Journal of Transport and Supply Chain Management
ISSN: (Online) 1995-5235, (Print) 2310-8789

The uncertainty–risk–efficiency pathway: Evidence from supply chains operating amid the Sudan conflict

Check for updates

Authors:
Abdelsalam A. Hamid[1]
Nancy George[2]
Adam Y.A. Hamad[3]
Muhammad Shafiq[1]

Affiliations:
[1]Department of Management, College of Business Administration, A'sharqiyah University, Ibra, Oman

[2]Department of Management/Marketing, College of Administrative Sciences, National University Sudan, Khartoum, Sudan

[3]Department of Business Administration, College of Business and Economics, Qassim University, Buraidah, Saudi Arabia

Corresponding author:
Abdelsalam Hamid,
abdelsalam.adam@asu.edu.om

Dates:
Received: 20 Jan. 2026
Accepted: 22 Apr. 2026
Published: 09 July 2026

How to cite this article:
Hamid, A.A., George, N., Hamad, A.Y.A. & Shafiq, M., 2026, 'The uncertainty–risk–efficiency pathway: Evidence from supply chains operating amid the Sudan conflict', *Journal of Transport and Supply Chain Management* 20(0), a1336. https://doi.org/10.4102/jtscm.v20i0.1336

Read online:
Scan this QR code with your smart phone or mobile device to read online.

Background: Environmental uncertainty, characterised by rapid changes in macroeconomic policies, geopolitical instability, and sectoral volatility, has become a major driver of supply chain risk.

Objectives: This study examines the relationships among environmental uncertainty, supply chain risk, supply chain security, and supply chain efficiency. Growing environmental unpredictability compels organisations to strengthen security measures and build resilient supply networks. Furthermore, the study investigates how firms allocate resources to mitigate risks and enhance security capabilities to reduce disruptions and maintain operational continuity during periods of instability.

Method: A quantitative cross-sectional research design was employed. Data were collected through a self-administered survey from 190 logistics, supply chain, and operations management professionals working in commercial companies in Sudan. The data were analysed using Partial Least Squares Structural Equation Modeling (PLS-SEM).

Results: The results indicate that environmental uncertainty does not directly affect supply chain efficiency. However, environmental uncertainty was found to have a significant positive relationship with both supply chain risk and supply chain security. In addition, supply chain risk and supply chain security positively mediate the relationship between environmental uncertainty and supply chain efficiency.

Conclusion: It is crucial that no organisation can adapt to uncertainty in its environment directly; they need to create integrated risk management and security systems that act as protective mechanisms for supply chain efficiency.

Contribution: Organisations should strengthen resilience through flexible sourcing strategies, strategic inventory management, operational decentralisation, and predefined emergency response protocols to ensure continuity during disruptions.

Keywords: environmental uncertainty; supply chain efficiency; supply chain risk; supply chain security; risk management; structural equation modelling; SEM.

Introduction

In recent years, risk management has assumed a significant importance. As organisations work to achieve their goals, they face a growing range of challenges, such as supply chain disruptions, financial pressures, sudden policy changes and unexpected events such as political instability or natural hazards (Shafiq & Soratana 2019a). Consequently, it is no longer sufficient to respond to risks reactively; organisations have to incorporate risk management into their planning and operational frameworks, in particular with regard to supply chains (Shafique, Shafiq & Saleem 2025). The judicious use of what if analyses and of probabilistic forecasting is an indispensable set of tools for anticipating and mitigating unforeseen contingencies. In the modern economy of globalisation, supply chains have moved beyond their conventional role as the lifelines for the flow of goods and services from supplier to consumer; they have become the lifeline arteries that connect disparate economies, markets and communities (Shafiq & Soratana 2019b). Any interruption within this whole network has the potential to cripple commerce and has severe repercussions on the livelihoods of affected populations (Belhadi et al. 2021). When operating with conditions of relative

Copyright: © 2026. The Authors. Licensee: AOSIS. This work is licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license (https://creativecommons.org/licenses/by/4.0/).

stability the control of such supply chains may be diagnosed as primarily a technical or a logistical challenge, therefore resolvable through meticulous planning and cutting-edge technological interventions (Shafiq & Soratana 2020). In Sudan, and specifically since April 2023, the conflict has created an extreme uncertainty in the environment, which shaped a need for over 30 million people to be extensively displaced. Logistics, infrastructure and supply chain operations have severely been interrupted because of the befallen instability, which consequently affected the movement of goods and services (OCHA 2025). According to the World Trade Organization (WTO 2023), conflict environments are characterised by heightened uncertainty, which adversely affects supply chain efficiency and undermines the reliability of supply chain operations.These distractions have exaggerated security threats together with risks of supply chain including scarcities and postponements, specifically in healthcare systems and food (WFP 2025; WHO 2024). Here a gap of linking the environmental uncertainty to supply chain efficiency by a mediator such as supply chain risk remains unexplored. However, in conflict-affected environments such as Sudan, these assumptions of relative stability no longer hold (Elamin 2025; Hansohm 2024; World Bank Group 2024). Since the outbreak of the Sudan war in 2023, the country has experienced severe disruptions across its industrial and logistics sectors, including damaged infrastructure, fragmented transportation networks, restricted access to ports and widespread insecurity affecting production and distribution activities (Elamin 2025; Elnourani et al. 2024; Hansohm 2024; Zheng et al. 2025). Supply chains have been repeatedly interrupted by fuel shortages, labour displacement and market fragmentation, creating extreme levels of environmental uncertainty for firms operating within the region. These conditions make Sudan an important empirical context for examining how organisations respond to compounded risks and uncertainty in real time (Elamin 2025; Elnourani et al. 2024; World Bank 2024). Yet in this highly volatile situation, the Sudan's industry every day poses a new test of corporate strength. Our research is based on the relationship between efficiency of supply chain and risk management, and the particular attention is given to logistics security, intensity of risk within the business environment and environmental uncertainty that are especially salient in the light of the war in Sudan (Hamid et al. 2025). The phenomenon of environmental uncertainty and risk pose formidable challenges to supply chain efficiency. Environmental uncertainty includes factors such as fluctuating market demand, unpredictable fluctuations in supply and the changing regulatory framework. According to Vilko, Ritala and Edelmann (2014)'s article in the section on evolution uncertainty and risk management: A timely contribution for the supply chain: 'The current need for better definitions of uncertainty in risk management contexts may stand as a key research priority, especially in the supply chain'. They say a holistic overarching framework taking into consideration the tangible and intangible nature of uncertainties is therefore urgently needed. Their findings lead to the suggestion that a better understanding of risk perceptions among supply-chain managers can lead to the shaping of a strategy that tends to presuppose the mitigation of uncertain outcomes. An additional area that deserves a deeper search stems from the work of Jajja, Chatha and Farooq (2018) who call for empirical research that would explore organisational response to risks in the supply chain with the objective of the organisations achieving agility performance. Moreover, in both studies of Hsieh et al. (2023) and Kamar et al. (2023) in their study explore the interrelations that exist between supply chain agility, resilience and performance, without explicitly focusing these outcomes in the context of conflict-related disruptions. Both studies highlighted the importance of these concepts of resilience in supply chains, while we focus on 2025 on the importance of resilience and sustainability, while failing to provide empirical relationships between environmental uncertainties to the concrete efficiency outcomes. Consequently, we are left with an evident gap in the body of literature: a dearth of research explicitly connecting these themes to humanitarian supply chains originating from conflict zones, for example, Sudan. Understanding how to effectively use agile methodologies in war torn environments, is an area that is heavily underexplored. The increasing body of research examining the impact of environmental uncertainty on supply chain efficiency is inspired by evidence that environmental uncertainty significantly affects both operational performance and strategic decision-making within organisations. The range of environmental factors affecting businesses includes instability of the market, changing consumer tastes, changes in regulation and technological rivalries (Sato, Tse & Tan 2020). The present knowledge deficit prevents us from determining how these uncertainties impact supply chain efficiency during organisation-wide development of adaptable supply chain systems. The research evaluates current studies to reveal critical knowledge deficiencies about this complex connection. Recent research shows supply chain organisations must build agility to effectively manage environmental uncertainties (Gligor, Esmark & Holcomb 2014). Organisations that operate in unstable business environments should implement flexible supply chain systems, which allow them to execute quick responses when market demand and supply levels experience changes (Gligor et al. 2014). Empirical studies of the agility-performance relationship are still in their infancy, in which most of the research studies have not collected enough empirical samples to establish the conditions under which agility provides superior performance outcomes. In their seminal discussion, Inman and Green suggest that organisations have to determine novel determinants that modulate the agility-performance relationship within the volatile environmental contexts (Inman & Green 2021). Though previous studies have examined the relationship between environmental uncertainty, risk management, and supply chain performance. This research endeavour aims at highlighting the centrality of risk management in supporting the efficacy of the supply chain and demonstrating how overlooking this relationship can risk the entire commercial apparatus. Although the past scholarship has investigated the (Busse, Duensing & Schleper 2026; Zheng et al. 2025; Zhu et al. 2026), the distinguishing contribution of this inquiry is its focused investigation of the role of risk management in enhancing the effectiveness of supply chains in the specific

