INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

OPEN ACCESS

Received: 26.11.2021

Accepted: 23.02.2022

Published: 25.03.2022

Citation: Ghosh SK, Sar AK (2022) Impact of Effective Supply Chain Management and Supply Chain Risk Management Capabilities on Construction Project Performance. Indian Journal of Science and Technology 15(11): 505-517. https://doi.org/10.17485/IJST/v15i12.2194

* **Corresponding author**.

sajal.ghosh@rvnl.org
sajal.talcher@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Impact of Effective Supply Chain Management and Supply Chain Risk Management Capabilities on Construction Project Performance

Sajal Kumar Ghosh[1,2]*, Ashok Kumar Sar[3]

1 Sr. Manager, Rail Vikas Nigam Limited (A Govt. of India Enterprise under Ministry of Railways), Bhubaneswar, Odisha, India
2 Research Scholar, Kalinga Institute of Industrial Technology Deemed to be University, Bhubaneswar, Odisha, India
3 Professor, Strategic Management, KSOM, Kalinga Institute of Industrial Technology Deemed to be University, Bhubaneswar, Odisha, India

Abstract

Objectives: To investigate the impact of effective Supply Chain Management (SCM) on construction project performance measured by project success criteria and on Supply Chain Risk Management (SCRM) capabilities. The study also aims to examine the mediating role of SCRM capabilities on the relation between effective SCM and project success criteria in an uncertain situation like COVID-19. **Methods:** The investigation was conducted on survey data received from 134 project practitioners from rail construction projects in India by the Partial Least Square Structural Equation Modeling (PLS-SEM) technique using Smart PLS3. **Findings/Results:** Results revealed a significant positive linkage between effective SCM and construction project success criteria of time, cost, quality, and also with SCRM capabilities. The findings also confirmed the mediating role of SCRM capabilities on the relation between effective SCM and project time and cost. However, no mediating role in the relationship between effective SCM and project quality was observed. **Application:** Findings will help in sensitizing construction project professionals on the importance of effective SCM and developing SCRM capabilities to make projects a success even in uncertain supply chain situations. The findings also reinforced the applicability of the Resource-based view and paradox theory in understanding Supply chains. **Novelty:** This research had used three project success criteria as dependent variables instead of using overall project success as done in earlier studies in the project management and the SCM arena.

Keywords: Supply Chain Management (SCM); Supply Chain Risk Management (SCRM); Railway Construction Project; Project Success; PLS-SEM

1 Introduction

The pandemic COVID-19 had created unprecedented interruption in almost every organization's supply chains and construction projects worldwide which form a sizeable portion of most nations' economies were also badly affected due to their dependency on supply chains [1]. Arrivals of essential supplies are desideratum to construction project's performance and it is necessary to ensure the existence of an effective SCM process in any construction project all the time. But to face unpredicted disruption risks to supply chains, which may also arise due to different natural or manmade disasters like tsunami, earthquakes, terrorist activity, war, economic change, political and other social and organizational situations like Govt. policy changes, strikes/lockouts, etc., it is necessary to buildup SCRM capabilities. Though this type of supply chain disruption risk has a low probability of happening but has a high impact on the performance of projects. Effective management of such supply chain disruptions can save unnecessary costs, delays, and increased reworks resulting from quality issues in projects [2]. Firms having supply chains with superior risk management capability can recover fast from the ill effects of disruptions and that can be a competitive advantage [3]. The most important and popular performance measures for construction projects are their success and the most important criteria for project success is project completion within the allotted time, cost, and quality also termed as project success criteria. So there is a need for investigating relations between SCM, SCRM capabilities, and criteria of construction project success.

Although we can trace a few pieces of research studying relationships between SCRM capabilities and the organization's performance, there is a dearth of empirical pieces of evidence on the effects of SCRM capabilities on construction project's success criteria [4]. To fill up this gap, this paper had examined the relationship between effective SCM of construction project organizations and their performance in terms of fulfilling project success criteria. The paper had also examined the relation between effective SCM and SCRM capabilities of construction project organizations and how it mediates the relationships between effective SCM and construction project success criteria. The study modeled effective SCM as a second-order reflective construct measured by four dimensions namely supply chain infrastructure, organizational linkages, procurement culture, and organizational information sharing. The study was conducted in the context of rail construction projects in India as the railway has huge economical and social importance in India. As far the best of our knowledge, no such study where the three most important project success criteria of time, cost, and quality were used as dependent variables instead of overall project success in construction project management and supply chain literature conducted earlier. This will help project professionals understand the effect of SCM and the role of SCRM capabilities on each success criteria and can take decisions according to the priority of particular success criteria in a project.

So, the objectives of this study are to (a) assess effective SCM as a second-order reflective, (b) examine the impact of effective SCM on three project success criteria (i.e. project time, cost, and quality) and SCRM capabilities of rail construction projects, and (c) assess the mediating role of SCRM capabilities on the relation between effective SCM and three project success criteria.

The rest of the paper has six distinct sections. This introduction section is followed by a literature review where different dimensions of effective SCM, SCRM capabilities, and project success criteria and the relationships between these constructs are discussed. In the next section, different theories relevant to this study, the concept for this investigation, and hypotheses postulated are described. In the methodology section, a detailed description of methods adopted for data collection and their analysis are enumerated. The fifth section presents the results of the data analysis. Section 6 has discussions of the results obtained. Section 7, which is the last section, has presented conclusions, managerial implications, the limitations of the research, and recommendations for future research.

2 Literature Review

2.1 Effective Supply Chain Management (SCM)

SCM is about formulating and constantly applying strategies to organize, control, and motivate all resources active in the supply chain of the organization. It is the foremost responsibility of SCM to make the supply chain both efficient and responsive. An effective SCM helps organizations in specifying the goals of the organization and measuring the extent of achieving its goal. Traditionally the performance of any supply chain is measured by its ability to save cost. Another measure of supply chain effectiveness is the timeliness of materials, neither before nor late. This type of approach mainly suggests the adoption of many modern techniques like digitization and automation of the whole supply chain thereby reducing cost and time. This thinking gave birth to modern supply chain models like lean supply chain and Just In Time (JIT). However, a supply chain can be tagged as effective when it can perfectly respond to uncertainty risks by building SCRM capabilities [5]. Some of the important dimensions of an effective SCM are organizational information sharing, organizational linkage, supply chain infrastructure, and supply chain culture.

