

A systematic approach to identify and manage supply chain risks in construction projects

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Received 1 September 2023

Revised 26 January 2024

2 April 2024

Accepted 26 June 2024

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Abstract

Purpose – This study aims to comprehensively identify supply chain risks and their causes, the factors influencing supply chain management and techniques to successfully mitigate and control supply chain risks in construction projects. This study developed a comprehensive framework showing various supply chain risks and how these risks that influence project execution are systematically identified and managed for the overall construction project success.

Design/methodology/approach – The research conducted was characterised by its descriptive, exploratory and quantitative nature. The collection of quantitative data was conducted by means of structured online questionnaires. The sample consisted of 205 construction project professionals who were selected randomly. This group included individuals with various roles in the construction industry, such as project managers, civil/structural engineers mechanical engineers, risk managers, architects, quantity surveyors, electrical engineers, construction managers, health, safety and environment managers, estate managers and other professionals. All participants were actively involved in construction projects located in the Gauteng province of South Africa. The data was analysed, using descriptive statistical methods, including factor analysis, reliability assessment and calculations of frequencies and percentages.

Findings – The result showed that predictable delivery, funding schedule, inventories, balanced demands, production capabilities, timely procurement, construction supply chain management coordination, delivery reliability, the proximity of suppliers, identification of supply chain risks in the conceptualisation stage of a project, identification of supply chain risks in the planning stage of a project, identification of supply chain risks in the execution stage and the reconciliation of material flows of the subcontractors with the contractors were identified as the key factors that influenced the construction supply chain management the most. The result also showed that subcontractor's negative attitudes towards supply chain management, procurement delays, imbalanced demands, clients' negative attitudes towards other project stakeholders, unpredictable delivery reliability, disorganised construction supply chain management approach, delayed funding, low delivery reliability, poor inventories, poor construction supply chain co-ordination, suppliers' negative attitudes towards supply chain management and when the material flows of the subcontractors with the contractors are not reconciled were identified as the factors that have the greatest impacts on construction supply chain risks management.

Research limitations/implications – For future research, it is recommended to incorporate fourth industrial revolution) such as machine learning prediction models and algorithms, Artificial intelligence and blockchain to identify and manage supply chain, supply chain risks and project stakeholders involved in



supply chain in construction projects. Green construction or sustainable construction was not fully covered in this study. The findings will be beneficial for sustainable construction projects in developing countries for sustainability, although it did not extensively cover green buildings and related risks.

Practical implications – Supply chain risk is one of the major challenges facing the construction industry because construction projects are complex by nature involving a lot of activities and participants with different responsibilities and tasks therefore it is highly recommended to implement the proposed frameworks in this paper from the conceptualisation stage to the execution stage, carefully identifying parties involved in supply chain, supply chain management, stakeholders, tasks, activities, responsibilities and supply chain risks generated as a result of the interactions between stakeholders involved in supply chain management and coordination to realise project objectives. The findings will be a foundation for identifying and managing supply risks in sustainable buildings in developing countries.

Social implications – Supply chain management is crucial in every enterprise. Managing supply chain risks is a major aspect of risk and disaster management and this implies that supply chain excellence is achievable by building communication, trust and mutual objectives, no blame culture, performance measurement, constant improvement and partnering.

Originality/value – The implementation of construction supply chain risk management framework involves assessing the impacts of these supply chain risks on the objectives of construction projects with respect to time, cost, safety, health, environment, stakeholders, financial performance, client satisfaction and quality.

Keywords Supply chain, Supply chain risk management, Projects, Construction, Stakeholders, Construction supply chain risks

Paper type Research paper

1. Introduction

Construction projects are characterised through short-term relationships, intrinsic complexities, several interruptions and interactions due to external and internal unexpected situations. The participation of numerous concentric stakeholders, rapidly varying environments, time and cost overruns and client dissatisfaction lead to uncertainties and risks in the project. Because of these different particularities and in terms of productivity, efficiency and performance, construction industry is behind other industries (Costa *et al.*, 2019). These attributes contribute extensively to the presence of high risks in construction projects (Dikmen *et al.*, 2018; El-Sayegh and Mansour, 2015; Siraj and Fayek, 2019). On this regard, managing supply chain risks (SCRs) ineffectively is a fundamental cause of poor reputation, delay, project failure and budget overrun (Carvalho and Rabechini Junior, 2015; Habibi and Kermanshachi, 2018). To identify the sources of SCRs is the important step to effectively manage SCRs because it could offer a base for the successive tiers (Siraj and Fayek, 2019). The contingency plan development for SCRs management happens to be more significant for construction industries in these days' complex and large projects (Gunduz and Elsherbeny, 2020). Information, service, material and financial flows between involved stakeholders have a vital influence on the supply network and some risks are handled by a specific stakeholder (Luo *et al.*, 2019). SCRs are directly connected to the associated project stakeholders, wherein interdependency among stakeholders is suggestively high, so, SCRs of construction tasks are managed safely through the consideration of stakeholders' perspectives since every stakeholder from requirement to maintenance stage are exposed to numerous risks (Luo *et al.*, 2019). In construction projects, ineffective inventory management leads to a bottleneck because of a great degree of interdependent activities and variability (Costa *et al.*, 2019).

A usual issue that usually occurs in a construction supply chain (CSC) is complexity, project communication, material flow and the internal company's communication (Thunberg and Fredriksson, 2018).

The paper's objective is to carefully identify SCRs through a structured questionnaire focusing on construction industry professional, identify and analyse factors that affect supply chain management and the causes of SCRs and determine the ways to effectively

mitigate and minimise these risks in construction projects. The study objective was to carry out a literature review on supply chain in construction, as well as SCRs and SCR management. The study's two main objectives were:

- to identify the factors that influence construction supply chain management (CSCM) and their extent levels; and
- to identify the causes of construction supply chain risks (CSCRs) and their extent levels.

To support the objectives of the study, these two research questions were asked. Respondents were asked to identify:

- the causes of SCRs; and
- factors that influenced CSCM

The study focused on a systematic approach of identifying and managing risks associated with supply chain in construction projects in every phase.

The literature review aimed to identify essential areas of knowledge in the field of research and provide a summary of recent literature on the topic. The study aimed to create a framework for identifying and managing SCRs in construction, ensuring project success.

This work was divided into sections: Section 1 – introduction, Section 2 – literature review, Section 3 – data and methodology, Section 4 – reliability statistics of data collected, Section 5 – results and discussion and Section 6 – conclusion.

2. Literature review

2.1 Construction supply chain management

Construction projects go through multiple phases, each with its own set of participants. Research indicates a correlation between construction project risks and participant interactions (Koc and Gurgun, 2021; Yuan *et al.*, 2021). CSC is a very complex system because many stakeholders and decision-makers are involved. Within the chains, there is an increase in uncertainty within the networks and more complex the networks are, the more uncertainty and risk will be.

CSCM involves the use of organisational, managerial and technological means to configure resources for the overall project success (Queiroz *et al.*, 2022). According to Hussein *et al.* (2021), successful completion of a construction project requires typical CSC operations across its various phases. Costa *et al.* (2019) examined customer–supplier relationship in CSC and carried out the decision-making trial and evaluation laboratory (DEMATEL) analysis to expose the source of the obstacles to enhance the relationships. Luo *et al.* (2019) recognised 30 stakeholder-related SCRs and associated those risks with one or greater supply chain stakeholders: government, transporter, manufacturer, primary contractor, designer, client and subcontractor. Construction operations have a significant negative influence on the environment Chuai *et al.* (2021). There are increases in the need for coordination between precast factories and construction sites, as well as collaboration among all key stakeholders participating in construction activities.

