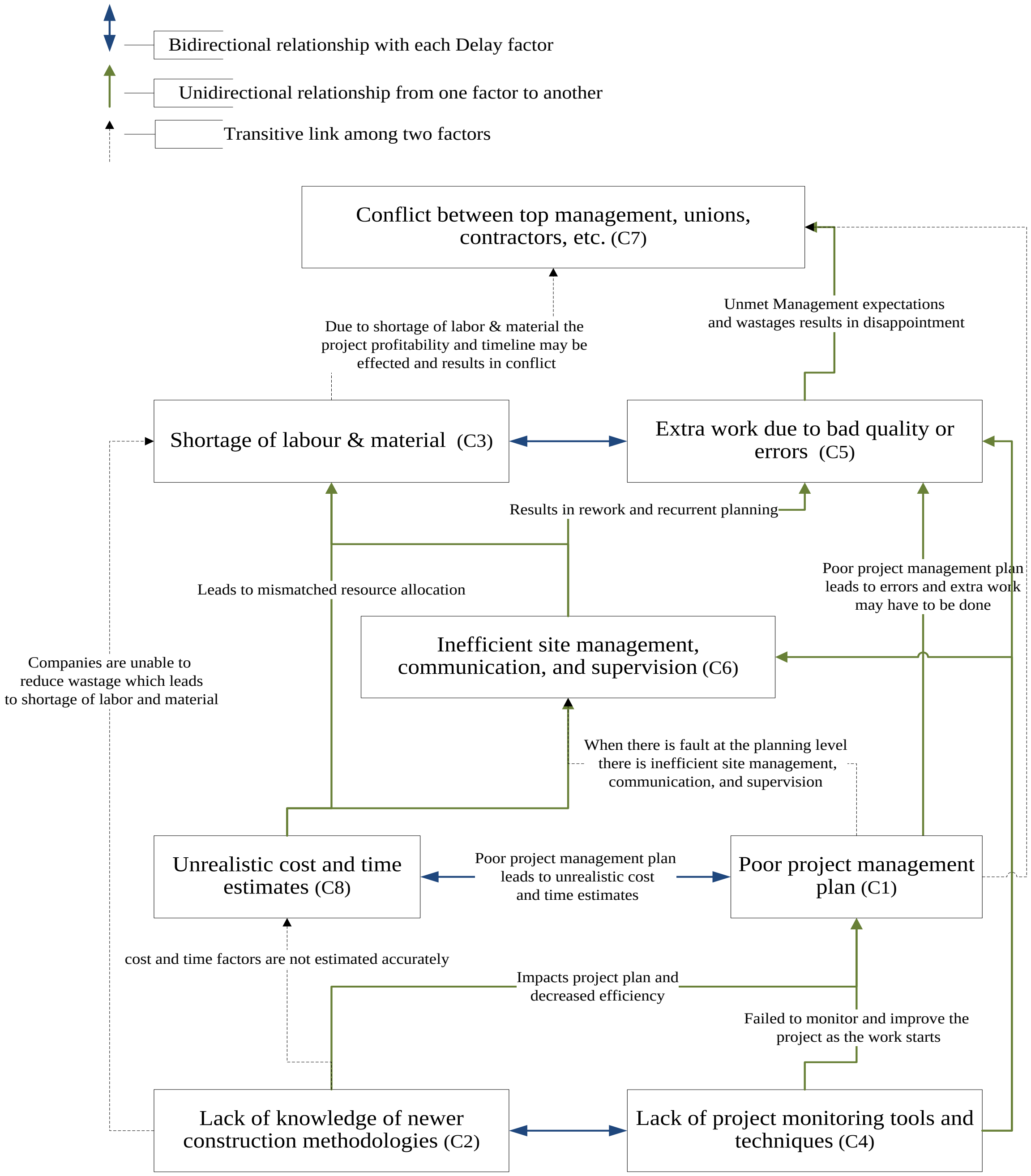

Figure 2. TISM diagram

In the level partitioning diagram of the TISM model, the delay factor at the top level has the same factors in reachability as well as intersection sets. These top-level delay factors having the same delay factor in both reachability and intersection sets are then removed before proceeding to the formation of the next level. This procedure is then continued till the level of all delay factors is determined. Each step in this process is termed an iteration, and the rows that are indicated in grey will be eliminated. The tables shown in the Appendix demonstrate three iterations that occurred while carrying out the process of iteration.