2.2 Organizational information sharing

Most of SCM literature has stressed the importance of information flow and developing a system to exchange product-related data between manufacturers and users[6]. Supplier information flow is measured by the amount of information made available by suppliers about their products to customers. Purchasers also can share information about details of their requirements with different suppliers[7]. This type of two ways information flow may help lower costs. Similarly, intra-organizational information flow about the supply chain within departments can be beneficial for the whole organization. The quality of supply chain information shared determines the responsiveness of the supply chain thus helping in building SCRM capabilities.

2.3 Organizational linkage

Organizational linkage is referred to sharing of vital information and data between organizations needed to plan and make decisions. A proper organizational linkage ensures the availability of this vital information in time throughout the chain without any change or distortion. Many times distorted information may create a ripple effect through all the processes of the organization. In the context of SCM, this linkage may be inter-organizational and or intra-organizational between different departments. Inter-organizational linkages between suppliers, buyers, and quality inspection departments can create a win-win situation for all stakeholders of the supply chain. Similarly, intra-organizational linkages between departments like finance, purchase, and user/production help improve the supply chain. Information and communication technology can improve organizational linkages and the performance of SCM[8]. An effective SCM with established organizational linkages can reduce cost, reduce delivery time as well as improve the quality of deliverables[9].

2.4 Supply Chain Infrastructure

Supply chain infrastructures are those systems that enable an efficient and effective flow of materials starting from its availability and manufacturing to its on-time delivery at the point of consumption in a cost-effective way. Implementation of information technology in SCM makes it more effective particularly by making the transportation system more efficient[10]. In the context of construction projects, many input materials are not readily available in the market due to their specialized nature. So there is a need for creating multiple sources by way of manufacturer and vendor development programs.

2.5 Supply Chain Culture

Any organization's procurement professionals play a vital business function. Procurement professionals work as a bridge between the supplier's organization and purchasing organization's technical experts. So the organization should have a culture where these professionals are trained to act in a responsible manner which can create an environment of trust, understanding, and cooperation among both stakeholders of the supply chain. The project organization's leader should develop and nourish a culture where suppliers are treated with care, respect and do not receive any wrong signals at any level. This will make suppliers feel like an integral part of the purchaser's supply chain and make the SCM more effective[11]. Unless a supply chain-oriented culture is developed, the effective SCM will remain a distant dream for organizations[12].

2.6 Supply Chain Risk Management (SCRM) capabilities

SCRM capability is an organization's ability to face supply chain disruptions due to either internal or external causes and maintain its normal activities in uncertain times by identification, evaluation, and mitigation of such risks. The current pandemic COVID-19 has exposed the weak SCRM capabilities of many organizations across the globe. The outbreak of this pandemic was idiosyncratic and quite differently affected all organizations throughout the globe. The shortages and delays in material delivery affected downstream of the supply chain which created a blue whip effect and badly affected the performance of the organization[13].

Sharing of resources may be one of the strategies to counter the avalanche a supply chain disruption can bring to the organization. Sharing of resource both at the intra-organizational level as well as inter-organizational level with partner organizations result in value creation for all participating organizations[14]. Normally maintaining a buffer stock of inventory in construction projects causes extra cost, increases waste, and hinders performance in the normal course. But in many uncertain situations, buffer stocks increase the performance of construction projects[15][16]. In the context of SCM in construction projects, actions like maintaining a judicious buffer stock instead of adopting always lean policy are helpful in such situations. These actions help in creating a viable supply chain[17]. The deciding success factors are how, where, and how much inventory to stock for uncertainties. Adoption of financial policies which encourage supply chain partners for planning and stocking reasonable supplies well in advance in construction projects instead of financial policies supporting only the "Just In Time"

(JIT) philosophy helps in establishing a viable model of SCM[17]. In construction projects, nonpayment of progress payment for supplies had been identified as an important reason for the delay in project completion[16].

2.7 Construction Project Success and Supply Chain

Out of many factors affecting the most important construction project success criteria of time, budget, and quality, availability of materials had always been identified as a major factor. As construction projects need varieties of materials in varying quantities during their lifecycle, any disruption in the supply chain can jeopardize the entire construction project[18]. Hence to become a success, it is of immense importance for construction project SCM to remain prepared to face any type of uncertainty arising in the supply chain.

3 Theoretical framework, Conceptual framework, and Hypotheses

Though many theories are used to explain the different phenomena in SCM, this paper had used Resource-Based View (RBV) and Paradox Theory as theoretical backgrounds. The concept behind RBV is, by using internal resources and capabilities a firm can create a competitive advantage for it. In the context of SCM, it can be interpreted as building an effective SCM can be a competitive advantage for firms whose performance depends on their supply chain[5]. As per the paradox theory, actions that at first instant seems to be opposing actually may be complementing each other and maybe a competitive strategy[19]. In the context of the supply chain, many actions to build up risk management capabilities may look to be more costly but actually, these create competitive advantages over other firms. Similarly, in an age when having information is considered a competitive advantage, sharing the supply chain information at the first instance may look to be a hindrance to building the competitive advantage. But in the SCM context, information sharing between supplier and purchaser becomes advantageous for both organizations depicting the paradoxical situation in SCM.

A study of Indian construction projects identified the availability of materials as the fourth important factor for construction project success. Like any other construction project, railway construction projects are material-intensive and the progress of work depends on the continuous functioning of supply chains. So both contractor and customer organizations working in railway construction projects have to understand and appreciate the importance of effective SCM and the importance of building risk management capability of the SCM in making projects successful and planning supply chains.

Based on the evidence of effective SCM with supply chain infrastructure, organizational linkages, procurement culture, and organizational information sharing as major dimensions influencing project performance and SCRM capabilities from literature, in the context of Indian rail construction projects, we had formulated the following hypotheses.