milieu of Sudan. Diverging from conventional studies that focus on stable settings, this article questions the interaction between risk management and the supply chain performance in the context of the exceptional and arduous conditions brought about by the Sudanese conflict.

Theoretical foundations

Resource dependence theory

The link between environmental uncertainty and supply chain efficiency can theoretically be based on a number of soundly established frameworks in supply chain management (SCM). This theory is useful for understanding how firms update the processes within their supply chains in response to uncertain conditions surrounding sustainability and how external pressures work to turn into operational inefficiencies. Resource Dependence Theory (RDT), proposed by Pfeffer and Salancik (1978), Reitz (2007) contends that organisations are resource-dependent with the external determining resources that they control, and resource availability of uncertainty forcing strategic responses. Environmental uncertainty can be viewed as a type of environmental turbulence where the firms are facing ambiguous constraints regarding the resources as a result of changing sustainability requirements, changing expectations of investors and changing environmental standards. In such environments, firms may respond to uncertainty by relying more heavily on specific supply chain strategies to manage their operations efficiently and to hedge against supply chain disruptions and rising compliance costs.

Real Options Theory, which was first conceptualised by Myers (1977) and further developed by Dixit and Pindyck (1994), emphasises the managerial flexibility under uncertainty. Firms confronting uncertain situations see investments and operational strategies as 'options' that they can employ when they have more information. In the face of environmental uncertainty, firms may postpone their efforts towards adopting lean supply chain efficiency systems or sustainable supply chain practices owing to ambiguous cost structures and long-term benefits for the same. As stated in contingency theory, the applicability of a company's structure is defined by such factors as the outside context of the company (Lawrence & Lorch 1967), the degree of unpredictability (Thompson 1967), operational technologies (Woodward 1958) and the rate of change that the company is facing (Burns & Stalker 1961). Contingency theory is contradictory to positivist views, which wish to formulate definitive scientific rules for maximising efficiency (Gonz´alez-Zapatero et al. 2024; Kessler, Nixon & Nord 2017). Thus, it is considered appropriate to use these well-established theories as a theoretical foundation for this study.

Literature review and hypotheses development

Environmental uncertainty

In the last decade, sustainability mandates, regulatory realignments and a growing chorus of stakeholder expectations – collectively broadly conceptualised as environmental imperatives have re-arranged the corporate landscape (Annesi et al. 2025). While environmental stewardship is becoming an increasingly entrenched strategic goal, the vagaries of environmental policy and compliance have been given relatively little scholarly attention. Such uncertainty represents a complex, evolving hindrance that seriously impedes organisational planning and execution (Tang et al. 2024). Environmental uncertainty is exacerbated by rapidly evolving environmental regulations, shifting investor expectations, and changing societal norms, all of which contribute to greater complexity in day-to-day organisational operations. This confluence of factors highlights the need to question the impact of environmental uncertainty on supply chain performance – a nexus that is largely uncharted in the body of literature. Indeed, environmental uncertainty has a dominant role in their motivation for rival firms to work together on common challenges (Seepana, Paulraj & Datar 2025). Accordingly, the skilful management of these uncertainties is of utmost importance, especially for operations management leaders who need to adapt in volatile business milieu and direct the flow of specialised knowledge within their organisations (Katsaliaki, Kumar & Loulos 2024; Meena, Dhir & Sushil 2023). These uncertainties arise from various areas, which include market dynamics, technological change etc. For example, the uncertainty in the market environment includes unexpected changes in the external environment – in terms of changing requirements and tastes of consumers – as well as variation in specifications of upcoming products (Seepana et al. 2025). Turning at the concept of technological uncertainty; this construct captures both the magnitude and the velocity of technological transformations permeating an industry's technological infrastructure in that it encapsulates the rapid evolution of methodologies that are employed in the fabrication of products or services (Jiyao, Reilly & Lynn 2005). A basic difference between market and technical uncertainty lies in their origin: market uncertainty is rooted in the difficulty to understand the evolution of consumer tastes and demands within individual markets (Oriani & Sobrero 2008). Corporate players often have difficulties in defining customer classes as well as tracking changing expectations about product or service characteristics (Jiyao et al. 2005). This predicament is caused by exogenous forces, such as changing consumer trends and demographic transitions (Oriani & Sobrero 2008). Given that environmental contamination leads to the creation of an elevated likelihood of damage to ecological systems and economic structures (Dixit & Pinckney 1994), scholarly inquiry has shifted to finding the optimal temporal frame within which to frame policy by drawing on insights from real options theory. This analytical framework views that under stochastic conditions, the latitude to delay an investment till the volatility subsides represents a valuable flexibility premium that can be valued analogously to a financial

derivative (Hussain et al. 2023). Existing scholarship has taken advantage of the real options construct in order to scrutinise investment prospects under such circumstances (Heidari & Heravi 2024; Zhao, Li & Liu 2024). Although the consequences of environmental uncertainty on firm performance and risk management have been widely studied, its positive or negative impact on operational factors such as supply chain efficiency is still concealed. While some preliminary inquiries have begun to shed some light on this relationship, no clear and empirically grounded connection has emerged to date, signalling the need for further empirical scrutiny.

Supply chain efficiency

A supply chain represents an integrated process of entities, persons, processes, data and assets needed for the production, movement and delivery of products and services to the end consumers (Huang et al. 2022a) approach to asset management and utilisation but it can also be a driver of organisational flexibility and agility in the fluid dynamics of the modern markets (Huang et al. 2022b; Wang, Huang & Fu 2025). Its basic role is to ensure that goods arrive at their destination, accurately, on time and in good condition. The administration of supply chains has become increasingly complex as a result of globalisation, the dispersion of supplier structures and the multiplicity of regional regulation. Moreover, consumers' demand has changed in its way of finding more personalised choices and faster shipment speed (Jain & Mishar 2024; Awashreh et al. 2024). In the field of SCM, the idea of 'efficiency' is widely used and could be interpreted across different meanings. Within the field of SCM scholarship, efficiency is defined as the ability of an organisation to maximise its profits by optimising the operations of its supply chain (Negi 2021). On an internal level, the efficiency of a firm is often defined as the lowering of manufacturing costs and manufacturing cycle times. Externally, it includes elements such as on-time delivery, satisfying the order speed, service quality and competitiveness. As a result, supply chain efficiency is a key performance measure and it directly impacts the performance result and economic results (Haque et al. 2025). It is also a basic force for the progression of supply chain and a major source of competitive advantage. The efficiency of a supply chain acts as a very important indicator of a firm's operational health and its ability to put resources to work. Contemporary studies of management and operations have identified it as one of the major areas of concern. A streamlined supply chain is not only a cost-efficient approach to asset management and utilisation but it can also be a driver of organisational flexibility and agility in the fluid dynamics of the modern markets (Huang et al. 2022b; Wang, Huang & Fu 2025). Extensive scholarly interest has attempted to outline the size and location of inefficiencies in supply chains around the world (Behzadi et al. 2018; Negi & Anand 2019; Suryawanshi & Dutta 2023), with the seminal work of Woodhead and Cotter (2017) providing a notable example of this form of work. It is commonly recognised that the anticipated growth of Australia's horticultural export supply chain will become increasingly dependent on fundamental improvements in efficiency. In this and similar vein, Silvestri et al. (2024) have proposed the development of efficiency-oriented framework, which is designed to protect the long-term viability of the supply chain through improved performance metrics. The main difficulty is not limited to increasing output levels but requires the determination of approaches to make resource utilisation and operational processes more effective, both in the production phases and the consumption phase of this production process. Haque et al. (2025) go further to state that identifying the critical determinants of efficiency will be indispensable to the successful formulation of the export supply chain framework.