From the results of MICMAC analysis, delay factors are positioned at the top level, if the intersection set and reachability set match (Verma et al., 2023). The process continues until all levels are determined, and the top-level delay factors having the same delay factor in both reachability and intersection sets are then removed before proceeding to the formation of the next level. This formation of various levels helps in the construction of the diagram. A five-level digraph was formed as a result of this.

Step 4: Development of diagram

Using the Level partitioning done in the previous step, a TISM model can be developed, highlighting the hierarchical relationship among the delay factors, as shown in Figure 2.

Table 4. Final Reachability Matrix with significant transitivity

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	0	1	0	1	**1***	**1***	1
C2	1	1	1*	1	0	0	0	1*
C3	0	0	1	0	1	0	1*	0
C4	1	1	0	1	1	1	0	0
C5	0	0	1	0	1	0	1	0
C6	0	0	1	0	1	1	0	0
C7	0	0	0	0	0	0	1	0
C8	1	0	1	0	0	1	0	1

Table 5. Interpretive matrix

	C1	C2	C3	C4	C5	C6	C7	C8
C1 Poor project management plan			Poor project management plan leads to shortage of labour & material		Poor project management plan leads to errors and extra work may have to be done	When there is fault at the planning level there is inefficient site management, communication, and supervision	Poor project management plan leads to poor work quality and enhances cost which ultimately causes Conflict between top management, unions, contractors, etc.	Poor project management plan leads to unrealistic cost and time estimates
C2 Lack of knowledge of newer construction methodologies	Lack of knowledge of newer construction methodologies impacts project plan and decreased efficiency		Due to lack of knowledge of newer construction methodologies construction companies are unable to reduce wastege which leads to shortage of labour and material	Lack of knowledge of newer construction methodologies leads to lack of project monitoring tools and techniques				Due to lack of knowledge of newer construction methodologies cost and time factors are not estimated properly
C3 Shortage of labour & material					Shortage of labour & material leads to extra work due to bad quality or errors		Due to shortage of labour & material the project profitability and timeline may be effected wich leads to Conflict between top management, unions, contractors, etc.	
C4 Lack of project monitoring tools and techniques	Lack of project monitoring tools and techniques impacts the project management plan	Due to lack of project monitoring tools and techniques there is lack of knowledge of newer construction methodologies			Lack of project monitoring tools and techniques leads to extra work due to bad quality or errors	Due to lack of project monitoring tools and techniques there is Inefficient site management, communication, and supervision		
C5 Extra work due to bad quality or errors			Extra work due to bad quality or errors leads to shortage of labour & material				Extra work due to bad quality or errors leads to Conflict between top management, unions, contractors, etc.	
C6 Inefficient site management, communication, and supervision			Inefficient site management, communication, and supervision causes shortage of labour & material		Inefficient site management, communication, and supervision causes extra work due to bad quality or errors			

C7 Conflict between top management, unions, contractors, etc.								
C8 Unrealistic cost and time estimates	Unrealistic cost and time estimates impacts project management plan and leads to unrealistic plans		Unrealistic cost and time estimates causes shortage of labour & material			Unrealistic cost and time estimates leads to inefficient site management, communication, and supervision		

Insignificant transitivity relationships were dropped during the formation of the digraph and only the significant relationships and transitivity were kept to form the digraph. This digraph was further shown to 5 experts to check the validity of the model. The expert's comments were noted, and an interpretive matrix was formed, which is shown in Table 5. Table 4 shows the final reachability matrix with only the significant transitivity.

Table 6. Dependent and Driving powers

	C1	C2	C3	C4	C5	C6	C7	C8	Driving power
C1	1	0	1	0	1	1*	1*	1	6
C2	1	1	1*	1	1*	1*	0	1*	7
C3	0	0	1	0	1	0	1*	0	3
C4	1	1	1*	1	1	1	1*	1*	8
C5	0	0	1	0	1	0	1	0	3
C6	0	0	1	0	1	1	1*	0	4
C7	0	0	0	0	0	0	1	0	1
C8	1	0	1	0	1*	1	0	1	5
Dependent power	4	2	7	2	7	5	6	4	