Hypothesis 1 (H_1): Effective SCM has a significant positive effect on project time in Railway construction projects in India.

Hypothesis 2 (H_2): Effective SCM has a significant positive effect on project cost in Railway construction projects in India.

Hypothesis 3 (H_3): Effective SCM has a significant positive effect on project quality in Railway construction projects in India.

Hypothesis 4 (H_4): Effective SCM has a significant positive effect on SCRM capability in Railway construction projects in India.

Hypothesis 5 (H_5): SCRM capability has a significant mediating effect on the relationship between effective SCM and project time in Railway construction projects in India.

Hypothesis 6 (H_6): SCRM capability has a significant mediating effect on the relationship between effective SCM and project cost in Railway construction projects in India.

Hypothesis 7 (H_7): SCRM capability has a significant mediating effect on the relationship between effective SCM and project quality in Railway construction projects in India.

The conceptual framework depicting hypothesized relationships among different variables based on our discussion in the introduction section and literature review is shown in Figure 1.

4 Methodology

In this quantitative empirical study, an extensive literature study was conducted to understand concepts of project success, effective SCM, the role of SCRM capabilities, and identify their constructs. On identification of constructs, an interview was conducted with a few respondents associated with railway construction projects each having more than 10 years of experience in railway construction projects to get their view on the importance of identified constructs. The final questionnaire was prepared with a five-point Likert scale having options ranging from "strongly disagree" to "strongly agree" to assess perceptions of respondents on identified constructs in organizations engaged in railway construction projects.

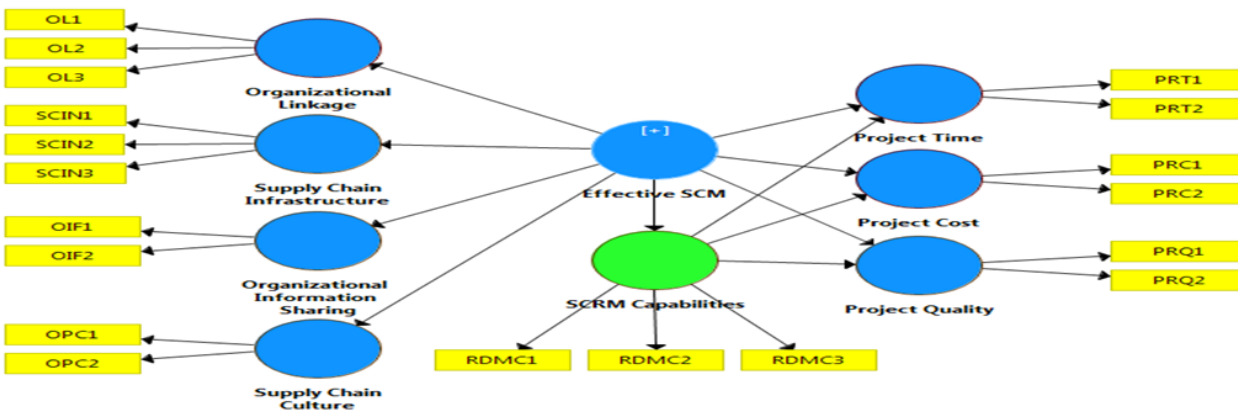

Fig 1. Conceptual framework showing hypothesized relationships between variables

4.1 Construct measures

Some of the indicators used in earlier research [9,20] and some indicators emerging from our literature review which were validated by interview were used to measure constructs in our survey instrument. These constructs and their indicators/dimensions are enumerated in Table 1.

4.2 Sampling and data collection

A purposive non-probability sampling technique was adopted for this quantitative research. Respondents were chosen from professionals who were associated with railway construction projects in different parts of India for at least ten years. To have a representative sample, respondents were chosen from the client as well as contractor and consultant organizations. The survey was conducted from September 2020 to May 2021 after the first wave of COVID-19 in India with 154 respondents. From154 respondents chosen, we were able to collect 140 responses. On scrutiny, 134 responses were found suitable for analysis as four responses had marked no answers for one question each while two responses had marked two answers for one question each.

PLS-SEM literature advises the use of data having minimum samples of 10 times the number of paths directed towards endogenous (dependent) constructs for obtaining sufficient robustness of the analysis [21,22]. In our conceptual model, six paths are directed towards endogenous constructs (Figure-1), which suggests a need for a minimum sample size of 60 for getting sufficient predictive power. By using more than twice the sample size compared to the minimum requirement, the robustness of our findings had increased.

4.3 Data analysis

The data obtained from the survey were tabulated using an MS Excel spreadsheet and analyzed using the Structural Equation Modeling (SEM) technique by smart PLS 3 software [23].After specifying the structural model, the next step of the PLS-SEM algorithm was to evaluate the measurement model through which the reliability and validity of the constructs were established, which becomes the basis for relationships among constructs in the structural model. Once the reliability and validity of the measurement model were established, the next step was to evaluate the hypothesized relationships in the structural model.

In this research second-order reflective-reflective, SEM model was used. For reliability, we had calculated Cronbach's alpha, composite reliability, and Dijkstra and Hensler's "rho-A". For testing convergent validity, average variance explained (AVE) value and factor loadings were examined. Discriminant validity was examined by Fornell & Lacker's criterion, Heterotrait-Monotrait ratio of correlations (HTMT), and cross-loadings.

On completion of the assessment of the measurement model, an assessment of the inner structural model was done. At first co-linearity checks of the inner structural model were carried out by examining Variance Inflation Factor (VIF) inner values. Next, the coefficient of determinant "R^2" was calculated. For testing the generalizability of the relationships, a predictive relevance test was carried out by examining Stone-Geisser's Q^2 score determined by the blindfolding process. For testing the goodness of fit of the proposed model we had examined. Standardized Root Mean Squared Error (SRMR) as it is a better measure for PLS-SEM.

