

Supply Chain Management of Road Projects in India using FMEA and ISM Technique

Purnima Bajpai*, Megha Kalra and Ambardar Sunyna Bushanchandar

Department of Civil and Environmental Engineering, The Northcap University, Gurugram - 122017, Haryana, India;
purnimabajpai@ncuindia.edu, meghakalra@ncuindia.edu, sunynaambardar@gmail.com

Abstract

Objective of the Study: This paper aims to study about the risks that affect the supply chain management of the road infrastructure projects. Supply chain management identifies the issues that slow down the process of road construction and helps in reconfiguration and re-engineering of supply chain. **Methodology:** A thorough literature review has been conducted to identify the major factors that cause delay in the completion of the road projects. After analysis of reviewed literature a questionnaire survey was prepared. The gathered data was analyzed and top ten risk factors having highest Risk Priority Number (RPN) were identified from Failure Mode and Effect Analysis technique (FMEA). The relationship between the various risks factors has been identified by the interpretive structural modeling (ISM). **Findings:** The findings of the study indicate that there are several risks that create a gap between planned completion time and actual completion time of the road projects. The delay in the road projects lead to several risks such as cost overrun, legal issues, contract termination and many others. **Application:** Roads are the lifeline of a Country and its timely development plays a very important role in the Development of the Nation. This study will enable various parties involved to understand and mitigate the risks in a n effective manner.

Keywords: Failure Mode and Effect Analysis Technique (FMEA), Interpretive Structural Modeling (ISM), Risk Priority Number (RPN), Risks, Supply Chain Management

1. Introduction

Roads are important for the overall social and economic development of any region. Around 65% of freight 180% of the passenger traffic is carried by the road sector. The roads directly or indirectly affect industrial location, housing markets, land prices, internal trade and many other things. The Indian road network is about 33 lakh kilometres which majorly consists of expressways, national highways, major district roads, state highways and rural and other roads. Time, cost and quality are very important for any road project. However, it has been observed that most road projects in India have been

completed with additional time, money as well as resources. The main objectives of the study have been the identification of the factors involved in the completion of the road projects in India. The major impact due to delay in road projects leads to the increase in project cost by several crores. Therefore it becomes important to identify the factors which are causing the delay in the completion of road projects and take necessary steps to rectify such problems. The thorough study of literature, case studies and project reports gave an insight to various risks which delay the construction of roads

The objective of the study was prioritizing the factors by finding Risk priority number by Failure Mode

*Author for correspondence

and Effect Analysis. Failures in road projects will be any defects that will cause delay in their completion. Failures can be prioritized according to their severity and their consequences and further their frequency and lastly the ease with which they can be detected.

The final step involved in the study was the modeling of factors to be carried out. It also helps in improving the performance of a supply chain. ISM (Interpretive Structural Modeling) method has been used in this study for modeling the factors affecting delays in road projects.

2. Literature Review

Through a detailed study¹ presented 52 delay causes under eight groups. Ranking of the delay parameters was done through a questionnaire survey approach. Severity index had been used for ranking the delay causes and top five causes were determined. The top five factors were political situation, segmentation between areas, lack of competition, delay in progress payment, delays by owner in approvals and shortage of equipment.

Similarly² through their study concluded that road projects are very prone to major cost overruns. Continuous changes in scope of work, omissions in contract documents have been identified as the key contributors to cost overruns in road projects.

Further³ identified 33 risks in highway construction projects in UAE. The priority of each risk is calculated which helps in identifying most significant risks. The most significant risk factors identified are the inefficient planning methods used, unexpected and unsurveyed ground utilities, quality and integrity of design, delay in the approvals and delays in expropriations. The ISM approach was used by⁴ to understand the dominant factors affecting the supply chain in the mining industry in India and analyze the interaction between environment and society.

A study by⁵ aimed to identify the various uncertainties and then categorize them in terms of their severity. The study identified three main uncertainties with the highest level of significance was obtained for timely and correct information provided by clients, the accuracy with which the project was planned and timely availability of permissions from the regulators. A few more factors were identified by⁶ identified that the supply chain agility depends on majorly the customer satisfaction, quality enhancement and minimization of operation cost, the speed of delivery of consumables, service level improvement

and the total lead-time reduction. Some particular typical attributes were studied² the construction industry and developed a model for analyzing and improving the relationships between various project partners of a construction supply chain system.