Table 6 shows the Dependent and Driving powers of the eight dealy causing factors for CPs. These powers are obtained from Table 4. On plotting the values of Dependent power and Driving power, graph of MICMAC is obtained as shown in Figure 3. Using MICMAC, the delay factors are categorized into four distinct zones: driving delay factors, autonomous delay factors, dependent delay factors, and linkage delay factors, as shown in Figure 3. The delay factors can be clarified as follows:

a) Zone I - Autonomous delay factors: These are the delay factors that possess a low degree of dependency and low degree of driving force (Jena et al. 2017). There are no autonomous delay factors in this study.

b) Zone II - Dependent delay factors: Dependent delay factors are those that have less driving force and a greater reliance on other factors. When the other elements change, these delay factors are also affected (Jena et al. 2017). In this study, the delay factors C7 (Conflict between top management, unions, contractors, etc.), C5 (Extra work due to bad quality or errors) and C3 (Shortage of labour & material) are the dependent delay factors.

c) Zone III - delay factors: Linkage delay factors are defined as delay factors with a high driving and dependency power. They demonstrate how the driving variables and the reliance are related (Jena et al. 2017). In this study, the delay factors C1 (Poor project management plan), C8 (Unrealistic cost and time estimates), and C6 (Inefficient site management, communication, and supervision) are the linkage delay factors.

d) Zone IV – Independent delay factors: These are delay factors that exhibit a high degree of driving force but a low degree of reliance (Jena et al. 2017). They are also known as driving delay factors. In this study, two delay factors were found to be in zone IV – C2 (Lack of knowledge of newer construction methodologies) and C4 (Lack of project monitoring tools and techniques). These two delay factors were the key or driving delay factors leading to delays in CPs.

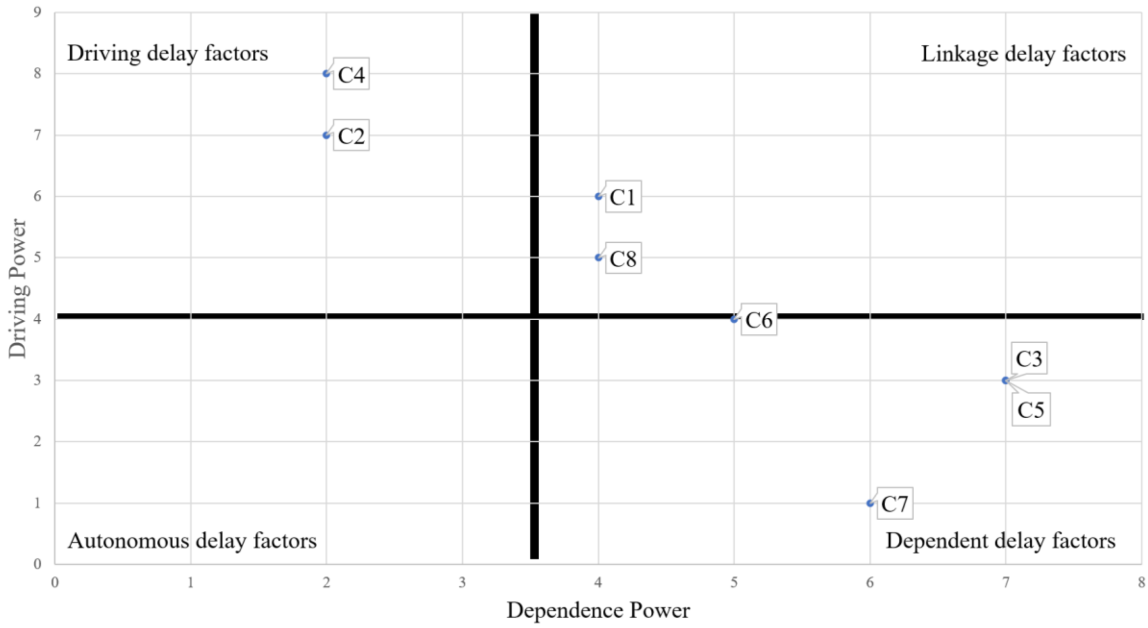

Figure 3. Graph of MICMAC Analysis

4. Results and Discussion

This section presents the results of integrated TISM-MICMAC analysis and discusses the findings. Five levels of the digraph have been formed as a result of level partitioning, and Figure 2 shows all five levels where lack of knowledge on newer construction methodologies and Lack of project monitoring tools and techniques are placed at the bottom. These delay factors affect the other two delay factors, namely poor project management plan and unrealistic time and cost estimates. In the middle, the delay factor named inefficient site management, communication, and supervision is affected by the delay factors placed below it, and it further affects the delay factors which are placed above it: extra work due to bad quality or errors and shortage of labour and material. Finally, these delay factors affect Conflict between top management, unions, contractors, etc. The delay factor shortage of labour and material has a transitive effect on the delay factor conflict between top management, unions, and contractors, while the factor extra work due to bad quality or errors has a direct effect on it.