Table 1. Constructs, Indicators and their relationships

Construct (Code)	Indicator / Dimension	Type of Variable	Description of Indicators / Dimensions (Code)	Relationship with Indicators / Dimensions
1. Project time (PROJ TIME)	2 Numbers	Dependent, Latent	1. Project Time (PRT1 and PRT2)	Reflective
2. Project Cost (PROJ COST)	2 Numbers	Dependent, Latent	1. Project Cost (PRC1 and PRC2)	Reflective
3. Project Quality (PROJ QULTY)	2 Numbers	Dependent, Latent	1. Project Quality (PRQ1 and PRQ2)	Reflective
4. Effective SCM (EFCTV SCM)	4 Numbers	Independent, Latent	1. Supply chain Organizational Linkage (SC ORG LNKG) 2. Supply Chain infrastructure (SC INFRA) 3. Organizational Information Sharing (ORG INF SHAR), 4. Organization's purchase Culture (ORG PUR CUL)	Reflective–2nd order
4a. Supply chain Organizational Linkage (SC ORG LNKG)	3 Numbers	Dimension of Independent, Latent	1. Early engagement in the product development phase (OL1) 2. Communication occurs at all levels sharing praise /criticism (OL2) 3. Performance measurements are shared among supply chain partners (OL3)	Reflective
4b. Supply Chain infrastructure (SC INFRA	3 Numbers	Dimension of Independent, Latent	1. Use of IT infrastructure in SCM activities (SCIN1) 2. Infrastructure for continuous adding new Sources for Supplies (SCIN2) 3. Infrastructure for continuous monitoring quality issues (SCIN3)	Reflective
4c.Organizational Information Sharing (ORG INF SHAR)	2 Numbers	Dimension of Independent, Latent	1. Information Exchange (OIF1) 2. Demand & supply visibility (OIF2)	Reflective
4d. Organization's purchase Culture (ORGPUR CUL)	2 Numbers	Dimension of Independent, Latent	1. SC partners are given due importance (OPC1) 2. Supply chain members get open and transparent dealing (OPC2)	Reflective
5. Risk management capability (SCM RISK CAP)	3 Numbers	Independent (Mediator), Latent	1. Resource Sharing Capability (RDMC1) 2. Risk Resilience (Maintaining Buffer stock (RDMC2) 3. Financial policy (Encourages bringing supplies in advance) (RDMC3)	Reflective

After establishing the suitability of the model, hypothesis testing was done. For hypotheses testing, beta scores of the inner model's construct to construct relationships and significance of the relationship ("p" values) were determined by complete bootstrapping with 5000 subsamples.

For determining the mediation effect of SCRM capability, the variance accounted for (VAF) method was adopted which was calculated from direct, indirect, and total effects. The significance of the mediating effect was also calculated by running complete bootstrapping with 5000 subsamples. To understand the nature of mediation whether competitive or complementary we had adopted a two-step approach proposed by Barren and Kenny.

5 Results and analysis

5.1 Profile of respondents

The response rate of the survey conducted received for this research is 90.90 percent (140 out of 154). The experience profile of 134 valid responses is shown in Table 2.

Table 2. Profile of valid responses

Worked in	Total respondents	Worked for client organizations	Worked for contractors	Worked in project consultants organization	Average years of experience in railway construction projects
Project Management	52	18	26	8	18.88
Supply Chain Management	24	6	16	2	16
Project Execution	48	18	22	8	18.85
Project Finance	10	2	7	1	17.8

(Source: Author's Calculation)

5.2 Assessment of measurement model

After running the PLS algorithm for Confirmative Factor Analysis (CFA), factor loadings of all indicators were noted. All of which were found to be well above the minimum value of 0.708 prescribed for continuing with indicators [24]. Outer reflective model's internal reliability and validity were tested by Cronbach's alpha, composite reliability, and Dijkstra and Hensler's "rho-A". Cronbach's alpha of all variables was found to be between 0.735 and 0.877 which were more than the minimum prescribed value of 0.70. Values of "rho-A" for all variables were found to be between 0.746 to 0.951which were higher than the minimum prescribed value of 0.70. Composite reliability values were found to be between 0.874 to 0.930 well within the lower and upper limits of 0.700 and 0.950 respectively. These three tests established the reliability and validity of constructs .

Convergent validity was confirmed by examining the Average Variance Extracted (AVE) score of variables, which was found to be above 0.50 for all reflective constructs. Results of CFA, internal reliability, and convergent validity are shown in Table 3.

Table 3. Reliability, convergent validity and Factor Loading Scores of the Scale measuring Constructs

	Cronbach's Alpha	rho_A	Composite Reliability	AVE	Factor loadings
SC ORG LNKG	0.783	0.799	0.874	0.699	OL1=0.752,OL2= 0.885, OL3= 0.865
SC INFRA	0.793	0.824	0.879	0.709	SCIN1=0.912, SCIN2= 0.848, SCIN3= 0.758
ORG INF SHAR	0.739	0.863	0.879	0.784	OIF1=0.939, OIF2=0.828
ORG PUR CUL	0.735	0.746	0.882	0.790	OPC1=0.871,OPC2=0.906
SCM RISK CAP	0.877	0.913	0.923	0.801	RDMC1=0.922, RDMC2=0.931, RDMC3=0.827
PROJECT TIME	0.855	0.951	0.930	0.869	PRT1=0.958, PRT2=0.906
PROJE COST	0.814	0.855	0.913	0.841	PRC1= 0.939, PRC2=0.894
PROJ QULTY	0.844	0.873	0.927	0.864	PRQ1= 0.945, PRQ2=0.914

(Source: Author's calculation using smart PLS 3)

For testing discriminant validity, Fornell and Lacker's Criterion and Heterotrait-Monotrait ratio of correlations (HTMT) tests were carried out. Though the threshold limit for the HTMT ratio is 0.90 the stricter measure prescribed is 0.85 [25]. Five ratios i.e between SC INFRA & ORG PUR CUL, between PROJE COST & ORG PUR CUL, between ORG INF SHAR & ORG PUR CUL, between SCM RISK CAP & ORG PUR CUL, and between SCM RISK CAP & PROJ TIME were found to be more than 0.85. On examining the confidence intervals of HTMT inference, these were found to be well within the upper and lower limit of the confidence interval as prescribed in HTMT inference criteria, which well established the uniqueness of all constructs. The results of discriminant validity tests are shown in Table 4 (Fornell and Lacker's criterion) and Table 5 (HTMT ratios). The absence of cross-loadings completed the test for discriminant validity.