The mediating role of supply chain risk

The concept of risk is invoked for the case of events where the probability of possible events can be estimated at some reasonable degree of confidence. In contrast, uncertainty defines situations in which information is incomplete or unreliable and no meaningful probabilities can be assigned. Scholars have broadened the concept of risk in the past few years and argue that uncertainty should replace probability as the defining feature in the domain of risk (Lee et al., 2024). The term 'Supply Chain Risk' usually encompasses uncertainties and vulnerabilities, both on the macro level and on the level of specific operational contexts, which disrupt the physical movement of goods and associated financial transactions in the fabric of a firm's supply network (Ho et al. 2015; Zhu, Huang & Huang 2025). A sizable number of academic researches have explored the consequences and effects of such supply chain risks (Wu 2024). Supply chain risk could be best described as the potential for a risk of incidents that could significantly affect the effectiveness of a firm's supply operations (Gonz´alez-Zapatero et al. 2024). Consequently, organisations need to embrace a three-phase strategy in dealing with it: firstly, identification of possible risks; secondly, assessment of the possible impact; and thirdly, implementation of plans to minimise their impact (Fan & Stevenson 2018; Ho et al. 2015). The first phase of detection aims to record the possible incidents that could negatively affect the supply chain by classifying them according to their origin (external and internal to the organisation). External incidents are caused by things performed in society as an example conflict, terrorism, political unrest or adverse legislation or by natural events such as disease outbreak, environmental disaster. Internal incidents, on the other hand, stem from the company or a member of its supply chain, examples of which are insufficient strategic planning activities, a lack of operational controls or self-interested activities. According to recent studies, businesses often have a reactive approach and take measures to reduce the negative effects of supply chain risks once they have occurred (Crosignani, Macchiavelli & Silva 2023; Manhart, Summers & Blackhurst 2020). Common measures to ensure

that demand can be met in the event of disruptions are keeping buffer stock, also known as redundant inventory, reserving excess production capacity and lead time (Zhu et al. 2025) and having large cash reserves (Wu 2024). Such approaches are aimed mostly to protect the company from the consequences of such breakdowns. The academic literature on SCM represents a large number of empirical investigations; however, these have often tended to be narrow in scope, being restricted to isolated elements. This limitation is especially pronounced with respect to one of the critical factors, which is supply chain risk mitigation. This factor has considerable and significant influences, and it actively determines both of the performance and efficiency of supply chains, a relationship that is particularly prominent in the manufacturing firms (Chang et al. 2019). The focus on developing resilient and reliable supply chains has become important for most manufacturers. Such focus allows them to achieve several competitive advantages and achieve high operating efficiency in their supply chains, which can be attained and sustained for the sake of attaining strong and sustainable supply chain performance in the current unpredictable and fast-paced markets (AL-Shboul 2023). Previous research has been conducted addressing aspects such as risk mitigation, overall supply chain effectiveness and responsiveness, individually or combined together, for the goal of managing a large number of customer demands (Mwesiumo, Nujen & Buvik 2021). The current research focuses on two particular dimensions of supply chain risk, namely, logistics security and work level of risk, and investigates their role as a mediator in the relationship between environmental uncertainty and supply chain efficiency.

Building upon the literature examined, this study puts forward the following hypotheses:

H1: Environmental uncertainty has a negative impact on supply chain efficiency.

H2: Environmental uncertainty has a negative impact on supply chain risk.

H3: Supply chain risk has a negative impact on supply chain efficiency.

H4: Supply chain risk (logistical security and level of work risks) have a positive mediate between environmental uncertainty and supply chain efficiency.

Framework

In this framework, the direct effect of environmental uncertainty on supply chain efficiency, the direct effect of environmental uncertainty on supply chain risk, and the direct effect of supply chain risk on supply chain efficiency are presented, as well as the indirect effect through the proposed mediation mechanism.

Methods and tools

Figure 1, demonstrated how the authors build their framework to make the study utilises descriptive research, in which methodology, designed to delineate phenomena and its interrelationships as they unfold in their natural context is utilised. The approach allows precision to be placed around the underlying problems and sharp focus is given to research inquiries. By using the holistic approach, this method of work creates holistic insights that offer substantial contributions to society's comprehension of complex issues. The study is quantitative in orientation and makes use of structured questionnaire to get empirical data from the representative sample of the target community. The instrument was carefully created to cover the full range of dimensions of inquiry related to the subject matter. Its design drew on validated measures taken from prior scholarly studies that examined the key variables and thematic constructs of the study.

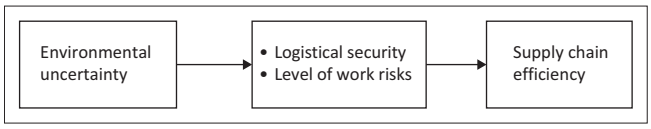


FIGURE 1: Conceptual framework.

Study population and sample

This study was conducted on the community of industrial and commercial companies in Sudan, where the study population is distributed between the cities of Port Sudan, River Nile, and Khartoum.

Sample

This study followed convenience sample of logistics operation managers, supply chain managers, operations managers, the sample consisted of (190) respondents. The convenience sample was selected because of the ongoing conflict in Sudan. Since April 2023 most of the companies either locked or moved out of the capital, therefore there are no accurate data about the exact numbers of the companies operating in Khartoum or other cities (Hamid & Eshag 2025; Hamid et al. 2022). We sent out an anonymous online questionnaire through various channels, including professional networks and online survey. By keeping the survey anonymous, we hoped to encourage honest and open responses. After collecting and cleaning the data, we were left with a solid set of responses to analyse.

The survey itself was built on well-respected and previously tested questions to make sure our findings were both reliable and valid. All questions were answered on a five-point scale, from 'strongly disagree' to 'strongly agree'.

Ethical considerations

Ethical clearance for this study was granted by the National University Research Ethics Committee (NU-REC) (Approval Number NU-REC/05-001/25, Date 25 May 2025). Every procedure conducted in this research involving human subjects adhered strictly to the ethical guidelines set forth by the institutional and/or national research committees, as well as the 1964 Helsinki declaration and its subsequent amendments or equivalent ethical standards. All participants provided written informed consent.

Consent

Prior to their participation, written informed consent was acquired from each person. Participants were guaranteed that their responses would remain confidential and that they could opt out of the study at any moment without facing any repercussions.

Results and analysis

The results of the study are divided into two parts. The first part consists of the analysis of the demographic data of the respondents. The second part of the study consists of the use of SmartPLS software and the analysis of the application of Partial Least Squares Structural Equation Modeling (PLS-SEM). The demographic data analysis has been summarised in Table 1.