From TISM analysis, it can be inferred that Lack of knowledge of newer construction methodologies and Lack of project monitoring tools and techniques are the most influencing delay factors. These findings are in congruence with the work done by Assaf & Al-Hejji (2006) and Toor & Ogunlana (2008). Poor project management plan and Unrealistic cost and time estimates are in level 2, while Inefficient site management, communication, and supervision are in level 3. The shortage of labour and materials and extra work due to bad quality or errors are in level 4. Ultimately, all these delay factors affect Conflict between top management, unions, contractors, etc., which is positioned at level 5.

Lack of knowledge of newer construction methodologies and lack of project monitoring tools and techniques are placed at the lowest level of the TISM model, which suggests that these delay factors drive other remaining delay factors. The positioning of these components in cluster four also validates the same behaviour. Numerous issues may be traced back to these elements, and any change in them could have an adverse impact. Unrealistic time and expense estimates and inadequate project management plans are caused by a lack of knowledge on newer construction methodologies. These results are consistent with those of the MICMAC analysis as well because the linkage variables in cluster three include factors such as a lack of a proper project management plan, a lack of project monitoring tools and techniques, ineffective site management, communication, and supervision. According to Faridi et al. (2006), 50% of building projects in the UAE are delayed and not finished on time. To reduce construction delays, Venkatesh et al. (2012) suggested improved project management practices that may be used at the project's conceptual and detailed planning stages. Shrivas and Singla (2022) also identified poor construction methods to be the main reason which affects or influences the rest of the factors. The delay factors extra work required because of poor quality or errors and Conflict between top management, unions, contractors, etc. are place in zone II which indicates that these are the dependent delay factors.

Figure 3 concludes that all the factors selected for the study are relevant because none of the factors falls under the autonomous category. From the MICMAC diagram, we can report that C1, C8, and C6 are the linkage factors having strong dependency. These delay factors can be characterized by strong sensitivity and higher driving power with the potential for substantial effect if the system or other factors are hindered. In the independent category of the MICMAC diagram, two factors, C4 (Lack of knowledge of newer construction methodologies), and C2 (Lack of knowledge of newer construction methodologies) has been reported. This signifies that other factors have limited to no influence on these factors. The rationale behind this can be the higher driving power but low dependency. On the contrary, C7 (Conflict between top management, union and contractors), C3 (Shortage of labour & material) and C5 (Extra work due to bad quality or errors) fall under the dependent category with higher dependency and low driving power.

4.1. Managerial Implications

The experts consulted during the study helped synthesize a few recommendations and provided some insights on how to resolve the issues of delays. The same has been discussed next.

4.1.1. Proper planning and design: Project planning is critical in all types of projects. A preliminary study should be conducted in order to have a better understanding of the resources required to complete the work, such as materials, labour, equipment, etc. a good amount of time and resources needs to be invested in the planning and design phase. Information regarding the newer construction methodologies that can be incorporated needs to be studied. The plan that is formulated before the start of the project should have timelines, milestones, resources required, budget, etc. This thorough study helps in identifying the potential causes of delays and helps in rectifying them.

4.1.2. Communication plan: A proper flow of communication between all stakeholders, various officials involved, contractors, managers, supervisors, workers, etc., is very crucial to project completion. Any information not communicated on time could lead to a PD. Hence a proper medium of communication needs to be ensured. Decision-makers can utilize state-of-the-art digitalization technologies for transparent and efficient communication. In this context, there is ample scope to adopt technologies such as Blockchain, enterprise resource planning applications etc.

4.1.3. Incorporation of technology: The usage of new advanced technologies can help in reducing delays to a greater extent. New advancements like Building Information Modelling (BIM), different designing software, and construction methodologies like pre-cast will help in reducing delays. It will help to improve the efficiency and precision of work.

4.1.4. Resource allocation: Proper resource allocation is a mandatory requirement for completing projects on time. Proper allocation of labour, materials, tools, and equipment help in reducing delays. A proper resource management plan formulated prior to work will help in the timely allocation of resources. This will not only reduces delays but saves the opportunity cost as well.