These diverse construction project participants will generate diverse information sources at each stage of the project, in addition to their own information requirements. These problems can be related to a disorganised management style. Specifically, firms involved in the construction project tend to focus on their own manufacturing operations, efficiency and performance, resulting in errors throughout project execution. As a result, issues such as overcapacity, late purchase and delivery of materials and equipment and mistimed transportation occur regularly. Furthermore, throughout project execution, information need

is gradually conveyed among the major project participants, and information deviation can increase. It is easy to produce information distortion and uncertainty (Liu *et al.*, 2022). This results in unsatisfactory performance for the construction project and its collaborating firms (Golpîra, 2020; RezaHoseini *et al.*, 2021). CSCM strives to deliver projects on time and at the lowest possible cost (economic and environmental) at the best time (RezaHoseini *et al.*, 2021). By balancing diverse construction resources, communicating with all key participating firms and integrating construction information, CSCM assists leadership teams in optimising project and enterprise performance through the project-centred management paradigm.

Numerous risks are rooted across CSCs that are related to various stakeholders (Luo *et al.*, 2019). Wuni *et al.* (2019) did a synthesis of 39 empirical papers on risks in sectional integrated construction and identified 30 serious risks. This sort of construction needs unique stakeholder composition, engineering, construction, design and supply chain management. These requirements create uncertainties and risks that undesirably influence modular incorporated projects success. Moreover, Derakhshanfar *et al.* (2019) systematically developed the taxonomy and terminology of delay risks. Some of the broadly adopted main risks classifications in the literature could be summarised as contractual, financial, managerial, social, economic, environmental and technical with respect to project risks (Kuo and Lu, 2013; Siraj and Fayek, 2019; Thunberg *et al.*, 2017), whereas they are supply, external, control, demand and coordination with respect to SCRs in construction (Luo *et al.*, 2019; Rudolf and Spinler, 2018). However, in spite of widespread studies in the CSCM research area, researchers did not study every supply chain life cycle phase discretely while linking methodically reviewed risks to the related stakeholders. Siraj and Fayek (2019) achieved a content evaluation based on the literature on identifying risks within the construction industry and observed that most researchers used expert interviews, a questionnaire survey and literature evaluation to identify risks.

2.2 Construction supply chain risks

CSCM provides evident benefits to the construction sector during the course of construction industrialisation. Nonetheless, unknown elements in the natural and social environment, such as broken capital chain and logistics interruption, frequently result in volatility and even disruption of CSC (Ekanayake *et al.* (2022a, 2022b)). Material management is a critical issue in construction activities, influencing CSC resilience through demand, procurement, transportation, delivery, inventory and other relationships. The emergence of modular buildings has presented CSC with new issues (Zhang and Yu, 2021). However, in recent years, researchers have discovered that CSC is influenced by a variety of internal and external factors, including the natural and social environment, as well as the construction project environment, resulting in CSC fluctuations and even disruptions (Ekanayake *et al.*, 2022a, 2022b). As a result, CSC resilience promotes CSC stability in stormy scenarios by addressing elements such as responsiveness, flexibility and robustness (Kazancoglu *et al.*, 2022), which is invaluable in ensuring construction project performance.

Furthermore, several researchers have investigated construction enterprise and CSC performance in terms of CSC disruption and reverse logistics (Kissi *et al.*, 2020; Pushpamali *et al.*, 2021). The existence of uncertain risks these days rises within the supply chain because of its globalisation, saturation and companies to use new risk evaluation concepts (Liker, 2019). Providers selection, resource allocation and variety of delivery determination are crucial parts of supply chain success (Deng *et al.*, 2019) Shahbaz *et al.* (2019) studied the effect of supply chain capacities on logistic effectiveness for the construction projects and they concluded that alliance with stakeholders and flexibility with respect to labour, time, cost and other essential decisions is effective in logistic supply chain. The adaptability and

convertibility of the supply chain to new conditions is referred to as resilience (Wieland and Durach, 2021), and thus CSC resilience can be defined as the ability of CSC to withstand fluctuations or disruptions by dynamically adjusting and optimising the structure of resources related to construction projects to cope with the impact of uncertain factors on CSC. Previous studies (Zainal Abidin and Ingirige, 2018; Abas *et al.*, 2022; Ekanayake *et al.*, 2022a, 2022b) examined the dynamics and impact of interlinked risks among construction organisations to improve resilience in dealing with disruptive events in construction projects. According to the CSC risk of large-scale engineering construction projects, systematic and structured situational risk management is performed to assure the project's successful delivery (Rudolf and Spinler, 2018).

Ahmed *et al.* (2019) recognised the critical limitations hindering the implementation of effective supply chain management in construction industries of developing nations such as UAE, Somalia, Ghana, Qatar, Kuwait, Egypt, India, Pakistan, Bangladesh, Iran, Saudi Arabia, Yemen and Argentina. The crucial elements recognised were regulations, incentives, government support, inadequate policies, top management or leadership, knowledge and lack of public awareness. Luo *et al.* (2018) concluded that supply chain excellence is achievable by building communication, trust and mutual objectives, no blame culture, performance measurement, constant improvement and partnering.

Panova and Hilletoft (2018) established that delays in the material supply and other resources, deficiency warehouse or overcapacity, shipment of goods and on-time loading are the potential risks within the supply chain. Reducing needless waste and tightening control are excellent ways to save money and enhance efficiency (Li *et al.*, 2020). Paying attention to customer requests also helps to ensure the quality of construction operations and finished products (Le and Nguyen, 2022).

Luo *et al.* (2018) acknowledged that without effective communication, achieving success in supply chain in construction projects is not feasible. Communication is a crucial part of a CSC. The managers and suppliers fail to communicate relevant information and other changes on time. For a successful supply chain, communication must be efficient and effective between every stakeholder. Technology integration can essentially minimise the communication gap. Other studies recognised expertise, good weather, teamwork, skills, rewards, timely funding, regulations, laws and availability of technical staff as success factors (Gunduz and Yahya, 2015; Mashwama *et al.*, 2017; Zakaria *et al.*, 2017; Afolabi *et al.*, 2019; Ahmadabadi and Heravi, 2019; Sfakianaki, 2019).

CSCs differ from industrial supply chains because they involve several stakeholders and complicated interactions throughout a project's lifecycle (Le *et al.*, 2021). The CSC's transient nature and varied offerings make management more challenging since CSCs face daily operating risks, such as design modifications and material shortages, in addition to disasters like COVID-19 (Ndukwe *et al.*, 2021; Raoufi and Fayek, 2021). Supply and demand risks are significant sources of operational uncertainty in CSCs (Pham *et al.*, 2023).

Supplier capacity restrictions might cause supply interruptions, impacting material availability and project resource management. Uncertainty in material demand in construction projects can stem from budget constraints, schedule changes, late deliveries, equipment malfunctions and low productivity. Improving construction supply chain resilience (CSCR) is crucial for mitigating supply and demand risks in the construction industry (Shishodia *et al.*, 2022; Siraj and Fayek, 2019; Chan, 2021; Raoufi and Fayek, 2021).

3. Methodology

The research conducted was characterised by its descriptive, exploratory and quantitative nature. The collection of quantitative data was conducted by means of structured online

questionnaires. The sample consisted of 205 construction project professionals who were selected randomly in construction industry in Gauteng province, South Africa. This group included individuals with various roles in the construction industry, like project managers, civil/structural engineers, mechanical engineers, risk managers, architects, quantity surveyors, electrical engineers, construction managers, health, safety and environment (HSE) managers, estate managers and other professionals.

The selection criteria for participants required the following characteristics as shown in a selection criteria for participants.

- active participants in the construction conceptualisation stages;
- active participants in the planning stages of construction;
- active participants in the design stages of construction;
- active participants in the procurement stages of construction;
- active participants in the contracting stages of construction;
- active participants in the sub-contracting stages of construction;
- active participants in production stages of construction;
- active participants in execution stages of construction;
- active participants in the CSC;
- active participants in commissioning stages of construction;
- active participants in the construction health, safety and environment management; and
- active participants in the pre-contracting stages of construction.