After the reliability and validity test of the 1st order outer model, Latent Variable Scores (LVS) of all four dimensions of effective SCM were calculated. These LVS of 1st order constructs were utilized to assess the second-order model in a two-stage approach by introducing EFCTV SCM with four latent variables. As validity and reliability of all indicators were established, we had proceeded to the assessment of the structural model.

Table 4. Fornell and Lacker's criterion

	ORG INF SHAR	ORG PUR CUL	PROJ QULTY	PROJE COST	PROJECT TIME	SC INFRA	SC ORG LNKG	SCM RISK CAP
ORG INF SHAR	0.886							
ORG PUR CUL	0.662	0.889						
PROJ QULTY	0.508	0.491	0.93					
PROJE COST	0.625	0.685	0.503	0.917				
PROJECT TIME	0.471	0.687	0.348	0.575	0.932			
SC INFRA	0.657	0.728	0.65	0.677	0.575	0.842		
SC ORG LNKG	0.582	0.52	0.558	0.609	0.442	0.636	0.836	
SCM RISK CAP	0.57	0.766	0.571	0.682	0.81	0.652	0.511	0.895

(Source: Author's calculation using smart PLS3)

Table 5. HTMT ratios (The values shown in brackets are the lower and the upper bounds of the 95% confidence interval)

	ORG INF SHAR	ORG PUR CUL	PROJ QULTY	PROJE COST	PROJECT TIME	SC INFRA	SC ORG LNKG	SCM RISK CAP
ORG INF SHAR								
ORG PUR CUL	0.877 (0.744-1.006)							
PROJ QULTY	0.62	0.618						
PROJE COST	0.761	0.863 (0.762-.978)	0.586					
PROJECT TIME	0.514	0.832	0.389	0.659				
SC INFRA	0.828	0.940 (0.835-1.048)	0.785	0.819	0.665			
SC ORG LNKG	0.756	0.676	0.672	0.748	0.517	0.796		
SCM RISK CAP	0.646	0.932 (0.840-1.034)	0.655	0.782	0.905 (0.842-0.958)	0.75	0.594	

(Source: Author's calculation using smart PLS3)

5.3 Assessment of Structural Model

For assessing the structural model also termed as an inner model, at first co-linearity checks for the inner model was carried out by Variance Inflation Factor (VIF) inner values, which was found to be 2.195 for PROJ QULTY, PROJE COST, PROJECT TIME, and 1.0 for SCM RISK CAP with respect to EFCTV SCM. As all values were less than the stricter threshold limit of 3.3, the nonexistence of multi-co-linearity was established. Also, inner VIF values less than 3.3 indicated the nonexistence of Common Method Bias (CMB) in the data. Next, the coefficient of determinant R^2 was calculated and found to be between 0.437 to 0.660 well above 0.20 which is considered a good score for behavioral science[26].

For the generalizability of the relationship, a predictive relevance test was carried out by examining Stone-Geisser's Q^2 score by blindfolding process where every third response was blindfolded. We found Q^2 values between 0.356 and 0.451 indicating moderate to strong predictive relevance[24]. For testing the goodness of fit of the proposed model we had examined the Standardized Root Mean Squared Error (SRMR) score as it is a better measure than other fit indices[27]. We had found

SRMR value of 0.088 for our proposed model which established an acceptable model fit as it was lower than 0.10, although a very stricter prescribed value is 0.085 [28].

In the first stage of hypotheses testing, we had examined the beta score (path coefficient) by running the PLS algorithm, the outcome of which is shown in Figure 2.

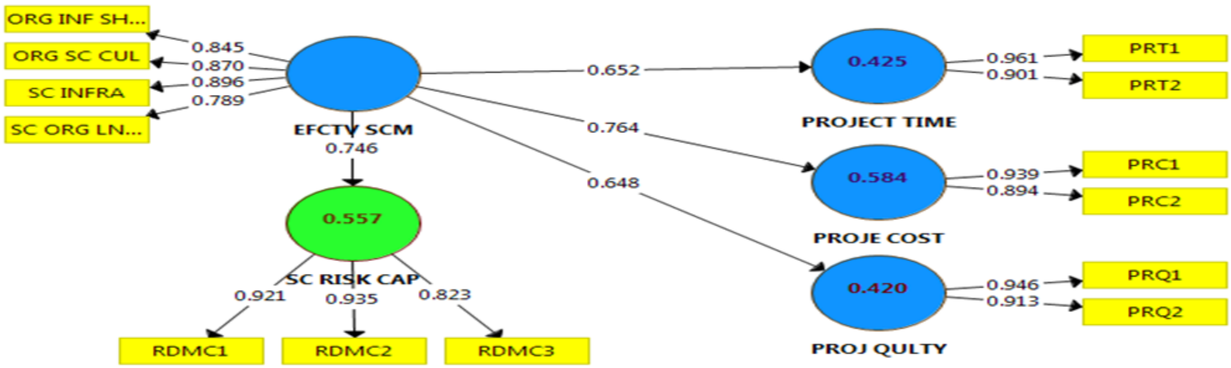

Fig 2. Higher (2^{nd}) order reflective -reflective model showing direct effects

For checking the significance of these beta scores (inner model's construct to construct relationships) complete bootstrapping with 5000 subsamples was run. The hypotheses test results are shown in Table 6.