Out of the 190 respondents, most of them were males (62.6%), while females comprised 35.3% of the sample, which corresponds with the male-dominance of supply chain and logistics roles within conflict-affected areas such as Sudan. With regard to age, the biggest portion (37.4%) of the respondents were in the 36–45 years age range. This was followed by the participants who were 25 years and younger (31.6%) and then, the ones who were 26–35 years (28.4%). This shows that the respondents were relatively young and mixed with mid-career personnel who were engaged in the supply chain activities. The marital status was split nearly equally between single (48.4%) and married (49.5%), implying that most of the respondents did not come from specific social backgrounds. When it comes to education, we find that most of them had a bachelor's degree (65.8%), and 25.3% of the participants had a master's degree, meaning the sample was educated enough to comprehend and analyse supply chain uncertainties and risks. As per the job category, most of the respondents were employees (52.1%). This was followed by supervisors (17.9%), managers (16.3%) and executive directors (7.4%), which means that the respondents were from the various levels of a given organisation. The variety in age and the participants' economic backgrounds also add depth to the information collected regarding the civil war in Sudan and the implications on supply chain risk and effectiveness. Overall, the demographic profile indicates that the data are drawn from a relatively experienced and educated workforce, with representation across different organisational levels. This strengthens the reliability of the findings, as the respondents are likely to possess practical exposure to supply chain disruptions and risk management in the Sudan war context. Furthermore, the inclusion of both operational staff and decision-makers enhances the study's ability to capture both strategic and operational perspectives on supply chain resilience under conditions of conflict and uncertainty.

TABLE 1: Demographic analysis.

Variable	Category	Frequency	%
Gender	Male	119	62.6
	Female	67	35.3
	Missing	4	2.1
	Total	190	100.0
Age (years)	25 and below	60	31.6
	26–35	54	28.4
	36–45	71	37.4
	Missing	5	2.6
	Total	190	100.0
Marital status	Single	92	48.4
	Married	94	49.5
	Missing	4	2.1
	Total	190	100.0
Education level	School	13	6.8
	Bachelor	125	65.8
	Postgraduate	48	25.3
	Missing	4	2.1
	Total	190	100.0
Job category	Employee	99	52.1
	Supervisor or Senior	34	17.9
	Manager or Head	31	16.3
	Executive Director	14	7.4
	Missing	12	6.3
	Total	190	100.0

Measurement model evaluation

In order to assess the constructs' reliability and validity, several measurement assessments were conducted. Reliability is corroborated by Cronbach's alpha and composite reliability, and both exceed the recommended levels. Discriminant validity for the constructs was assessed using the heterotrait–monotrait (HTMT) ratio. The presence of convergent validity is indicated by the average variance extracted (AVE) values being above the acceptable threshold. The recorded results for the above analyses are presented in Table 2 and the respective figures are summarised in Figure 2.

The measurement model was evaluated based on construct reliability and validity, and the findings indicate the study's latent variables have met the minimum threshold requirements on internal consistency and convergent validity on average. For the construct Supply Chain Efficiency, all indicator loadings achieved strong reliability reflected in the Cronbach's alpha of 0.777 and composite reliability (rho_c) of 0.858, which is above the 0.70 threshold, and therefore the construct sustained strong reliability (Table 2).

The AVE value of 0.604 also suggests reasonable convergent validity. The construct Environmental Uncertainty also demonstrated reasonable reliability wherein Cronbach's alpha was 0.719 while composite reliability was 0.824, and the construct's AVE of 0.540 further suggests that more than half the variance in the items is related to the construct. For the Supply Chain Risks construct, the Cronbach's alpha and composite reliability, which stood at 0.662 and 0.795, respectively, were the lowest among the other constructs but was still in the reasonable range for preliminary research. The AVE value of 0.492, which is just below the recommended 0.50 threshold, does imply weaker convergent validity but is still considered acceptable. Lastly, the construct of Logistical Security demonstrated reasonable reliability with Cronbach's

TABLE 2: Reliability and validity indicators for measurement constructs.

Variable	Construct	Loading value	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Efficiency	-	-	0.777	0.798	0.858	0.604
	Eff2	1.382	-	-	-	-
	Eff3	2.257	-	-	-	-
	Eff4	2.153	-	-	-	-
	Eff5	1.376	-	-	-	-
Envir Unce	-	-	0.719	0.736	0.824	0.540
	EnUc3	1.263	-	-	-	-
	EnUc4	1.529	-	-	-	-
	EnUc5	1.326	-	-	-	-
	EnUc7	1.399	-	-	-	-
RISKs	-	-	0.662	0.672	0.795	0.492
	RISK2	1.349	-	-	-	-
	RISK3	1.395	-	-	-	-
	RISK4	1.215	-	-	-	-
	RISK6	1.185	-	-	-	-
Security	-	-	0.643	0.659	0.808	0.585
	Sec2	1.159	-	-	-	-
	Sec4	1.351	-	-	-	-
	Sec6	1.427	-	-	-	-

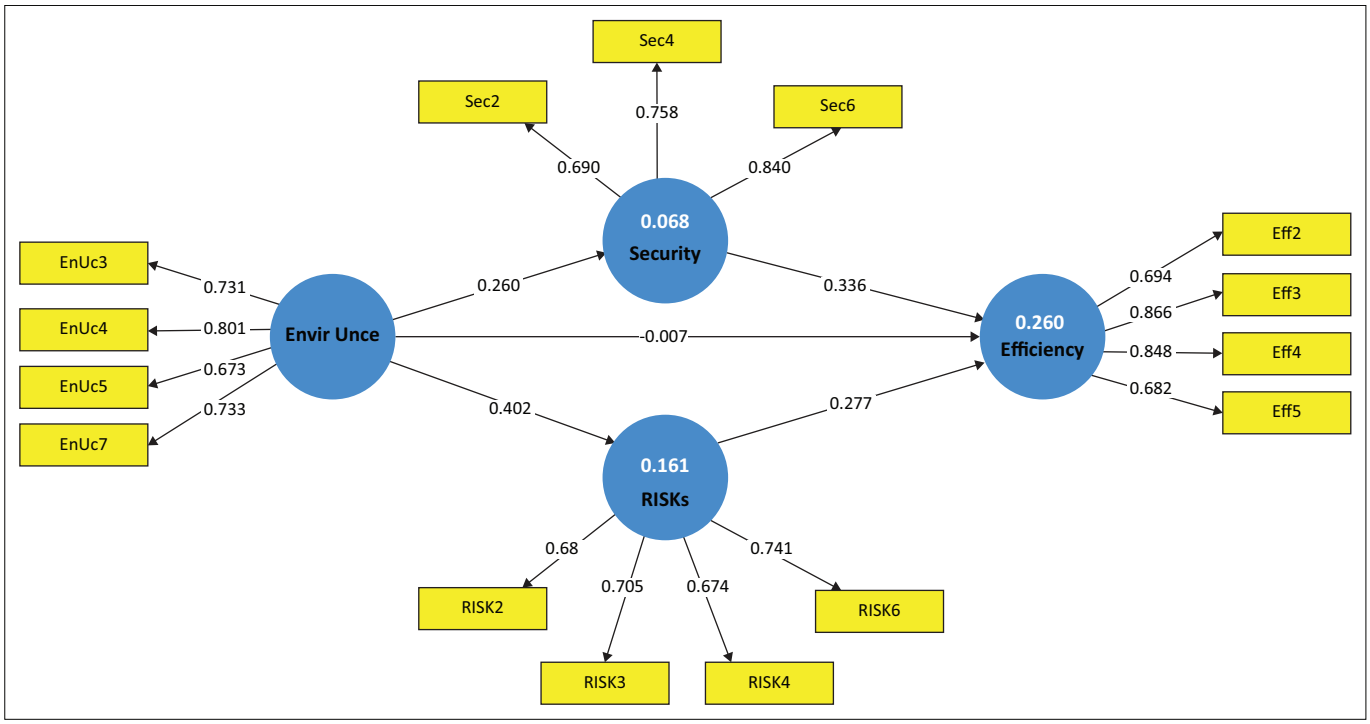


FIGURE 2: Measurement model.

alpha of 0.643 and composite reliability of 0.808. An AVE value of 0.585 indicates a reasonable level of convergent validity. In summary, the majority of the constructs exhibit adequate reliability and validity, which supports the continued evaluation of the structural model. Overall, these results confirm that the measurement model is statistically sound and suitable for further structural analysis. Despite minor limitations in the AVE of the risk construct, the overall reliability and validity indicators fall within acceptable ranges, indicating that the constructs are measured consistently and adequately capture the underlying theoretical concepts in the Sudan war context. This strengthens confidence in the robustness of the subsequent hypothesis testing and model estimation.