During phase A of the dissemination of survey questionnaires to industry specialists within the construction industry, the sampling strategy was based on a random probability sample. Construction experts, specialists, leadership, construction and project managers who were actively involved in the construction business and executed construction projects to ensure that selected participants possessed the necessary skillset and knowledge on CSCM and CSCR management and relevant construction activities to successfully answer the survey questions.

3.1 Data collection

The primary data were collected from active project stakeholders as shown in a selection criteria for participants above. Secondary data were collected through a review of the relevant literature, articles and journals related to supply chain management in the construction industry. A total of 205 research questionnaires were distributed to participants active in the construction industry.

The data collection process commenced by administering a biographical questionnaire to ascertain the appropriate research participants in the first section. Section C, (specifically C5 and C6) encompassed the questions related to SCRs in construction projects. The data obtained from the questionnaire was coded, recorded and analysed using the Statistical Package for the Social Sciences (SPSS, V25). The items or questions in each section were coded for ease of analysis. For the five-point Linkert scale chosen, the extent scale was used to find out the extent in which each statement or item in the questionnaire influenced CSCM. In addition, “to no extent” was coded as a 1, “to a small extent” was coded as a 2, “to a moderate extent” was coded as a 3, “to a large extent” was coded as a 4 and “to a very large extent” was coded as a 5.

Factor analysis was conducted to identify the latent dimensions underlying the measured variables, as these variables are expected to exhibit correlations or anticipated correlations. The paper aims to investigate the impact of measured variables and examine the interrelationships among a predetermined set of defined, observed and quantifiable constructs. According to the guidelines provided in the SPSS manual, the Kaiser–Meyer–Olkin (KMO) measure and the Bartlett’s Test of Sphericity are used to assess the suitability of the correlation matrix as an identity matrix, thereby determining the appropriateness of the factor model.

The questionnaire was structured in a way to identify SCRs, the factors that influence supply chain management and their levels of impacts and ways to effectively mitigate and manage SCRs in construction projects. All participants were actively involved in construction projects located in the Gauteng province of South Africa. Finally, the data underwent analysis using descriptive statistical methods, including factor analysis, reliability assessment and calculations of frequencies and percentages.

4. Data analysis

Exploratory factor analysis, empirical and theoretical reliabilities and frequencies and descriptives were the statistical approaches used to analyse the data collected. The study also used the KMO measure and Bartlett’s test to measure the interrelationships among variables, thereby informed the decision to advance with the factor analysis of the collected data. A comprehensive set of 205 responses was obtained from the designated target population, which primarily comprised of individuals within the construction industry as described in the context of questionnaire design and target group identification. [Table 1](#) shows the summary of the biographical data of the respondents who participated in the online survey.

From [Table 1](#), out of the 205 responses from the online questionnaire, 16 respondents were quantity surveyors, 9 were architects, 7 were builders, 8 were project engineers, 9 were project administrators, 10 were safety officers/engineers/managers, 10 were risk managers, 20 were mechanical engineers, 13 were construction engineers, 18 were project managers,

Profession	Frequency	%	Valid (%)	Cumulative (%)
Quantity surveyor	16	7.8	7.8	7.8
Architect	9	4.4	4.4	12.2
Civil engineer/structural engineer	27	13.2	13.2	25.4
Builder	7	3.4	3.4	28.8
Construction manager	25	12.2	12.2	41.0
Electrical engineer	22	10.7	10.7	51.7
Mechanical engineer	20	9.8	9.8	61.5
Estate manager	8	3.9	3.9	65.4
Project manager	18	8.8	8.8	74.1
Construction engineer	13	6.3	6.3	80.5
Project engineer	8	3.9	3.9	84.4
Project administrator	9	4.4	4.4	88.8
Safety officer/engineer/manager	10	4.9	4.9	93.7
Risk manager	10	4.9	4.9	98.5
Other construction professionals	3	1.5	1.5	100.0
Total	205	100.0	100.0	

Table 1. Survey participants professions in the South African construction industry

Source: Authors’ own work

8 were estate managers, 22 were electrical engineers, 25 were construction managers, 27 were civil/structural engineers and 3 respondents were other construction professionals. Table 2 shows age distribution of participants.

From the Table 2, out of the 205 respondents, 4 respondents were in the age group of 21–25 years, 16 were 26–30 years, 32 were 31–35 years, 42 were 36–40 years, 53 were 41–45 years, 46 respondents were 46 years and above. Table 3 shows the academic qualifications of the respondents.

From Table 3, 11 respondents out of the 205 respondents, which represented 5.4% of the total respondents, had post matric or diplomas as their highest academic qualifications; 55 (26.8%) had bachelor's degrees; 28 (13.7%) had honours degrees; 70 (34.1%) had master's degrees; and 41 respondents, which represented 20.0% of the total respondents, had doctoral degrees. Table 4 shows the organisational size of the respondents.

From the Table 4, 72 respondents, which represent 35.1% of the total respondents, work in the small-sized industries and 74, which represent 36.1%, work at medium-sized industries and 59 of the respondents, which represent 28.8%, work in the large-scale construction industries. Table 5 represents the frequency distribution for question 1 (factors that influence CSCM).

Age group	Frequency	%	Valid (%)	Cumulative (%)
21–25 years	4	2.0	2.0	2.0
26–30 years	16	7.8	7.8	9.8
31–35 years	32	15.6	15.6	25.4
36–40 years	42	20.5	20.5	45.9
41–45 years	53	25.9	25.9	71.7
46 years and above	58	28.3	28.3	100.0
Total	205	100.0	100.0	

Table 2.
Age distribution of respondents

Source: Author's own work

Highest academic qualification	Frequency	%	Valid (%)	Cumulative (%)
Post matric certificate or diploma	11	5.4	5.4	5.4
Bachelor's degree	55	26.8	26.8	32.2
Honours degree	28	13.7	13.7	45.9
Master's degree	70	34.1	34.1	80.0
Doctorate degree	41	20.0	20.0	100.0
Total	205	100.0	100.0	

Table 3.
Academic qualifications of the respondents

Source: Authors' own work

Organisational size	Frequency	%	Valid (%)	Cumulative (%)
Small (1–100 staff)	72	35.1	35.1	35.1
Medium (101–500)	74	36.1	36.1	71.2
Large (501–5,000+)	59	28.8	28.8	100.0
Total	205	100.0	100.0	

Table 4.
Size of organisations of respondents

Source: Authors' own work

Survey items – C5		To no extent	Small extent	Moderate extent	Large extent	Very large extent	Total
C5.1 Identification of supply chain risks in the conceptualisation stage of a project	Count	0	2	20	101	82	205
	Row N %	0.0%	1.0%	9.8%	49.3%	40.0%	100.0%
C5.2 Identification of supply chain risks in the planning stage of a project	Count	0	3	19	103	80	205
	Row N %	0.0%	1.5%	9.3%	50.2%	39.0%	100.0%
C5.3 Identification of supply chain risks in the execution stage	Count	0	5	37	96	67	205
	Row N %	0.0%	2.4%	18.0%	46.8%	32.7%	100.0%
C5.4 The proximity of suppliers	Count	3	7	46	121	28	205
	Row N %	1.5%	3.4%	22.4%	59.0%	13.7%	100.0%
C5.5 The proximity of vendors	Count	2	12	65	97	29	205
	Row N %	1.0%	5.9%	31.7%	47.3%	14.1%	100.0%
C5.6 The proximity of customers	Count	3	21	68	98	15	205
	Row N %	1.5%	10.2%	33.2%	47.8%	7.3%	100.0%
C5.7 The reconciliation of material flows of the sub-contractors with the contractors	Count	0	9	51	112	33	205
	Row N %	0.0%	4.4%	24.9%	54.6%	16.1%	100.0%
C5.8 Delivery reliability	Count	0	3	29	132	41	205
	Row N %	0.0%	1.5%	14.1%	64.4%	20.0%	100.0%
C5.9 Construction supply chain management coordination	Count	1	5	17	106	76	205
	Row N %	0.5%	2.4%	8.3%	51.7%	37.1%	100.0%
C5.10 Timely procurement	Count	1	2	27	121	54	205
	Row N %	0.5%	1.0%	13.2%	59.0%	26.3%	100.0%
C5.11 Balanced demands	Count	0	2	39	122	42	205
	Row N %	0.0%	1.0%	19.0%	59.5%	20.5%	100.0%
C5.12 Inventories	Count	0	7	47	109	42	205
	Row N %	0.0%	3.4%	22.9%	53.2%	20.5%	100.0%
C5.13 Production capabilities	Count	1	3	29	121	51	205
	Row N %	0.5%	1.5%	14.1%	59.0%	24.9%	100.0%
C5.14 Funding schedule	Count	0	2	14	103	86	205
	Row N %	0.0%	1.0%	6.8%	50.2%	42.0%	100.0%
C5.15 Predictable delivery	Count	0	4	22	130	49	205
	Row N %	0.0%	2.0%	10.7%	63.4%	23.9%	100.0%