4.1.5. Proper monitoring and supervision: Proper monitoring, supervising, and reporting of work helps in better management of CPs. The adoption of the right project monitoring tools and techniques helps in better sequencing of work.

4.1.6. Scope creep: Scope creep needs to be eliminated. This is an unexpected expansion in the scope of the projects. This could be some additional work or maintenance work etc. Proper care should be taken at the beginning of the work itself to ensure that the objectives are clearly laid out.

5. Conclusion, limitations and scope for future research

The study aims to identify and model delay factors in construction and identify which delay factors are the driving and dependent among them. To understand the relationship between those delay factors and predict the impact of these delay factors on construction, this study adopts a TISM-MICMAC approach. On the basis of experts' opinion, eight most important delay factors of CPs were identified. TISM diagraph and MICMAC matrices are built based on the judgement of the experts.

The study findings can help the construction industry resolve the issues of delays by developing suitable course of actions. The suggestions regarding the implementation of project management, adoption of smart technologies, workers' training, and stakeholders' awareness can expedite the construction process.

Even with the comprehensive scope covered in this study, there are a few limitations. The work focuses on the Indian construction industry, and the experts consulted were from one of the Indian states. Thus, there may be some variation in the findings when experts consulted will belong to multiple countries. Future research can take up this work in the context of multiple countries. Some critical elements, such as corruption, have been intentionally removed from the study as it will be cumbersome and unfeasible to quantify the impact. Future researchers can also use simulation studies to conduct case studies and quantify the impact of each of these factors. This can help devise a suitable course of action. Finally, future researchers are advised to explore the implications of adopting emerging technologies in the construction industry from the context of PDs.

Appendix A

Table A1. Iteration 1

Delay Factor	Reachability Set	Antecedents Set	Intersection Set	Level
C1	C1 C3 C5 C6 C7 C8	C1 C2 C4 C8	C1 C8	0
C2	C1 C2 C3 C4 C5 C6 C8	C2 C4	C2 C4	0
C3	C3 C5 C7	C1 C2 C3 C4 C5 C6 C8	C3 C5	0
C4	C1 C2 C3 C4 C5 C6 C7 C8	C2 C4	C2 C4	0
C5	C3 C5 C7	C1 C2 C3 C4 C5 C6 C8	C3 C5	0
C6	C3 C5 C6 C7	C1 C2 C4 C6 C8	C6	0
C7	C7	C1 C3 C4 C5 C6 C7	C7	**1**
C8	C1 C3 C5 C6 C8	C1 C2 C4 C8	C1 C8	0

Table A2. Iteration 2

Delay Factor	Reachability Set	Antecedents Set	Intersection Set	Level
C1	C1 C3 C5 C6 C8	C1 C2 C4 C8	C1 C8	0
C2	C1 C2 C3 C4 C5 C6 C8	C2 C4	C2 C4	0
C3	C3 C5	C1 C2 C3 C4 C5 C6 C8	C3 C5	**2**
C4	C1 C2 C3 C4 C5 C6 C8	C2 C4	C2 C4	0
C5	C3 C5	C1 C2 C3 C4 C5 C6 C8	C3 C5	**2**
C6	C3 C5 C6	C1 C2 C4 C6 C8	C6	0
C8	C1 C3 C5 C6 C8	C1 C2 C4 C8	C1 C8	0

Table A3. Iteration 3

Delay Factor	Reachability Set	Antecedents Set	Intersection Set	Level
C1	C1 C6 C8	C1 C2 C4 C8	C1 C8	0
C2	C1 C2 C4 C6 C8	C2 C4	C2 C4	0
C4	C1 C2 C4 C6 C8	C2 C4	C2 C4	0
C6	C6	C1 C2 C4 C6 C8	C6	**3**
C8	C1 C6 C8	C1 C2 C4 C8	C1 C8	0

Table A4. Iteration 4

Delay Factor	Reachability Set	Antecedents Set	Intersection Set	Level
C1	C1 C8	C1 C2 C4 C8	C1 C8	**4**
C2	C1 C2 C4 C8	C2 C4	C2 C4	0
C4	C1 C2 C4 C8	C2 C4	C2 C4	0
C8	C1 C8	C1 C2 C4 C8	C1 C8	**4**

Table A5. Iteration 5

Delay Factor	Reachability Set	Antecedents Set	Intersection Set	Level
C2	C2 C4	C2 C4	C2 C4	**5**
C4	C2 C4	C2 C4	C2 C4	**5**

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