The HTMT ratios obtained and shown in Table 3 were used to assess the constructs in the model for the HTMT measure of discriminant validity. All of the constructs in the model were shown to meet the recommended criteria. The HTMT ratios for the constructs in the model ranged between 0.264 and 0.607, which is well below the more conservative value of 0.85, thus evidence of each construct being different from all the other constructs of the model, in being fully distinct and separate construct from each other. A value of 0.264 for the interconstruct HTMT value for 'Efficiency and Environmental Uncertainty' is an indication of being conceptually distinct and poles apart. Moderately correlated constructs, as is expected in the context of the supply chain,

TABLE 3: Discriminant validity test, heterotrait–monotrait ratio.

Variable	Efficiency	Environmental uncertainty	RISKs	Security
Efficiency	-	-	-	-
Environmental uncertainty	0.264	-	-	-
RISKs	0.552	0.560	-	-
Security	0.607	0.390	0.577	-

are 'Efficiency and Supply Chain Risks' (0.552) and 'Efficiency and Logistical Security' (0.607), which is evidence of the individual constructs for each being distinct and in being fully separate from one another. The interconstruct HTMT value of **Environmental Uncertainty and Supply Chain Risks** (0.560) is acceptable by all standards and is supportive of the construct of uncertainty in its contribution towards a risk construct, the separate constructs being fully different in their dimensions of the supply chain. The interconstruct HTMT value of **Environmental Uncertainty** (0.390) and **Logistical Security** (0.577) is interconstruct HTMT value and is supportive of the discriminant validity of the model. Overall, all HTMT findings vindicate their inclusion as unrelated latent variables in the structural model as each construct keeps its character and its own unique conceptual identity intact. In practical terms, these findings confirm that the constructs used in the study do not overlap conceptually and can be treated as independent dimensions of SCM. This is particularly important in the Sudan war context, where environmental uncertainty, risk, security and efficiency represent distinct yet interrelated challenges. The clear separation of these constructs enhances the credibility of the model and ensures that the relationships tested in the structural model are not affected by measurement redundancy or multicollinearity issues.

Findings from the structural model assessment and hypothesis evaluation

All relations postulated by the study are case relationships fit to the structural model and hypotheses testing. Results of the research are summarised in Table 4.

Within the framework of the structural model, the analysis of the direct hypotheses shows differences in significance among the relationships being studied. The Environmental Uncertainty – Efficiency path was non-significant ($\beta = -0.007$, $p = 0.943$), implying that external environmental uncertainty has no bearing on supply chain efficiency in the context of the Sudan war. This finding suggests that firms operating in conflict environments may have already internalised uncertainty as a normal condition, and therefore efficiency is maintained through adaptive operational practices rather than being directly disrupted by external instability. On the contrary, Environmental Uncertainty was found to have a large, statistically significant and positive effect on Supply Chain Risks ($\beta = 0.402$, $p < 0.001$), meaning that the higher the uncertainty, the greater the level of risks, which supply chain operations face. Practically, this indicates that increases in volatility, such as border closures, infrastructure damage or policy disruptions, translate directly into higher operational

TABLE 4: Direct hypotheses test.

Hypothesis relationship	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	p-value
Environmental uncertainty -> Efficiency	-0.007	-0.001	0.098	0.072	0.943
Environmental uncertainty -> RISKs	0.402	0.411	0.083	4.843	0.000
Environmental uncertainty -> Security	0.260	0.266	0.106	2.447	0.014
RISKs -> Efficiency	0.277	0.281	0.090	3.084	0.002
Security -> Efficiency	0.336	0.343	0.097	3.469	0.001

TABLE 5: Indirect hypotheses.

Hypothesis relationship	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	p-value
Environmental uncertainty -> Security -> Efficiency	0.087	0.089	0.041	2.117	0.034
Environmental uncertainty -> RISKs -> Efficiency	0.111	0.115	0.043	2.580	0.010

risks for firms, requiring continuous monitoring and mitigation strategies. For the relationships Environmental Uncertainty and Logistical Security, similar positive significant effect was reported ($\beta = 0.260$, $p = 0.014$), meaning that in times of uncertainty, there is a greater level of challenge related to the security of transport and logistics. This reflects the heightened need for secure transport routes, cargo protection and controlled logistics operations in war-affected regions such as Sudan. Both of the mediating constructs, Supply Chain Risks and Logistical Security had positive significant effect on Supply Chain Efficiency and these effects were sizeable, being $\beta = 0.277$ ($p = 0.002$) and $\beta = 0.336$ ($p = 0.001$), respectively. This means that, indeed, greater efficiency in supply chain is realised through positive risk management practices and enhanced logistical security. This highlights that efficiency in conflict settings is not achieved despite risk and security challenges, but rather through actively managing them as core operational priorities. In conclusion, the findings suggest that although there is environmental unpredictability, it does still not lead to the diminishing of effectiveness, but it does indirectly lead to effectiveness getting lowered as a result of the greater dangers as well as of the greater requirement for safety, emphasising the mediating role of operational weaknesses in the supply chains affected by conflict.

The mediation model contained in the indirect hypothesis (as illustrated in Table 5) shows substantial mediation effects. In this instance, the data indicate that Environmental Uncertainty has a statistically significant indirect effect on Supply Chain Efficiency via Logistical Security ($\beta = 0.087$, $p = 0.034$). This suggests that uncertainty in the external environment encourages the adoption of security measures that positively impact efficiency. This implies that firms responding to uncertainty by strengthening logistics security (e.g. route planning, cargo tracking or guarded transport) are better able to sustain operational performance. Furthermore, Environmental Uncertainty exhibits an indirect effect on Efficiency through Supply Chain Risks ($\beta = 0.111$, $p = 0.010$). This means that higher levels of

TABLE 6: *R*-square and adjusted *R*-square values for endogenous constructs.

Variable	*R*-square	*R*-square adjusted
Efficiency	0.260	0.248
RISKs	0.161	0.157
Security	0.068	0.063

uncertainty create operational risks, and the effective management of these risks results in improved efficiency in the supply chain. This finding reinforces the idea that risk management acts as a transformation mechanism, converting external instability into structured operational responses that sustain efficiency. Such results show that Environmental Uncertainty has no direct effect on Efficiency, suggesting that Environmental Uncertainty interrelates with the operational context of risk and security in conflict-ridden places such as Sudan.

Based on the *R*-square values (Table 6), the model shows that about 26.0% of the variance in Supply Chain Efficiency can be predicted from Supply Chain Risks and Logistical Security, which is understood as being within a moderate range of predictability. This is supported the adjusted *R*-square value of 0.248, which suggests valid stability of the estimate. Environmental Uncertainty, on the other hand, explains 16.1% of the variance in Supply Chain Risks (adjusted R^2 = 0.157), which indicates a steady significance of Uncertainty as a parameter to predict the levels of Risks associated in the Supply Chain. This level of explanatory power is reasonable given the highly volatile and unpredictable nature of conflict environments, where many external variables remain beyond managerial control. Last among the Environmental Uncertainty domains is the 6.8% of the variance in Logistical Security (adjusted R^2 = 0.063), which while being a weak predictability domain, sufficiently explains a significance of the relationship. This suggests that while uncertainty influences security, additional external factors such as military activity, infrastructure damage and regulatory disruptions may also play a significant role. In conclusion, the *R*-square values in the model point to there being a moderate capacity of explainability, while the presence of significant indirect effects indicates the value of indirect effects in high mediating environments to centre on as a framework in performance of the Supply chains in environments of high uncertainty and conflict.