Source: Authors' own work

Table 5.
Responses to the extent in which each of the following factors influence the construction supply chain management

Table 5 shows that predictable delivery, funding schedule, inventories, balanced demands, production capabilities, timely procurement, CSCM coordination, delivery reliability, the proximity of suppliers, identification of SCRs in the conceptualisation stage of a project, identification of SCRs in the planning stage of a project, identifying SCRs in the execution stage and the reconciliation of material flows of the subcontractors with the contractors were identified as the key factors that influenced the CSCM the most. Table 6 shows the extent in which the following factors contributed to the causes of CSCRs.

From Table 6, subcontractors' negative attitudes towards supply chain management, procurement delays, imbalanced demands, clients' negative attitudes towards other project stakeholders, unpredictable delivery, disorganised CSCM approach, delayed funding, low delivery reliability, poor inventories, poor CSC coordination, suppliers' negative attitudes towards supply chain management and when the material flows of the subcontractors with the contractors are not reconciled were identified as the major causes of CSCRs. Table 7

Table 6. Responses for the extent in which the following factors contributed to the causes of construction supply chain risks – research objective 2 – C6

Survey items – C6		To no extent	Small extent	Moderate extent	Large extent	Very large extent	Total
C6.1 When the material flows of the subcontractors with the contractors are not reconciled	Count	1	2	34	132	36	205
	Row N %	0.5%	1.0%	16.6%	64.4%	17.6%	100.0%
C6.2 Suppliers' negative attitudes towards supply chain management	Count	0	6	63	107	29	205
	Row N %	0.0%	2.9%	30.7%	52.2%	14.1%	100.0%
C6.3 Vendors negative attitudes towards supply chain management	Count	1	14	73	86	31	205
	Row N %	0.5%	6.8%	35.6%	42.0%	15.1%	100.0%
C6.4 Third parties' negative attitudes towards supply chain management	Count	1	18	83	85	18	205
	Row N %	0.5%	8.8%	40.5%	41.5%	8.8%	100.0%
C6.5 Procurement delays	Count	0	5	29	125	46	205
	Row N %	0.0%	2.4%	14.1%	61.0%	22.4%	100.0%
C6.6 Clients' negative attitudes towards supply chain management	Count	1	4	35	122	43	205
	Row N %	0.5%	2.0%	17.1%	59.5%	21.0%	100.0%
C6.7 Subcontractor's negative attitudes towards supply chain management	Count	0	6	26	129	44	205
	Row N %	0.0%	2.9%	12.7%	62.9%	21.5%	100.0%
C6.8 Imbalanced demands	Count	0	6	44	122	33	205
	Row N %	0.0%	2.9%	21.5%	59.5%	16.1%	100.0%
C6.9 Poor construction supply chain coordination	Count	0	3	13	109	80	205
	Row N %	0.0%	1.5%	6.3%	53.2%	39.0%	100.0%
C6.10 Clients' negative attitudes towards other project stakeholders	Count	2	3	36	122	42	205
	Row N %	1.0%	1.5%	17.6%	59.5%	20.5%	100.0%
C6.11 Poor inventories	Count	0	5	31	134	35	205
	Row N %	0.0%	2.4%	15.1%	65.4%	17.1%	100.0%
C6.12 Delayed funding	Count	0	2	13	109	81	205
	Row N %	0.0%	1.0%	6.3%	53.2%	39.5%	100.0%
C6.13 Disorganised construction supply chain management approach	Count	0	1	9	105	90	205
	Row N %	0.0%	0.5%	4.4%	51.2%	43.9%	100.0%
C6.14 Low delivery reliability	Count	0	2	29	137	37	205
	Row N %	0.0%	1.0%	14.1%	66.8%	18.0%	100.0%
C6.15 Unpredictable delivery	Count	0	2	23	128	52	205
	Row N %	0.0%	1.0%	11.2%	62.4%	25.4%	100.0%

Source: Authors' own work

Table 7. KMO and Bartlett's test for research objective 1 (factors that influence construction supply chain management and their extent levels)

KMO and Bartlett's test	
Kaiser–Meyer–Olkin measure of sampling adequacy	0.902
Bartlett's test of sphericity	Approx. chi-square 1,845.508
	df 105
	Sig. 0.000

Source: Authors' own work

shows the KMO and Bartlett's test for research objective 1 (factors that influence CSCM and their extent levels).

From Table 7, the KMO measure of sampling adequacy is 0.902 which is greater than 0.6 and for Bartlett's test of sphericity, the significance (sig) was zero (0.000) which is the *p*-value and it was less than 0.05 and this supports the factorability of the correlation matrix.

Table 8 shows the KMO and Bartlett's test for research objective 2 (to identify the causes of CSCRs and their extent levels).

From Table 8, the KMO measure of sampling adequacy is 0.895 which was greater than 0.6 For Bartlett's test of sphericity, the significance (sig) is zero (0.000) which is the *p*-value and it was less than 0.05 and this supports the factorability of the correlation matrix.

4.1 Exploratory factor analysis for sections C5 and C6

With a sample size of 205, factor analysis was done to reduce the data or summarise using a lesser set of factors. This was achieved by intercorrelation identification of variables. To carry out factor analysis, the correlation matrix should show at least have some correlations of *r* = 0.3 or greater. Barlett's test of sphericity should be *p* < 0.05, KMO values must be 0.6 or above. These values are shown as parts of the factor analysis result. Table 9 depicts the exploratory factor analysis for research objective 1.

From Table 9, the factors that influence CSCM were loaded on three factors with eigenvalues of 7.237, 1.589 and 1.105. These three factors explained 66.207% of the variance

Table 8.
KMO and bartlett's test for research objective 2 (causes of construction supply chain risks and their extent levels)

KMO and Bartlett's test			
Kaiser–Meyer–Olkin measure of sampling adequacy			0.895
Bartlett's test of sphericity	Approx. chi-square		1,916.682
	df		105
	Sig.		0.000

Source: Authors' own work

Table 9.
Exploratory factor analysis for research objective 1 (factors that influence construction supply chain management and their extent levels) – C5

Factor	Total	Initial eigenvalues		Total variance explained			Rotation sums of squared loadings		
		% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)
1	7.237	48.246	48.246	6.854	45.693	45.693	3.770	25.133	25.133
2	1.589	10.591	58.837	1.175	7.831	53.524	2.908	19.388	44.520
3	1.105	7.369	66.207	0.775	5.167	58.690	2.126	14.170	58.690
4	0.995	6.633	72.840						
5	0.640	4.268	77.108						
6	0.602	4.016	81.124						
7	0.521	3.473	84.596						
8	0.413	2.752	87.348						
9	0.377	2.511	89.859						
10	0.331	2.205	92.064						
11	0.299	1.994	94.058						
12	0.269	1.796	95.854						
13	0.239	1.593	97.447						
14	0.219	1.463	98.910						
15	0.164	1.090	100.000						

Note: Extraction method: Principal axis factoring
Source: Authors' own work

before rotation and 58.690% of the variance after rotation. Table 10 shows the correlation matrix for research objective 1 for section C5.