3. Results and Discussions

The risks that cause the delay in construction of road projects have been identified with thorough study of the literature, case studies and the project reports. 25 factors have been identified as main risks which delay the completion of the road projects. A questionnaire is prepared which includes these 25 risks. These risks had to be rated between 1 to 5 on a likert scale. 1 being its probability of occurring is highest and 5 being its probability of occurring is least. Each risk had to be rated for three parts i.e. likelihood of occurrence, likelihood of detection and severity. The questionnaire survey was distributed among industry professionals. 33 responses were received. Failure Mode and Effect analysis has been used to priorities' the risks. The rating for likelihood of occurrence, likelihood of detection and severity for each risk was identified from the responses received and their weighted average was determined. Risk Priority Number for each risk was determined based on which the final top ten parameters were identified. Table 1 below represents the top ten parameters causing delays in road projects based on the RPN methodology and used further for study.

Table 1. Top ten parameters causing delay

Sr. no	Top ten factors
1	Land Acquisition (LA)
2	Delay in Financial Closure (FC)
3	Delay in permits and permissions (PP)
4	Delay in progress payment (PPT)
5	Delay in approvals and revision of design, drawing and documents (ARD)
6	Environmental Clearance (EC)
7	Legal Risks(LR)
8	Delay in Sub Contractors work (SCW)
9	Delay in Site Mobilisation (SM)
10	Poor management and supervision by contractor (PMS)

The Modeling of these factors is done by Interpretive Structure Modeling (ISM). ISM helps in identifying

relationships among risks which affect the completion of the road projects. In this methodology factors are identified and a contextual relationship is decided. It may be noted that in Structural Self Interaction Matrix (SSIM) the relation of influence has been the main focus. A pair wise comparison of each factor has been carried out and has been recorded in a matrix form below in Table 2 below using the following 4 notation. V-indicates that i will affect enabler j, A-indicates that j will be effect j. X-indicates that i and j affect each other. O-indicates i and j are unrelated.

Table 2. Contextual relation between variables (SSIM)

	PSM	SM	SCW	LR	EC	ARD	PPT	PP	FC
LA	O	V	V	X	A	O	O	A	O
FC	O	V	O	O	O	O	V	O	
PP	O	O	O	A	O	O	O		
PPT	X	O	X	V	O	O			
ARD	O	O	V	O	O				
EC	O	O	O	O					
LR	O	O	O						
SCW	O	O							
SM	O								

The subsequent step is obtaining the initial reachabil-ity matrix from the SSIM as mentioned in Table 3 Below and is done by transforming the information obtained from each cell of SSIM into binary digits (1s or 0s).

The next step shown in table 4 below represents the final reachability matrix which has been obtained from the initial reachability matrix by introducing the concept of transitivity. The transitivity entries are marked by 1*. Table 4 represents the final reachability matrix

The ISM methodology used above utilizes the level partitioning system. From the final reachability matrix obtained above subsequently the reachability set and antecedent sets have been derived .The intersection of these sets has been derived for all the above factors and the levels of different factors are determined. Once top level factor is identified, it is removed from consideration. This process continues until the level of each factor is found.

Based on conical matrix the diagraph is developed as shown in Figure 1 below in the diagraph top level factors will occupy the top level. Second level factors will occupy second level and so on till the lowest level factor is located at the lowest level of the diagraph.

ISM Model is developed by changing factor nodes with statements.

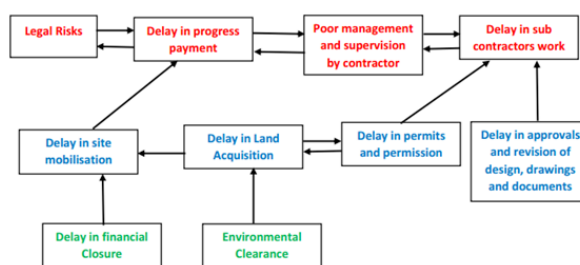


Figure 1. ISM model for delay in road development.