See Table 7 to find that f^2 effect sizes show the predictive power of each construct in the model. The effect of environmental uncertainty (EUN) on efficiency (EFF) is 0.000, which shows the absence of a direct effect which is in line with the earlier observed insignificant path coefficient. This further confirms that efficiency is not directly disrupted by uncertainty but is instead shaped through intermediary mechanisms. On the other hand, EUN has a 'Medium Effect' on 'Supply Chain Risks' (f^2 = 0.192), which means that risks operationalised within the supply chain could stem from the uncertainties. This highlights risk as the primary channel through which environmental uncertainty influences supply chain dynamics. It has less direct effect on 'Logistical Security' (f^2 = 0.072), which shows a 'small but meaningful'

TABLE 7: Effect size (f^2) for predictor variables in the structural model.

Hypothesis relationships	*f*-square
Environmental uncertainty -> Efficiency	0.000
Environmental uncertainty -> RISKs	0.192
Environmental uncertainty -> Security	0.072
RISKs -> Efficiency	0.078
Security -> Efficiency	0.128

influence of Uncertainty on security risks. As for the endogenous construct of Efficiency, there is 'Supply Chain Risks (f^2 = 0.078)' and 'Logistical Security (f^2 = 0.128)' which also indicate 'small to moderate effect sizes' which suggests that each of them has a great role in inflating the supply chain performance, and Logistical Security has a greater in bearing effect to the performance than risks. This indicates that investments in logistical security may yield relatively stronger improvements in efficiency compared to risk mitigation alone in conflict settings. All in all, the *f*-square values indicate that with the absence of direct effect of Environmental uncertainty (EUN) on EFF, there is also indirect effect via the other constructs of the model. This is also positive to the overall model to be in the escalated or in conflict scenario of the supply chain in Sudan (SUD).

Discussion

This study examines the impact of the ongoing war in Sudan and the associated volatility, insecurity and operational disruptions on the interactions of supply chains in quarters that have operationalised the existing environment with closed borders or refugee crises, troubled political conditions and a war. Unexpectedly, in comparison with the results of major previous studies, while other previous studies reached to similar results (Gligor et al. 2014; Inman & Green 2021; Shen et al. 2023). The current results do not indicate that the existing environmental uncertainties have an immediate impact on the operational efficiencies of supply chains. Thus, the results indicate that the operational efficiencies of supply chains in highly unstable conditions do not self-evidently deteriorate as a result of external uncertainties. Rather, the operational adjustments in such unstable environments seem to have been taken to address the environmental uncertainties, as such adjustments appear to have been taken as the norm in operational conditions of the supply chains. The operational environments of such supply chains, in highly unstable environments, seem to integrate either or both of positive and negative buffering strategies to mitigate the impact of external uncertainty in operational conditions, as conditions have integrated the internal uncertainties. However, a positive impact has been shown to exist, and there appears to be little to no doubt that such impacts are positive in determining the operationalisations of such environments as being operationally unsustainable. What has positively impacted the operations in environmental uncertainties, self-evidently of operational activities, is that the environmental impacts on the activities have integrated positive or negative impacts. Furthermore, the uncertainties integrated have shown to impact the operational efficiencies

in logistical security, as the operational security has conditions that are operationally unstable and the conditions have shown to impact the operational inefficiencies in combat conditions.

The results proved that environmental uncertainty positively affects supply chain risks.

The key driver of the positive relationship between environmental uncertainty and supply chain risk is its effect on operational stability via market volatility. Market volatility is defined as rapid and chaotic changes in demand and supply in the marketplace. In periods of volatility, firms are faced with systematic, fundamental mismatches between their operational capacity and what the marketplace demands (Lu et al. 2018). Specifically, the research literature indicates that as environmental uncertainty increases, the reliability of demand forecasting declines. This not only places a higher risk of stockouts, but excessive inventory (Hançerlioğulları, Şen & Aktunç 2016). In either case, however, this creates operational risk and ultimately results in financial loss and poor organisational performance. Environmental uncertainty also increases the frequency and severity of so-called disruptive risks – high impact, low probability events that halt the flow of the supply chain. In a volatile environment, the 'triggering events' of damaging disruptions, such as port closures, labour strikes and natural hazards, become more frequent and unsure. The results proved that environmental uncertainty positively affects supply chain security. This result is consistent with what some previous studies have shown, as study (Shen et al. 2023) proved that Environmental uncertainty positively affects supply chain security through enhanced resilience and performance. In the Sudanese context, war and instability persist, with insecurity and uncertainty dominating the business climate. Companies operating in unstable Sudan work under the pressure of insecurity risks, demonstrating that the environmental uncertainty resulting from war impacts the perception of error (Hamid & Eshag 2025).

Geopolitical instability and sovereign risk are widely acknowledged as critical macro-environmental factors that influence supply chain performance and organisational decision-making.

Trade wars, tariff shocks and regional conflicts cause dramatic shifts in supply chains, and the accessibility of raw materials (Ivanov 2022). For instance, oil prices fluctuate accepting that value, in terms of either price or availability, impacts supply chain costs and sentiments sometimes without a sense of how it occurs to consumers using the products (Li et al. 2024).

Macroeconomic factors influence every firm regardless of the number of resources each firm possesses.

The relationship between supply chain security and efficiency is similarly synergistic. Rather than impeding operational agility, modern security protocols and certifications offer measurable efficiency gains through improved risk management, process standardization, and enhanced supply chain coordination. These security measures commonly lead to the increased process control, as well as inspection times at border check-points and reliable transit schedules, which, in total, adds to the overall performance of any supply-chain (Urciuoli & Ekwall 2015). Empirical inquiry proves that security-certified companies are regularly able to achieve better operations in comparison to their non-certified colleagues, especially in the complex upstream supply chains where visibility is key (Pero & Sudy 2014). By ensuring that security is a strategic imperative for an organisation, organisations not only protect assets against both intentional and inadvertent threats but also create a more disciplined and transparent operating environment that inherently ensures sustainable levels of efficiency (Tong et al. 2022). Notably, the supply chain risks as well as the logistic security exert a positive influence in respect to the supply chain efficiency. At first glance this may seem counterintuitive, as at least conventionally risks and security issues have been thought to hinder effective performance. Conversely, the positive observed correlations indicate that to the extent risks and security issues intensify, organisations may have responded by improving internal processes and risk mitigation strategies and improving the efficiency of coordination. A similar phenomenon is observed in conflict settings, where companies are forced to develop solid and creative strategies to survive and operationalise many different workflows. The indirect effects give plausibility to this argument. Environmental uncertainty leads to increased efficiency of supply chains through a paradoxical link between supply chain risks and security of the logistics chain. Such uncertainty does seem to activate the imperative for risk and security management processes, and when applied well to deliver better supply chain performance. These mechanisms therefore highlight the ability of an organisation to adapt and survive during turbulent times. The *R*-square values point towards a moderate explanatory power of the model in accounting for 26% of the variance in efficiency and 16% in variance of supply chain risks. Although these values are not particularly high, they are reasonable in applied settings given the instability of most conflict settings and the large number of variables outside of theoretical control. The f-square values suggest that the contextual uncertainty has a significant role in shaping both risks and security, but has negligible direct effect on efficiency. The findings of this study suggest a certain degree of complexity in the relationships of uncertainty and risks, and security, and performance, largely resulting from flexibility of supply chain actors within the conflict.

Conclusion

The current investigation determined that during the Sudan war, there is a relational connection between environmental uncertainty, supply chain risks and logistical insecurity, despite the fact that environmental uncertainty does not have a direct impact on supply chain efficiency. These three variables, although, do have direct positive effects on supply

chain efficiency and demonstrates that enterprises operating in wartime rely on the operational security and risk management layers to sustain their supply chain performance. The results in question show that in order to reach a particular level of efficiency, organisations do not have to deal with uncertainty directly, but rather deal with the consequences of that uncertainty. The results are a positive contribution to the supply chain theory. In addition, the results show that efficiency is war-affected supply chains is a function of operational preparedness and risk and security management are the variables of interest and not the absence of external stability. The results of the current investigation create a foundation for future studies of the humanitarian supply chain, the crisis supply chain, and resilience in fragile systems.