From Table 10, many of the correlations were bigger than 0.3. C5.14 and C5.1 had the correlation of 0.255, C5.12 and C5.1 had the correlation of 0.292, C5.8 and C5.1 had the correlation of 0.255, C5.2 and C5.3 had the correlation of 0.273, C5.13 and C5.2 had the correlation of 0.260, C5.14 and C5.13 had the correlation of 0.245, C4.6 and C4.14 had the correlation of 0.269, C5.14 and C5.7 had the correlation of 0.263, C5.14 and C5.5 had the correlation of 0.183, C5.14 and C5.11 had the correlation of 0.210, C5.10 and C5.1 had the correlation of 0.183 and C5.11 and C5.5 had the correlation of 0.278. Table 11 shows the communalities of research objective 1 – C5.

From Table 11, the extractions are all above 0.3 which means there was at least 30% common variance shared among them. Figure 1 shows the scree plot for section C5.

	C5.1	C5.2	C5.3	C5.4	C5.5	C5.6	C5.7	C5.8	C5.9	C5.10	C5.11	C5.12	C5.13	C5.14	C5.15	
Correlation	C5.1	1.000	0.405	0.499	0.307	0.497	0.352	0.477	0.255	0.577	0.183	0.398	0.292	0.375	0.255	0.354
	C5.2	0.405	1.000	0.273	0.454	0.248	0.402	0.350	0.568	0.469	0.485	0.284	0.438	0.260	0.372	0.352
	C5.3	0.499	0.273	1.000	0.313	0.441	0.336	0.505	0.344	0.501	0.305	0.500	0.336	0.405	0.160	0.423
	C5.4	0.307	0.454	0.313	1.000	0.663	0.706	0.459	0.585	0.372	0.501	0.278	0.510	0.360	0.291	0.392
	C5.5	0.497	0.248	0.441	0.663	1.000	0.718	0.648	0.450	0.489	0.402	0.501	0.434	0.561	0.183	0.525
	C5.6	0.352	0.402	0.336	0.706	0.718	1.000	0.574	0.577	0.409	0.465	0.397	0.552	0.417	0.269	0.398
	C5.7	0.477	0.350	0.505	0.459	0.648	0.574	1.000	0.467	0.622	0.426	0.625	0.530	0.621	0.263	0.643
	C5.8	0.255	0.568	0.344	0.585	0.450	0.577	0.467	1.000	0.436	0.727	0.352	0.624	0.427	0.431	0.460
	C5.9	0.577	0.469	0.501	0.372	0.489	0.409	0.622	0.436	1.000	0.382	0.534	0.390	0.530	0.325	0.530
	C5.10	0.183	0.485	0.305	0.501	0.402	0.465	0.426	0.727	0.382	1.000	0.369	0.654	0.497	0.534	0.488
	C5.11	0.398	0.284	0.500	0.278	0.501	0.397	0.625	0.352	0.534	0.369	1.000	0.493	0.573	0.210	0.564
	C5.12	0.292	0.438	0.336	0.510	0.434	0.552	0.530	0.624	0.390	0.654	0.493	1.000	0.477	0.406	0.431
	C5.13	0.375	0.260	0.405	0.360	0.561	0.417	0.621	0.427	0.530	0.497	0.573	0.477	1.000	0.245	0.690
	C5.14	0.255	0.372	0.160	0.291	0.183	0.269	0.263	0.431	0.325	0.534	0.210	0.406	0.245	1.000	0.301
	C5.15	0.354	0.352	0.423	0.392	0.525	0.398	0.643	0.460	0.530	0.488	0.564	0.431	0.690	0.301	1.000

Table 10.
Correlation matrix for research objective 1 – C5

Source: Authors' own work

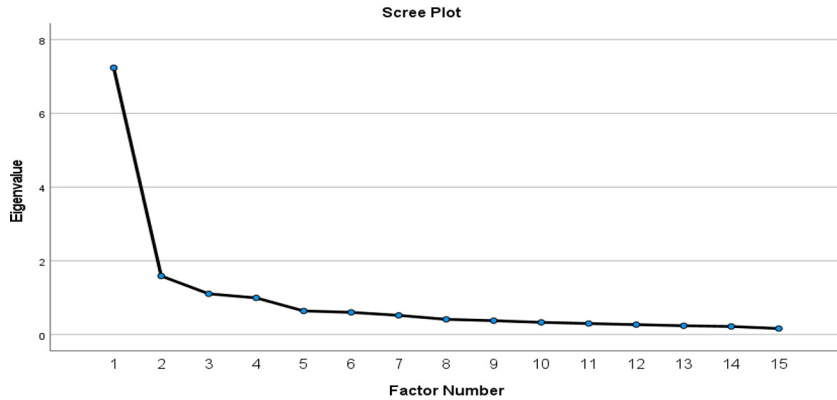
	Communalities	
	Initial	Extraction
C5.1	0.520	0.382
C5.2	0.506	0.389
C5.3	0.409	0.405
C5.4	0.638	0.706
C5.5	0.735	0.815
C5.6	0.671	0.745
C5.7	0.661	0.702
C5.8	0.658	0.722
C5.9	0.571	0.579
C5.10	0.679	0.761
C5.11	0.539	0.561
C5.12	0.588	0.567
C5.13	0.603	0.559
C5.14	0.353	0.343
C5.15	0.597	0.568

Table 11.
Communalities for research objective 1 – C5

Note: Extraction method: Principal axis factoring

Source: Authors' own work

Figure 1.
Scree plot for
research objective
1 – C5



Source: Author’s own work

In [Figure 1](#), variables 4 to 15 were not significant so they were not added in the rotation. For the first factor, the eigenvalue was around 7.2, for the second factor, the eigenvalue was around 1.5 and the third factor has the eigenvalue of 1.1. [Table 12](#) depicts the rotated factor matrix for research objective 1 – C5.

From [Table 12](#), C5.7, C5.11, C5.13, C5.9, C5.1, C5.15, C5.3 were grouped into factor 1 while C5.10, C5.12, C5.8, C5.14 and C5.2 were grouped into factor 2 while C5.6, C5.4 and C5.5 were grouped into factor 3.

Each item was grouped into factors based on the KPIs (time, cost, quality, safety and health, internal and external stakeholder, client satisfaction, financial performance, environment and information, technology and innovation) they are associated with.

	Rotated factor matrix ^a		
	1	Factor 2	3
C5.7	0.727	0.249	0.334
C5.11	0.706	0.216	0.130
C5.9	0.685	0.294	0.152
C5.13	0.662	0.298	0.179
C5.15	0.653	0.344	0.156
C5.3	0.593	0.154	0.171
C5.1	0.571	0.116	0.208
C5.10	0.231	0.818	0.197
C5.8	0.227	0.739	0.353
C5.12	0.336	0.605	0.298
C5.14	0.165	0.560	0.046
C5.2	0.252	0.538	0.190
C5.6	0.296	0.332	0.740
C5.4	0.188	0.407	0.711
C5.5	0.550	0.102	0.708

Table 12.
Rotated factor matrix
for research objective
1 – C5

Notes: Extraction method: principal axis factoring. Rotation method: Varimax with Kaiser normalisation
^aRotation converged in six iterations

Source: Authors’ own work

Factor 1 contains items related to quality, people, IT and innovations, time, cost, safety and health, environment, internal and external stakeholders and client satisfaction (P, C, Q, IT&I, T, SH, I&ES, E and CS) and factor 2 includes items related to quality, people, IT and innovations, time, cost, internal and external stakeholders (P, C, Q, IT&I, T and I&ES), whereas factor 3 includes items related to internal and external stakeholders, cost, time, people (I&ES, P, C and T).