Red –Level I Factors ●

Blue-Level II Factors ●

Green-Level III Factors ●

4. Conclusion

The top ten critical factors which affect the completion of road projects are land acquisition, delay in financial closure, delay in permits and permissions, delay in progress payment, delay in approvals and revision of design, drawings and documents, environmental clearance, legal risks, delay in sub-contractors work, delay in site mobilization and poor management and supervision by contractor. The level III factors obtained from level partition are financial closure and Environmental Clearance. Site cannot be mobilized till there is financial closure. Delay in site mobilization will cause delay in the execution of work. If the work is not completed as per the schedule, it will lead to delay in payments. Delay in progress payments can cause poor management and supervision of the site by contractor as there will be shortage of resources. This will then lead to delay in sub contractors work, again due to lack of resources such as money, manpower, equipment and material. Such factors may give rise to conditions which will create legal risks.

Delay in environmental clearance will cause delay in acquiring the land. If land acquired is late it will cause delay in site mobilization and permits and permissions. Delay in permits and permissions will again affect the sub contractors’ work which in turn will cause poor site management by the contractor leading to delay in progress payment. Delay in progress payments can cause legal risks. Delay in approval and revision of design and drawings is a II level risk. It will lead to delay in sub contractors’ work.

Table 3. Initial Reachability matrix

Elements		1	2	3	4	5	6	7	8	9	10
		LA	FC	PP	PPT	ARD	EC	LR	SCW	SM	PSM
1	LA	1	0	0	0	0	0	1	1	1	0
2	FC	0	1	0	1	0	0	0	0	1	0
3	PP	1	0	1	0	0	0	0	0	0	0
4	PPT	0	0	0	1	0	0	1	1	0	1
5	ARD	0	0	0	0	1	0	0	1	0	0
6	EC	1	0	0	0	0	1	0	0	0	0
7	LR	1	0	1	0	0	0	1	0	0	0
8	SCW	0	0	0	1	0	0	0	1	0	0
9	SM	0	0	0	0	0	0	0	0	1	0
10	PSM	0	0	0	1	0	0	0	0	0	1

Table 4. Final Reachability Matrix

Elements		1	2	3	4	5	6	7	8	9	10
		LA	FC	PP	PPT	ARD	EC	LR	SCW	SM	PSM
1	LA	1	0	1*	1*	0	0	1	1	1	1*
2	FC	1*	1	1*	1	0	0	1*	1*	1	1*
3	PP	1	0	1	1*	0	0	1*	1*	1*	1*
4	PPT	1*	0	1*	1	0	0	1	1	1*	1
5	ARD	0	0	0	0	1	0	0	1	0	0
6	EC	1	0	1*	1*	0	1	1*	1*	1*	1*
7	LR	1	0	1	0	0	0	1	1*	1*	1*
8	SCW	1*	0	1*	1	0	0	1*	1	1*	1*
9	SM	0	0	0	0	0	0	0	0	1	0
10	PSM	1*	0	1*	1	0	0	1*	1*	1*	1

Table 5. Final Conical Matrix

	Elements	9	1	3	7	8	10	4	5	2	6	Driving Power	Ranks
		SM	LA	PP	LR	SCW	PSM	PPT	ARD	FC	EC		
SM	9	1	0	0	0	0	0	0	0	0	0	1	V
LA	1	1	1	1	1	1	1	1	0	0	0	7	II
PP	3	1	1	1	1	1	1	1	0	0	0	7	II
LR	7	1	1	1	1	1	1	0	0	0	0	6	III
SCW	8	1	1	1	1	1	1	1	0	0	0	7	II
PSM	10	1	1	1	1	1	1	1	0	0	0	7	II
PPT	4	1	1	1	1	1	1	1	0	0	0	7	II
ARD	5	0	0	0	0	1	0	0	1	0	0	2	IV
FC	2	1	1	1	1	1	1	1	0	1	0	7	II
EC	6	1	1	1	1	1	1	1	0	0	1	8	I
Dependence		9	8	8	8	9	8	7	1	1	1		
Ranks		I	II	II	II	I	II	III	IV	IV	IV		

This will again cause poor site management by contractor leading to delay in payments and causing legal risks. Land acquisition and delay in permits and permissions will affect each other which will subsequently cause delay in site mobilization and delay in subcontractors work respectively. If there is a legal issue, it can cause delay in progress payments which in turn can cause poor management and supervision of site by contractor which will lead to delay in sub contractors' work. Similarly if work is not completed in time by sub contractor, this will cause poor site management leading to delay in the progress payment. These factors may therefore give rise to legal risks.

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