Practical implications

Several recommendations have been proposed to improve supply chain efficiency in conflict-affected environments such as Sudan, among these is the development and implementation of comprehensive risk tracking and assessment systems to identify, monitor, and mitigate potential disruptions. For predictively dealing with the uncertainty posed by the environment, systems should be developed with real time event monitoring, scenario planning and environmental scanning. Logistical security is also an area where improvements are needed, especially with the implementation of controlled documents, security routing of transport and tracking of vehicles, goods and personnel security. To support the continuity of the organisation during disruptions, resilient structures should be put in place, including flexible sourcing and sustaining strategic inventory, operational decentralisation and pre-defined emergency response protocols. Building staff preparedness in these areas should be a priority: risk management, crises communication and rapid decision making. The imperative to fortify the collaboration of actors in the supply chain – private enterprises, humanitarian agencies, public authorities cannot be overemphasised if we are to have a robust and responsive system of data exchange, coordination of transport and security. In modern literature, the effectiveness of such collaboration is very much dependent on such mutual protocols, trust and a common governance system breaking down strict sectoral boundaries. Additionally, managers should prioritise supplier diversification to reduce dependency on single sourcing regions, invest in digital supply chain visibility tools (e.g. real-time tracking systems) and establish contingency contracts with alternative logistics providers to ensure operational continuity during disruptions. Managers are also encouraged to implement decentralised warehousing strategies in safer regions to minimise the risks associated with centralised distribution systems in conflict zones. In terms of policy, the improvement of road infrastructure, the creation of safe transport corridors, a decrease in bureaucratic delays, digitalisation of supply chain processes and provision of exhaustive humanitarian support emerge as important levers both for government and humanitarian actors. The promise of these interventions delivered synergistically is that they will increase the overall resilience and adaptability of the supply chain ecosystem. Furthermore, policymakers should develop crisis-responsive trade policies (e.g. temporary tariff reductions on essential goods), establish public and private coordination platforms for supply chain crisis management, and invest in secure logistics hubs to facilitate uninterrupted movement of critical supplies. Strengthening regulatory frameworks for emergency logistics and incentivising private sector participation in resilient infrastructure development are also recommended. Directors should adopt a risk-based method to supply chain strategy by inserting risk management into core decision-making procedures. This includes the use of performance system of measurement, pressure testing, resilience-focused and situation planning, to better anticipate and respond to disruptions.

Theoretical implications

The analysis discussed in this study outlines a number of important theoretical implications to contribute to the contemporary understanding of how supply chain dynamics are influenced in volatile environments. The study's results also support RDT by showing that firms operating under high environmental uncertainty in Sudan adapt their supply chain processes to manage dependencies on scarce or volatile resources. This aligns with RDT's premise that resource scarcity and uncertainty drive strategic responses to maintain operational performance (Pfeffer & Salancik 1978; Reitz 2007). First of all, the investigation goes further by attempting to apply contingency theory to this area by showing that the security posture and risk management framework of a firm are not static but need to be dynamically adjusted relative to the character and intensity of environmental turbulence. By demonstrating the importance of high-uncertainty environments requiring stronger security protocols in order to maintain the organisational integrity of things, the study is able to support the 'fit' between external complexity and internal defense mechanisms, thus challenging the traditional conception of security as a secondary concern in operation management and establishing it as a primary prerequisite for organisational survival in conditions of radical ambiguity. In the same context, the authors enriched the literature by placing the mediation-based frameworks in supply chain research. Additionally, the result shifts the theoretical focus from 'fit with the environment' to 'capability in managing environmental disruptions'. Whereas the findings extended the theory of contingency by representing that in risky environments such as war contexts, organisational performance is not exclusively depending on external environmental factors, but rather on the organisation's ability to manage the consequences of those factors Furthermore, the study demonstrates principles of Real Options Theory. The operational adjustments and flexible risk/security management strategies observed in Sudanese supply chains reflect managerial flexibility under uncertainty, where firms treat

investments in security, risk mitigation and logistics adjustments as 'options' to be exercised when additional information or stability emerges. This aligns with the theory's emphasis on the value of preserving flexibility under uncertain conditions (Dixit & Pindyck 1994; Myers 1977). While supply chain risk management (SCRM) is often thought of as a defensive or cost intensive function, modern scholarship highlights an important positive link between effective SCRM practices and supply chain efficiency. Effective risk management helps firms to identify potential bottlenecks and mitigate them before they evolve into disruption projects to ensure a smooth flow of goods and information. Empirical evidence exists to show the direct effect of SCRM capabilities in improving operational performance by promoting better resource deployment and organisational stability. Finally, the study contributes to the emerging body of knowledge on supply chains in conflict-affected, breakable and high-risk settings, as most of the existing studies are based on steady or mostly uncertain environments, so by conducting the analysis within the Sudan war context it expands the geographical and appropriate scope of supply chain theory where uncertainty is persistent and systemic rather than temporary (Ivanov & Dolgui 2021; Queiroz et al. 2022).

Limitation and direction for future research

As with all research studies, this study has certain limitations. The cross-sectional nature of the data provides a cross section of the climate at the time but does not provide insight into longitudinal dynamics. Future investigations should more rigorously outline the development of supply chain risk and security strategies in the context of the Sudan. Comparative analyses between Sudan and other unstable jurisdictions would further define regional variations in supply chain risk and security. Future studies should include more factors in the supply chain, such as flexibility, digital transformation, etc., to implement cross conflict site comparative research, and more temporal dimension for the supply chain variables to be quantified in complex environments, and more accurate research results can be obtained.

Acknowledgements

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Abdelsalam A. Hamid: Conceptualisation; Formal analysis; Methodology; Software; Writing – original draft. Nancy George: Conceptualisation Data curation; Investigation; Project administration; Writing – original draft. Adam Y.A. Hamad: Investigation; Resources; Writing – original draft; Writing – review & editing. Muhammad Shafiq: Conceptualisation; Validation; Writing – review & editing. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

Funding information

The authors received no financial support for the research, authorship, and/or publication of this article.

Data availability

The data that support the findings of this study are available on request from the corresponding author, Abdelsalam A. Hamid.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. They do not necessarily reflect the official policy or position of any affiliated institution, funder, agency or that of the publisher. The authors are responsible for this article's results, findings and content.

References

AL-Shboul, M.A., 2023, 'Enabling manufacturing firms' supply chain performance in the Middle East region through boosting the quality of multi-directional relationship, and supply chain risk dilution: A moderated-mediation model', *Heliyon* 9, e22059. https://doi.org/10.1016/j.heliyon.2023.e22059

Annesi, N., Battaglia, M., Ceglia, I. & Mercuri, F., 2025, 'Navigating paradoxes: Building a sustainable strategy for an integrated ESG corporate governance', *Management Decision* 63(3), 531–559. https://doi.org/10.1108/MD-10-2023-2006

Awashreh, R., Hamid, A., Mohamed, B.E. & Farsi, H.A., 2024, 'The impact of logistics management on logistics service performance: A study on maritime transportation services in Oman', *Uncertain Supply Chain Management* 12(4), 2113–2122. https://doi.org/10.5267/j.uscm.2024.7.004

Behzadi, G., O'Sullivan, M.J., Olsen, T.L. & Zhang, A., 2018, 'Agribusiness supply chain risk management: A review of quantitative decision models', *Omega* 79, 21–42. https://doi.org/10.1016/j.omega.2017.07.005

Belhadi, A., Kamble, S., Jabbour, C.J.C., Gunasekaran, A., Ndubisi, N.O. & Mani, V., 2021, 'Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries', *Technological Forecasting and Social Change* 163, 120447. https://doi.org/10.1016/j.techfore.2020.120447