Table 13 represents the exploratory factor analysis for research objective 2 (causes of CSCRs) for section C6.

From Table 13, the causes of CSCRs were loaded on three factors with eigenvalues of 7.402, 1.484 and 1.181, respectively. These three factors explained 67.111% of the variance before rotation and 59.199% of the variance after rotation. Table 14 shows the correlation matrix for research objective 2.

From Table 14, many of the correlations were bigger than 0.3. C6.12 and C6.1 had the correlation of 0.244, C6.1 and C6.8 had the correlation of 0.264, C6.5 and C6.6 had the correlation of 0.295, C6.6 and C6.15 had the correlation of 0.224, C6.7 and C6.12 had the correlation of 0.241, C6.14 and C6.7 had the correlation of 0.287, C6.8 and C6.1 had the correlation of 0.264, C6.12 and C6.3 had the correlation of 0.294 and C6.15 and C6.6 had a correlation of 0.224.

Table 15 depicts the communalities for section C6.

From Table 15, the extractions are all above 0.3 which means there was at least 30% common variance shared among them. Figure 2 shows the scree plot for section C6.

In Figure 2, variables 4 to 15 were not significant so they were not added in the rotation. For the first factor, the eigenvalue was around 7,4, for the second factor, the eigenvalue was around 1.48 and the third factor has the eigenvalue of 1.18. Table 16 depicts the rotated factor matrix for research objective 2 – C6.

Factor	Total variance explained								
	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)
1	7.402	49.344	49.344	7.004	46.691	46.691	3.656	24.373	24.373
2	1.484	9.896	59.240	1.080	7.199	53.890	2.832	18.878	43.250
3	1.181	7.871	67.111	0.796	5.309	59.199	2.392	15.948	59.199
4	0.926	6.172	73.283						
5	0.676	4.509	77.792						
6	0.597	3.983	81.775						
7	0.479	3.192	84.966						
8	0.443	2.953	87.919						
9	0.378	2.523	90.442						
10	0.322	2.148	92.590						
11	0.282	1.878	94.469						
12	0.240	1.601	96.070						
13	0.231	1.538	97.608						
14	0.183	1.223	98.831						
15	0.175	1.169	100.000						

Note: Extraction method: Principal axis factoring

Source: Authors' own work

Table 13. Exploratory factor analysis for research objective 2 (causes of construction supply chain risks) – C6

Table 14.
Correlation matrix
for research objective
2 – C6

	C6.1	C6.2	C6.3	C6.4	C6.5	C6.6	C6.7	C6.8	C6.9	C6.10	C6.11	C6.12	C6.13	C6.14	C6.15	
Correlation	C6.1	1.000	0.343	0.531	0.448	0.564	0.306	0.445	0.264	0.512	0.443	0.450	0.244	0.427	0.413	0.535
	C6.2	0.343	1.000	0.656	0.699	0.375	0.530	0.415	0.498	0.383	0.475	0.458	0.326	0.397	0.417	0.322
	C6.3	0.531	0.656	1.000	0.721	0.520	0.436	0.631	0.462	0.536	0.418	0.558	0.294	0.433	0.374	0.485
	C6.4	0.448	0.699	0.721	1.000	0.439	0.524	0.518	0.615	0.386	0.457	0.436	0.344	0.331	0.430	0.390
	C6.5	0.564	0.375	0.520	0.439	1.000	0.295	0.475	0.360	0.638	0.398	0.568	0.350	0.510	0.560	0.634
	C6.6	0.306	0.530	0.436	0.524	0.295	1.000	0.571	0.503	0.422	0.711	0.361	0.467	0.360	0.379	0.224
	C6.7	0.445	0.415	0.631	0.518	0.475	0.571	1.000	0.392	0.534	0.549	0.570	0.241	0.457	0.287	0.465
	C6.8	0.264	0.498	0.462	0.615	0.360	0.503	0.392	1.000	0.420	0.566	0.482	0.458	0.306	0.486	0.347
	C6.9	0.512	0.383	0.536	0.386	0.638	0.422	0.534	0.420	1.000	0.514	0.623	0.402	0.712	0.385	0.595
	C6.10	0.443	0.475	0.418	0.457	0.398	0.711	0.549	0.566	0.514	1.000	0.435	0.541	0.456	0.528	0.396
	C6.11	0.450	0.458	0.558	0.436	0.568	0.361	0.570	0.482	0.623	0.435	1.000	0.177	0.536	0.378	0.516
	C6.12	0.244	0.326	0.294	0.344	0.350	0.467	0.241	0.458	0.402	0.541	0.177	1.000	0.328	0.549	0.348
	C6.13	0.427	0.397	0.433	0.331	0.510	0.360	0.457	0.306	0.712	0.456	0.536	0.328	1.000	0.320	0.504
	C6.14	0.413	0.417	0.374	0.430	0.560	0.379	0.287	0.486	0.385	0.528	0.378	0.549	0.320	1.000	0.527
	C6.15	0.535	0.322	0.485	0.390	0.634	0.224	0.465	0.347	0.595	0.396	0.516	0.348	0.504	0.527	1.000

Source: Authors' own work

Table 15.
Communalities for
section C6

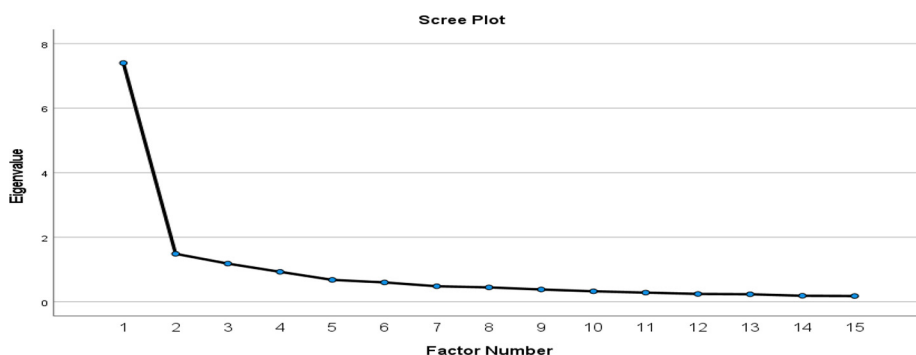
	Communalities Initial	Extraction
C6.1	0.487	0.450
C6.2	0.616	0.598
C6.3	0.702	0.762
C6.4	0.701	0.727
C6.5	0.613	0.644
C6.6	0.640	0.595
C6.7	0.622	0.517
C6.8	0.572	0.517
C6.9	0.693	0.688
C6.10	0.677	0.681
C6.11	0.590	0.564
C6.12	0.486	0.558
C6.13	0.554	0.490
C6.14	0.569	0.492
C6.15	0.564	0.599

Note: Extraction method: Principal axis factoring
Source: Author's own work

From Table 16, C6.11, C6.9, C6.1, C6.15, C6.13 and C6.5 were grouped into factor 1 while C6.4, C6.3, C6.2 and C6.7 were grouped into factor 2 and C6.12, C6.10, C6.8, C6.6 and C6.14 were grouped into factor 3.

Each item was grouped into factors based on the KPIs (time, cost, quality, safety and health, internal and external stakeholder, client satisfaction, financial performance, environment and information, technology and innovation) they are associated with.