Table 6. Hypotheses testing results (without mediating variable in model)

Hypothesis	Relationship	Path coefficient /	P value	Supported
H1	EFCTV SCM -> PROJECT TIME	0.652	0.00***	YES
H2	EFCTV SCM -> PROJE COST	0.764	0.00***	YES
H3	EFCTV SCM -> PROJ QULTY	0.648	0.00***	YES
H4	EFCTV SCM -> SC RISK CAP	0.746	0.00***	YES

(Source: Author's calculation using smart PLS3) (*p<0.05, **p<0.01, ***p<0.001)

For testing the mediating effect of risk management capability of SC (SC RISK CAP), PLS algorithm was run showing the relationship between SC RISK CAP and PROJECT TIME, PROJE COST, AND PROJ QLTY, the outcome of which is shown in Figure 3.

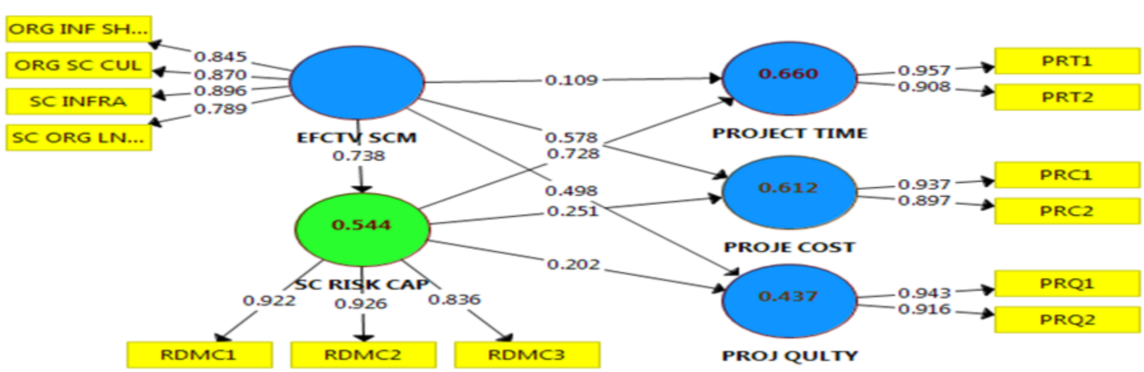

Fig 3. Higher (2^{nd}) order reflective-reflective model showing direct and indirect effects with mediating variable

Table 7. Test of significance for direct effect when mediating variable introduced in the model

Relationship	Path coefficient / value	P-value	Significant
EFCTV SCM -> PROJECT TIME	0.109	0.195	No
EFCTV SCM -> PROJE COST	0.578	0.00***	Yes
EFCTV SCM -> PROJ QULTY	0.498	0.00***	Yes

(Source: Author's calculation using smart PLS3) (*p<0.05, **p<0.01, ***p<0.001)

It was observed that on the introduction of the mediating variable the path coefficients between independent and dependent variables were drastically reduced in the case of PROJ TIME and marginally reduced in the case of PROJE COST and PROJ QLTY. This indicated presence of mediation as suggested by Baron and Kenny. Bootstrapping with 5000 subsamples was run to find out the significance of the mediations of risk management capability of SCM on the relation between effective SCM and project time, project cost, and project quality. The direct effect of the mediation test is shown in Table 7. The indirect effect showing the mediation hypotheses is shown in Table 8.

Table 8. Mediation hypothesis test result summary (indirect effect)

Hypothesis	Relationship	Path coefficient / value	P value	Supported
H5	EFCTV SCM -> SC RISK CAP -> PROJECT TIME	0.537	0.000***	Yes
H6	EFCTV SCM -> SC RISK CAP -> PROJE COST	0.185	0.003**	Yes
H7	EFCTV SCM -> SC RISK CAP -> PROJ QULTY	0.149	0.060	No

(Source: Author's calculation using smart PLS3) (*p<0.05, **p<0.01, ***p<0.001)

For determining the overall mediation effect of risk capability of SC on three dependent variables, the variance accounted for (VAF) was calculated as the ratio of indirect effect to total effect, where the total effect is the sum of direct effect and indirect effect. We found VAF values of 0.831, 0.242, and 0.230 for project time, project cost, and project quality respectively when mediator variable SCM RISK CAP was considered in the model indicating full mediation for project time. The mediation effect on project cost was partial and significant. The mediation effect on project quality though found to be marginally partial but it was not significant indicating the absence of mediation.

6 Discussion

The purpose of our study was to examine linkages between effective SCM and different project success criteria and the mediating effect of SCRM capabilities on these linkages. From the results, it was found that effective SCM in construction projects has a significant positive effect on project time, project cost, and project quality as hypothesized. By examining beta scores it was concluded that effective SCM had the highest effect on project cost followed by project time and project quality. It was also observed that effective SCM has a significant positive influence on building SCRM capabilities in construction projects. These findings are in line with the earlier findings in the context of Indian construction projects which identified supply chain as one of the major success factors for construction projects[18]. The finding of our study was also consistent with findings in Swedish construction projects where the impact of SCM on project performance was empirically proven[29]. Our findings also reinforced the generalizability of findings in Malaysian new car development projects where a positive link of SCM and SCRM capabilities with project success was established[30].

The effective SCM helps to maintain the continuity of the supply chain so that the works can be continued without waiting for materials. So an effective SCM can help the construction project complete without any delay due to want for input materials. The effective SCM helps reduce project costs in two ways by savings both in procurement cost well as other costs due to uninterrupted work progress. Early completion of projects helps the organization save project costs on other fronts like human resources, capital cost, and other infrastructure costs.

Our results had shown that effective SCM's impact on construction project time became insignificant with a path coefficient of 0.109 from a significant path coefficient of 0.652 when the mediating variable SCRM capability was introduced. The findings suggest the presence of full mediation effect of SCRM capability on the relation between effective SCM and project time. This was also confirmed by the VAF values. The mediation effect on the relationship between effective SCM and project time is complementary as both direct effects had a positive sign. The SCRM capability remains an unobserved capability of the project organization in a normal situation. But in the time of uncertain times like the recent pandemic when normal supply chains were disrupted, the SCRM capabilities emerged as a strategic advantage for the construction organization and helped complete projects in time.