Factor 1 contains items related to quality, people, IT and innovations, time, cost, financial performance, safety and health, environment, internal and external stakeholders and client satisfaction (P, C, Q, IT&I, T, SH, I&ES, E, FP and CS), factor 2 includes items related to quality, people, time, safety and health and internal and external stakeholders (P, Q, SH, T and



Source: Author's own work

Figure 2. Scree plot for research objective 2 – C6

Rotated factor matrix ^a			
	1	Factor 2	3
C6.9	0.746	0.218	0.289
C6.5	0.741	0.200	0.232
C6.15	0.725	0.146	0.228
C6.13	0.627	0.202	0.238
C6.11	0.620	0.403	0.131
C6.1	0.586	0.283	0.165
C6.4	0.240	0.768	0.283
C6.3	0.472	0.728	0.097
C6.2	0.220	0.678	0.300
C6.7	0.468	0.504	0.209
C6.12	0.209	0.092	0.711
C6.10	0.306	0.338	0.687
C6.6	0.133	0.491	0.580
C6.14	0.397	0.171	0.552
C6.8	0.210	0.462	0.509

Table 16.

Rotated factor matrix for research objective 2 – C6

Notes: Extraction method: principal axis factoring. Rotation method: Varimax with Kaiser normalisation^a

^aRotation converged in five iterations

Source: Authors' own work

I&ES) and factor 3 includes items related to internal and external stakeholders, cost, time, people, quality, clients satisfaction and financial performance (I&ES, P, C, Q, CS, FP and T).

5. Reliability statistics of data collected

5.1 Reliability of theoretical factors

To establish data consistency of the theoretical factors, the value of the Cronbach's alpha (coefficient alpha was determined). A Cronbach alpha value of 0.7 and above signifies an acceptable internal consistency. Tables 17–24 showed Cronbach's alpha values above 0.7. Table 17 shows the reliability statistics for research objective 1 – C5.

Table 17 depicts the reliability statistics for research object 1, which measures the internal consistency of the measured variables and the Cronbach's alpha was 0.921 which confirms its reliability. Table 18 depicts reliability statistics for research objective 2 – C6.

Table 18 depicts the reliability statistics for research object 2, which measures the internal consistency of the measured variables. From Table 18, the Cronbach's alpha was 0.926 which confirmed its reliability.

5.2 Reliability of empirical factors

To establish data consistency of the empirical factors, the value of the Cronbach's alpha (coefficient values) was determined. Table 19 shows the reliability statistics for research objective 1 – C5.

The empirical reliability was carried out for all the three factors in section C5 to confirm their reliability. Table 19 shows the reliability statistics for section C5 – factor 1.

Table 19 shows the reliability statistics for C5 – factor 1, which measures the internal consistency of the measured variables. From Table 19, the Cronbach's alpha was 0.883 which shows it was reliable. Table 20 depicts the reliability statistics for section C5 – factor 2.

Table 20 represents the reliability statistics for C5 – factor 2, which measures the internal consistency of the measured variables. The Cronbach's alpha was 0.845 as

Table 17.
Reliability statistics
for research objective
1 – C5 – factors that
influence
construction supply
chain management
and their extent
levels

Reliability statistics	
Cronbach's alpha	No. of items
0.921	15
Source: Author's own work	

Table 18.
Reliability statistics
for research objective
2 – the causes of
construction supply
chain risks and their
extent levels

Reliability statistics	
Cronbach's alpha	No. of items
0.926	15
Source: Authors' own work	

Table 19.
Reliability statistics
for section
C5 – factor 1

Reliability statistics	
Cronbach's alpha	No. of items
0.883	7
Source: Authors' own work	

Table 20.
Reliability statistics
for section
C5 – factor 2

Reliability statistics	
Cronbach's alpha	No. of items
0.845	5
Source: Authors' own work	

shown in Table 20, therefore, it was reliable. Table 21 depicts the reliability statistics for section C5 – factor 3.

Table 21 depicts the reliability statistics for C5 – factor 2, which measures the internal consistency of the measured variables. From Table 21, the Cronbach's alpha was 0.872, so it was reliable. Table 22 shows the reliability statistics for the empirical factor 1 for research objective 2 – C6.

The reliability of the empirical factors was carried out to determine their reliability. Table 22 shows the reliability statistics for research objective 2 – section C6 – factor 1.

Table 22 depicts the reliability statistics for C6 – factor 1, which measures the internal consistency of the measured variables. Table 22 shows that the Cronbach's alpha was 0.882 and this confirms its reliability. Table 23 represents the reliability statistics for section C6 – factor 2.

Table 23 shows the reliability statistics for C6 – factor 2, which measures the internal consistency of the measured variables. From Table 23, the Cronbach's alpha was 0.862 so it was reliable. Table 24 shows the reliability statistics for section C6 – factor 3.

Table 24 illustrates the reliability statistics for C6 – factor 3, which measures the internal consistency of the measured variables. From Table 24, the Cronbach's alpha was 0.844, which shows it was reliable.

Reliability statistics		
Cronbach's alpha		No. of items
0.872		3
Source: Authors' own work		

Table 21.
Reliability statistics for section C5 – factor 3

Reliability statistics		
Cronbach's alpha		No. of items
0.882		6
Source: Authors' own work		

Table 22.
Reliability statistics for section C6 – factor 1

Reliability statistics		
Cronbach's alpha		No. of items
0.862		4
Source: Authors' own work		

Table 23.
Reliability statistics for section C6 – factor 2

Reliability statistics		
Cronbach's alpha		No. of items
0.844		5
Source: Authors' own work		

Table 24.
Reliability statistics for section C6 – factor 3

The reliability analysis shows that both the empirical and theoretical factors have Cronbach's alpha values greater than 0.7, which confirms the internal consistency of the measured variables in each section.

6. Result and discussions

The respondents were asked to identify the factors that influence CSCM and their extent levels as depicted by [Table 5](#). The result shows that predictable delivery, funding schedule, inventories, balanced demands, production capabilities, timely procurement, CSCM coordination, delivery reliability, the proximity of suppliers, identification of SCRs in the conceptualisation stage of a project, identification of SCRs in the planning stage of a project, identification of SCRs in the execution stage and the reconciliation of material flows of the subcontractors with the contractors were identified as the key factors that influenced the CSCM the most. The values of the Spearman's coefficient were bigger than 0.3 which shows the items correlate and from [Table 7](#), for the Bartlett's Test of Sphericity, the significance, p -value was 0.000 which was less than 0.05, which means the higher the probability of the factors that influence CSCM, the more they influence the project. The KMO Measure of Sampling Adequacy was 0.902, which was bigger than 0.6 which shows that factor analysis can be done. From [Table 17](#), the Cronbach's alpha for the theoretical factors was 0.921, which confirms its reliability. This shows that the theoretical factors were reliable because their values were greater than 0.7.