As far as the mediation effect of SCRM capabilities on the relationship between effective SCM and project cost and project quality are concerned, from the VAF values, the presence of a partial effect was observed. But from the bootstrapping test results, only the partial mediation effect on project cost was found to be significant. These present findings are in line with the earlier findings where SCRM capabilities were found to be mediating the relation between SCM and supplier's performance[(29)]. To overcome the problems during a disruption in the supply chain if buffer stocks are maintained, this will cause the extra cost for the project, however in-time completion of the project will result in savings in other overhead costs making it more advantageous for the organization. This result of our study provides fresh support to the applicability of paradox theory in SCM and SCRM capability research.

From the results, it was observed that the SCRM capabilities did not have any mediation effect on the relationship between effective SCM and project quality. This finding was inconsistent with earlier findings that claimed the presence of mediation effect of SCRM capabilities on the relation between supply chain and supply chain performance of which product quality was a dimension[(31)]. The contradiction of our findings with earlier findings may be due to two reasons. Firstly, the qualities of construction projects are mostly dependent on the quality policy of the organization. Secondly, in case of non-arrival of materials in time, if a construction organization compromised the quality by using whatever locally available low-quality materials, then the risk management capability might have a significant effect on the relationship between effective SCM and project quality. It seems railway construction organizations in India wait for the proper material to arrive affecting the time of the project instead of compromising quality.

One distinctive feature of our research was finding the impact of effective SCM and SCRM capabilities on individual project success criteria of time, cost, and quality whereas earlier studies tried to establish the relation with different dimensions of SCM on overall project success. As the importance of particular success criteria is dependent on the contingencies of the project, our findings will help project participants to take decisions on SCM and SCRM capabilities according to the situation of the project.

7 Summary and Conclusions

Out of seven hypotheses postulated, six were supported by findings. The SEM model's fit index SRMR value of 0.088 indicates the suitability of the model for use in other similar studies. The impact of effective SCM was found to be highest on project cost followed by SCRM capability, project time, and project quality in railway construction projects in India. With a special focus on building SCRM capability at the time of COVID-19 like unpredictable situations, it was observed that the project completion time is fully mediated by the SCRM capability. The mediating effect of SCRM capability is partial on the relation between effective SCM and project cost and no mediating effect was observed on the relation between effective SCM and project quality. The findings have good generalizability indices (Q^2 values between 0.356 and 0.451), indicating the usefulness of findings in other geographical areas also in other construction projects. In an unpredictable situation like the recent COVID-19 pandemic if the SCRM policies of the organization do not have any capability to manage the disruption by way of either immediate sharing of materials from other projects or supplying from buffer stock, then the project schedule will have the maximum probability to get burst, thereby creating blue whip ripple effect causing extra cost in human resource and other infrastructures.

7.1 Managerial relevance

The findings will help construction project professionals working in both customer and contractor organizations working in different roles in understanding the importance of effective SCM and developing SCRM capability of their supply chains by adopting the measures discussed. This will help to complete the construction project in time during uncertain supply chain situations, particularly in critical construction projects where a lot of pressure to complete projects in time and costs are there.

7.2 Limitations and recommendation for future study

Our findings were based on cross-sectional data from Indian rail construction projects only. Though statistical analysis resulted in moderate to strong Q^2 indicating good generalizability, future studies in other parts of the world may provide more insights and applicability in other contexts. Due to the collection of data within a small period, the causality valid for a longer period cannot be claimed in absence of longitudinal data. So, future studies with longitudinal data might bring more rightful insights on the interaction between SCM, SCRM capabilities, and project success criteria. We had studied the mediating role of only one variable that is SCRM capability but there exists every possibility of other constructs have a moderating effect on the relationship between effective SCM and project success criteria. In addition to completion of project within schedule, budget, and quality many other strategic and long-term success criteria are being suggested in project management literature. Further research may be conducted to examine the impact of effective SCM on these success criteria of construction projects. This will help in making construction projects strategically successful by using the benefits of effective SCM and SCRM capabilities.