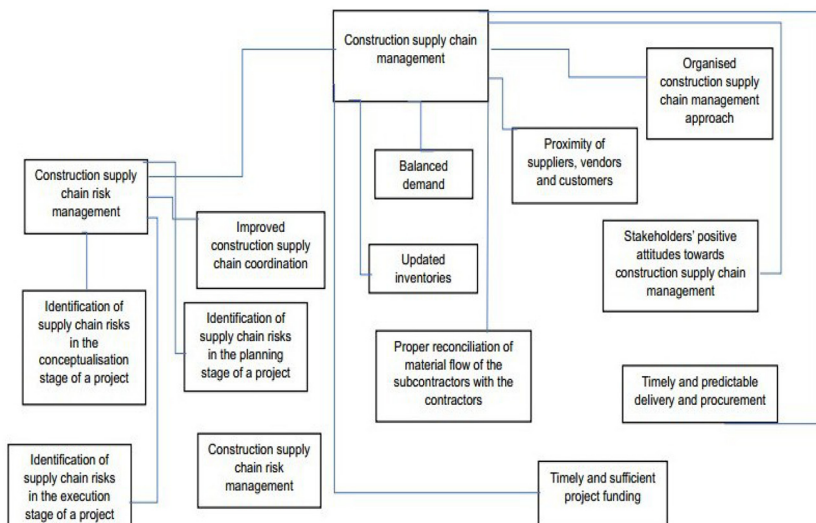
For the second research objective, the respondents were asked to identify the extent in which the following causes of SCRs influence construction projects as shown in [Table 6](#), the result shows that subcontractor's negative attitudes towards supply chain management, procurement delays, imbalanced demands, clients' negative attitudes towards other project stakeholders, unpredictable delivery reliability, disorganised CSCM approach, delayed funding, low delivery reliability, poor inventories, poor CSC coordination, suppliers' negative attitudes towards supply chain management and when the material flows of the subcontractors with the contractors are not reconciled were identified as the factors that have the greatest impacts on CSCRs management. The values of the Spearman's coefficient were bigger than 0.3 which shows the items correlate and from [Table 8](#), for the Bartlett's Test of Sphericity, the significance, p -value was 0.000 which was less than 0.05, which means the higher the probability of the factors that cause SCRs, the higher their influences on CSCM. The KMO Measure of Sampling Adequacy was 0.895 which was bigger than 0.6, which shows that factor analysis is feasible. From [Table 18](#), the Cronbach's alpha for the theoretical factors was 0.926, which confirms its reliability. The Cronbach's alpha for the empirical factors (1, 2 and 3) for research objective 1 – C5 were 0.883, 0.845 and 0.872, respectively, and this shows that the factors were reliable. Also, the Cronbach's alpha for the empirical factors (1, 2 and 3) for research objective 2 – C6 were 0.882, 0.862 and 0.844, respectively, and this shows that the empirical factors were reliable because the values were all above 0.7.

The Cronbach's alpha values were all above 0.7 for all the measured variables, which indicated internal consistency for the measuring instrument.

6.1 Proposed new framework

6.1.1 Discussions. [Figure 3](#) depicts the CSCM approach fully incorporating factors that influenced supply chain management and methods to mitigate the impacts of these risks and the causes of SCRs on construction project success.

The framework shown in [Figure 3](#) was designed by carefully analysing the major contributing factors to CSCRs and how these factors influenced CSCM and the success of the project and by paying attention to these areas and factors, supply chain resilience will be



Source: Author's own work

Figure 3.
Proposed new
framework for
managing supply
chain risks in
construction projects

improved in construction projects. This new framework will help organisations to carefully and effectively assess and manage these contributing factors to CSCRs so that suppliers, vendors, distributors, wholesalers and retail partners' relationships will be established and managed successfully. Organisations will effectively collaborate with internal and external stakeholders to establish contingency plans for critical supplies and services, effectively implement supply chain strategies that ensure efficient production, distribution and delivery of materials, labour and other resources, develop a global supply chain strategy that optimises logistics and reduce transportation costs and timely, continually and effectively Identify and assesses potential risks in the supply chain, including geopolitical, economic and operational risks for the overall construction project success.

The proposed framework depicted in Figure 3 will ensure that CSCR management and coordination are effective and every risk involved is carefully identified during the conceptualisation, planning and execution stages of the project and risk mitigation steps put in place to manage these risks. It is recommended to engage with suppliers, vendors and customers close to the project sites to guarantee timely, predictable and reliable deliveries and procurements. Balanced demands and updated inventories ensure the possibility of shortages and surplus of labour and materials are mitigated and eliminated. Sufficient production capabilities to meet production schedules and deadlines, timely and adequate project funding to ensure there are no delays in procurements and availability of labour and stakeholders' positive attitudes towards supply chain management are crucial for the effective identification and management of CSCRs for a successful project completion. Research objective three will be discussed in Section 7.

7. Conclusion

Construction is a key element of sustainable development and poor supply chain management is one of the major challenges faced in construction due to the presence of many stakeholders, phases, activities, tasks and risks involved in executing construction

projects. These risks if not carefully identified, assessed, analysed, monitored, controlled and mitigated throughout the project can lead to project delays, abandonment, failures, compromised safety and quality, reputational damage, claims, additional costs and extended project completion time and can negatively influence the overall key performance. Moreover, effective SCR management is a key element in achieving green buildings in developing countries.

SCRs are inevitable in every construction project, so this paper investigated the factors that influence CSCM and the causes of SCRs in construction projects and their level of impacts and proposed ways to improve construction supply chain resilience by identifying these factors that influenced CSCM. The methods used explored the relationships between project stakeholders with respect to CSCM and how these relationships affect supply chain management and associated risks generated in the project life cycle. To effectively mitigate SCRs and enhance supply chain management in construction projects, it is paramount that stakeholders fully understand how their attitudes, experiences, behaviours and competency directly and indirectly influence the outcome of a project and must encourage effective collaboration among project participants. To minimise costs, save time, avoid delivery delays and failures and avoid other uncertainties and risks associated with logistics, procurements and supply chain management, it is recommended to engage with suppliers, customers and vendors that are within favourable proximity without compromising the standard, safety, quality and environment.

From the results obtained, predictable delivery, funding schedule, inventories, production capabilities, timely procurement, CSCM coordination, delivery reliability, the proximity of suppliers, identification of SCRs in the conceptualisation stage of a project, identification of SCRs in the planning stage of a project, identification of SCRs in the execution stage and the reconciliation of material flows of the subcontractors with the contractors were identified as the key factors that influenced the CSCM the most because they showed highest extent levels. The findings will help project managers, project planners, project engineers and contractors to effectively plan project schedules and supply chain coordination from conceptualisation stage to finish. For a successful CSCRs management, it is crucial to have a reliable, timely and predictable delivery of materials, labour and resources as any delay will negatively influence the progress of any or other construction activities and incur additional costs. Identifying supply chains risks during the conceptualisation and planning stages is vital in putting risk mitigation strategies in place early enough to mitigate, minimise or eliminate these risks if they eventually occur during project contracting, procurement and execution phases. Funding schedule and updated inventories facilitate successful project delivery because any delay in funding, halts or delays project progress and this leads to extended project time and inventories facilitate effective supply chain coordination by ensuring delivery records are up to date and material flows of the subcontractors with the contractors are effectively reconciled to avoid shortages, discrepancies or excess supply of materials on site and for the overall successful CSCM coordination. The result also showed that to effectively manage CSCRs, subcontractors, clients and suppliers must display positive attitudes towards supply chain management and other project stakeholders because by not doing so, it will lead to communication breach and eventually result in a disorganised construction supply chain coordination which will either delay the project, cause the project to be abandoned or result in project failure. The proximity of suppliers is also important as to reduce cost and ensure timely and predictable delivery. So, to facilitate CSCM, every stakeholder must play an active role to ensure the flow of materials, resources and labour are coordinated efficiently and they are used effectively and ensure that demands are reconciled with supplies to realise project's objectives with respect to time, safety, quality, cost and financial performance.

In summary, as developing countries embark on sustainable building adoption for sustainable development, construction industry professionals must ensure that CSCR management and coordination are effective and every risk involved is carefully identified during the conceptualisation, planning and execution stages of the project and risk mitigation steps put in place to manage these risks. Every aspect of construction KPIs such as time, safety, environment, cost, quality, financial performance, labour, materials, stakeholders etc. are carefully assessed, analysed, monitored and controlled to ensure that risks associated with supply chain will not adversely influence project delivery. It is recommended to engage with suppliers, vendors and customers close to the project sites to guarantee timely, predictable and reliable deliveries and procurements. Balanced demands and updated inventories ensure the possibility of shortages and surplus of labour and materials are mitigated and eliminated. Sufficient production capabilities to meet production schedules and deadlines, timely and adequate project funding to ensure there are no delays in procurements and availability of labour and stakeholders' positive attitudes towards supply chain management are crucial for the effective identification and management of CSCRs for a successful project completion. The findings will facilitate successful project delivery when adopted by investors, governmental bodies, project managers, funders, host communities, private sectors, contractors, sub-contractors and other stakeholders involved in contracting and executing construction projects in South Africa and other developing countries for sustainability and decarbonisation in the construction industry locally and globally.

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