References

1) Alsharef A, Banerjee S, Uddin SMJ, Albert A, Jaselskis E. Early Impacts of the COVID-19 Pandemic on the United States Construction Industry. *International Journal of Environmental Research and Public Health*. 2021;18(4):1559–1559. Available from: https://dx.doi.org/10.3390/ijerph18041559. doi:10.3390/ijerph18041559.
2) Sundquist V, Gadde LE, Hulthén K. Reorganizing construction logistics for improved performance. *Construction Management and Economics*. 2018;36(1):49–65. Available from: https://dx.doi.org/10.1080/01446193.2017.1356931.
3) Gurtu A, Johny J. Supply Chain Risk Management: Literature Review. *Risks*. 2021;9(1):16–16. Available from: https://dx.doi.org/10.3390/risks9010016.
4) Rudolf CA, Spinler S. Key risks in the supply chain of large scale engineering and construction projects. *Supply Chain Management: An International Journal*. 2018;23(4):336–350. Available from: https://dx.doi.org/10.1108/scm-09-2017-0292.
5) Baz JE, Ruel S. Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *International Journal of Production Economics*. 2021;233:107972–107972. Available from: https://dx.doi.org/10.1016/j.ijpe.2020.107972.
6) Madenas N, Tiwari A, Turner CJ, Woodward J. Information flow in supply chain management: A review across the product lifecycle. *CIRP Journal of Manufacturing Science and Technology*. 2014;7(4):335–346. Available from: https://dx.doi.org/10.1016/j.cirpj.2014.07.002.
7) Messina D, Barros AC, Soares AL, Matopoulos A. An information management approach for supply chain disruption recovery. *The International Journal of Logistics Management*. 2020;31(3):489–519. Available from: https://dx.doi.org/10.1108/ijlm-11-2018-0294.
8) Nair PR, Anbuudayasankar SP. An Investigation on the benefits of ICT deployment in Supply Chain Management (SCM). *Indian Journal of Science and Technology*. 2016;9(30):1–7. Available from: https://dx.doi.org/10.17485/ijst/2016/v9i30/99063.
9) Rajagopal P, Zailani S, Sulaiman M. Assessing the effectiveness of supply chain partnering with scalable partnering as a moderator. *International Journal of Physical Distribution & Logistics Management*. 2009;39(8):649–668. Available from: https://dx.doi.org/10.1108/09600030910996305.
10) Ganesan V, Maragatham G, Lavanya US. A Study of IoT in SCM and its nodes in Multimodal Business Process. *Indian Journal of Science and Technology*. 2016;9(21). Available from: https://dx.doi.org/10.17485/ijst/2016/v9i21/95281.
11) Graham R. Supply Chain Sustainability and Rail Infrastructure : Leadership Pulling together or falling apart ? London, UK. Royal Institution of Chartered Surveyors (RICS). 2017. Available from: https://www.rics.org/globalassets/rics-website/media/knowledge/research/insights/supply-chain-sustainability-and-rail-infrastructure-leadership-rics.pdf.
12) Mello JE, Stank TP. Linking firm culture and orientation to supply chain success. *International Journal of Physical Distribution & Logistics Management*. 2005;35(8):542–554. Available from: https://dx.doi.org/10.1108/09600030510623320.
13) Li Y, Zobel CW. Exploring supply chain network resilience in the presence of the ripple effect. *International Journal of Production Economics*. 2020;228:107693–107693. Available from: https://dx.doi.org/10.1016/j.ijpe.2020.107693.
14) Cockx R, Armbruster D, Bendul JC. Resource Sharing as Supply Chain Disruption Risk Management Measure. *IFAC-PapersOnLine*. 2019;52(13):802–807. Available from: https://dx.doi.org/10.1016/j.ifacol.2019.11.228.
15) Poshdar M, Gonzalez VA. Buffer Management in Construction - a New Zealand Study. *26th Annual Conference of the International Group for Lean Construction*. 2018;p. 818–846. Available from: https://apo.org.au/node/304886.
16) Bajpai P, Kalra M, Bushanchandar AS. Supply Chain Management of Road Projects in India using FMEA and ISM Technique. *Indian Journal of Science and Technology*. 2016;9(S1):1–5. Available from: https://dx.doi.org/10.17485/ijst/2016/v9is1/105699.
17) Ivanov D. Viable supply chain model: integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic. *Annals of Operations Research*. 2020. Available from: https://doi.org/10.1007/s10479-020-03640-6.
18) Tripathi KK, Jha KN. An empirical study on factors leading to the success of construction organizations in India. *International Journal of Construction Management*. 2019;19(3):222–239. Available from: https://dx.doi.org/10.1080/15623599.2017.1423162.
19) Pålsson H, Sandberg E. Paradoxes in supply chains: a conceptual framework for packed products. *The International Journal of Logistics Management*. 2020;31(3):423–442. Available from: https://dx.doi.org/10.1108/ijlm-12-2019-0338.
20) Huo B, Zhao X. The impact of organizational culture on supply chain integration : A contingency and configuration approach. *Supply Chain Management: An International Journal*. 2015;20(1):24–41. Available from: http://dx.doi.org/10.1108/SCM-11-2013-0426.
21) Astrachan CB, Patel VK, Wanzenried G. A comparative study of CB-SEM and PLS-SEM for theory development in family firm research. *Journal of Family Business Strategy*. 2014;5(1):116–128. Available from: https://dx.doi.org/10.1016/j.jfbs.2013.12.002.
22) Hair JF, Ringle CM, Sarstedt M. PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice*. 2011;19(2):139–152. Available from: https://dx.doi.org/10.2753/mtp1069-6679190202. doi:10.2753/mtp1069-6679190202.
23) Ringle CM, Wende S, Becker JM. SmartPLS 3. 2015. Available from: https://www.smartpls.com.
24) Hair JF, Risher JJ, Sarstedt M, Ringle CM. When to use and how to report the results of PLS-SEM. *European Business Review*. 2019;31(1):2–24. Available from: https://dx.doi.org/10.1108/ebr-11-2018-0203.
25) Rasoolimanesh SM. Discriminant validity assessment in PLS-SEM : A comprehensive composite-based approach. *Data Analysis Perspectives Journal*. 2022;3(2):1–8. Available from: https://scriptwarp.com/dapj/2022_DAPJ_3_2/Rasoolimanesh_2022_DAPJ_3_2_DiscriminantValidity.pdf.
26) Sarstedt M, Hair JF, Cheah JH, Becker JM, Ringle CM. How to Specify, Estimate, and Validate Higher-Order Constructs in PLS-SEM. *Australasian Marketing Journal*. 2019;27(3):197–211. Available from: https://dx.doi.org/10.1016/j.ausmj.2019.05.003.
27) Shi D, Maydeu-Olivares A, Rosseel Y. Assessing Fit in Ordinal Factor Analysis Models : SRMR vs . RMSEA Assessing Fit in Ordinal Factor Analysis Models : SRMR vs . RMSEA. *Structural Equation Modeling: A Multidisciplinary Journal*. 2019;0:1–15. Available from: https://doi.org/10.1080/10705511.2019.1611434.
28) Hair JF, Howard MC, Nitzl C. Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*. 2020;109:101–110. Available from: https://dx.doi.org/10.1016/j.jbusres.2019.11.069.
29) Ekeskär A, Rudberg M. Third-party logistics in construction: the case of a large hospital project. *Construction Management and Economics*. 2016;34(3):174–191. Available from: https://dx.doi.org/10.1080/01446193.2016.1186809.

30) Fernando Y, Walters T, Ismail MN, Seo YW, Kaimasu M. Managing project success using project risk and green supply chain management. *International Journal of Managing Projects in Business*. 2018;11(2):332–365. Available from: https://dx.doi.org/10.1108/ijmpb-01-2017-0007.

31) Tukamuhabwa B, Mutebi H, Isabirye D. Supplier performance in the public healthcare: internal social capital, logistics capabilities and supply chain risk management capabilities as antecedents in a developing economy. *Journal of Business and Socio-economic Development*. 2021. Available from: https://dx.doi.org/10.1108/jbsed-04-2021-0046.