Burns, T. & Stalker, G.M., 1994, *The management of innovation*, Oxform University presss, London. https://doi.org/10.1093/acprof:oso/9780198288787.001.0001

Busse, C., Duensing, S. & Schleper, M.C., 2026, 'Supply chain (as) risk: A unifying typology', *International Journal of Operations & Production Management* 46(13), 63–94. https://doi.org/10.1108/IJOPM-09-2025-0915

Chang, C.H., Xu, J., Dong, J.X. & Yang, Z., 2019, 'Selection of effective risk mitigation strategies in container shipping operations', *Maritime Business Review* 4(4), 413–431. https://doi.org/10.1108/MABR-10-2019-0043

Crosignani, M., Macchiavelli, M. & Silva, A.F., 2023, 'Pirates without borders: The propagation of cyberattacks through firms' supply chains', *Journal of Financial Economics* 147(2), 432–448. https://doi.org/10.1016/j.jfineco.2022.10.002

Dixit, A.K. & Pindyck, R.S., 1994, Investment under uncertainty, Princeton University Press, Princeton, NJ

Elamin, N.E., 2025, 'Analysing the impact of the Sudan armed conflict (2023) on export and import dynamics', *South African Journal of International Affairs* 32(3), 305–327. https://doi.org/10.1080/10220461.2025.2550609

Elnourani, M., Elhag, H.S.H., Alasad, W.I. & Bashier, M.N., 2024, 'Khartoum War's echoes in oil and energy sectors: Economic and environmental implications for Sudan and South Sudan', *Heliyon* 10(15), e34739. https://doi.org/10.1016/j.heliyon.2024.e34739

Fan, Y. & Stevenson, M., 2018, 'A review of supply chain risk management: Definition, theory, and research agenda', *International Journal of Physical Distribution & Logistics Management* 48(3), 205–230. https://doi.org/10.1108/ijpdlm-01-2017-0043

Gligor, D., Esmark, C.L. & Holcomb, M., 2014, 'Performance outcomes of supply chain agility: When should you be agile?', *Journal of Operations Management* 33–34(1), 71–82. https://doi.org/10.1016/j.jom.2014.10.008

Gligor, D., Holcomb, M., Maloni, M.J. & Davis-Sramek, E., 2019, 'Achieving financial performance in uncertain times: Leveraging supply chain agility', *Transportation Journal* 58(4), 247–279. https://doi.org/10.5325/transportationj.58.4.0247

Gonz´alez-Zapatero, C., Gonz´alez-Benito, J., Byung-Gak, S. & Lannelongue, G., 2024, 'Is supply chain risk mitigation affected by organisational design? The roles of organic structures and cultures', *European Research on Management and Business Economic*s 30, 100248, https://doi.org/10.1016/j.iedeen.2024.100248

Hamid, A.A. & Eshag, E.A.E., 2025, 'Does green purchasing mediate the relationship between smart supply chain and green performance of pharmaceutical companies in Sudan: Implications for underdevelopment countries', *International Journal of Productivity and Performance Management* 74(9), 3103–3130. https://doi.org/10.1108/IJPPM-10-2024-0703

Hamid, A.A., Eshag, E.A.E., Alemu, A.E. & Yuruyen, U.M., 2022, 'The effects of transaction attributes on logistics performance: Empirical study on Sudanese food and beverage companies', *International Journal of Supply and Operations Management* 9(3), 264–280.

Hamid, A.A., Eshag, E.A.E., Karim, N.H. & Abdul Rahman, N.S.F., 2025, 'Investigating the mediating effect of logistics capabilities on the relationship between logistics information sharing and logistics performance', *International Journal of Productivity and Performance Management* 74(5), 1564–1588. https://doi.org/10.1108/IJPPM-05-2024-0284

Hançerlioğulları, G., Şen, A. & Aktunç, E.A., 2016, 'Demand uncertainty and inventory turnover performance: An empirical analysis of the US retail industry', *International Journal of Physical Distribution & Logistics Management* 46(6/7), 681–708. https://doi.org/10.1108/IJPDLM-12-2014-0303

Hansohm, D., 2025, 'Trade for peace in South Sudan', in World Trade Organization (ed.), *Trade for peace programme: Pathways to ustainable trade and peace*, pp. 163–174, World Trade Organization. https://doi.org/10.30875/9789287054135

Haque, S., Akbar, D., Kinnear, S. & Rahman, A., 2025, 'A scoping review of export supply chain efficiency frameworks for perishable horticultural products', *Supply Chain Analytics* 10, 100112. https://doi.org/10.1016/j.sca.2025.100112

Heidari, M.R. & Heravi, G., 2024, 'Development of flexible supportive policy with real options for renewable energy projects: Case of photovoltaic system', *Renewable Energy* 225, 120326. https://doi.org/10.1016/j.renene.2023.120326

Ho, W., Tian, Z., Yildiz, H. & Talluri, S., 2015, 'Supply chain risk management: A literature review', *International Journal of Production Research* 53(16), 5031–5069. https://doi.org/10.1080/00207543.2015.1030467

Hsieh, C.C., Chen, S.L. & Huang, C.C., 2023, 'Investigating the role of supply chain environmental risk in shaping the nexus of supply chain agility, resilience, and performance', *Sustainability* 15(20), 15003. https://doi.org/10.3390/su152015003

Huang, L., Zhen, L., Wang, J. & Zhang, X., 2022a, 'Blockchain implementation for circular supply chain management: Evaluating critical success factors', *Industrial Marketing Management* 102, 451–464. https://doi.org/10.1016/j.indmarman.2022.01.010

Huang, Z., Shao, W., Meng, L., Zhang, G. & Qiang, Q. (Patrick), 2022b, 'Pricing decision for a closed-loop supply chain with technology licensing under collection and remanufacturing cost disruptions', *Sustainability* 14(6), 3354. https://doi.org/10.3390/su14063354

Hussain, S., Ali, R., Emam, W., Tashkandy, Y., Mishra, P., Fahlevi, M. et al., 2023, 'Economic policy uncertainty and firm value: Impact of investment sentiments in energy and petroleum', *Sustainability* 15(12), 9656. https://doi.org/10.3390/su15129656

Inman, R.A. & Green, K.W., 2021, 'Environmental uncertainty and supply chain performance: The effect of agility', *Journal of Manufacturing Technology Management* 33(2), 239–258. https://doi.org/10.1108/jmtm-03-2021-0097

Ivanov, D. & Dolgui, A., 2021, 'OR-methods for coping with the ripple effect in supply chains during COVID-19 pandemic: Managerial insights and research implications', *International Journal of Production Economics* 232, 107921. https://doi.org/10.1016/j.ijpe.2020.107921

Ivanov, D., 2022, 'Viable supply chain model: Integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic', *Annals of operations research* 319(1), 1411–1431. https://doi.org/10.1007/s10479-020-03640-6

Jain, P. & Mishar, N.K., 2024, 'Enhancing supply chain efficiency with blockchain: Addressing information sensitivity for increased manufacturer profitability', *IFAC PapersOnLine* 58(19), 688–693. https://doi.org/10.1016/j.ifacol.2024.09.220

Jajja, M.S.S., Chatha, K.A., & Farooq, S., 2018, 'Impact of supply chain risk on agility performance: Mediating role of supply chain integration', *International Journal of Production Economics* 205, 118–138. https://doi.org/10.1016/j.ijpe.2018.08.032

Jiyao, C., Reilly, R.R. & Lynn, G.S., 2005, 'The impacts of speed-to-market on new product success: The moderating effects of uncertainty', *IEEE Transactions on Engineering Management* 52(2), 199–212. https://doi.org/10.1109/TEM.2005.844926

Kamar, M.A., Albadry, O.M., Sheikhelsouk, S., Al-Abyadh, M.H.A. & Alsetoohy, O., 2023, 'Dynamic capabilities influence on the operational performance of hotel food supply chains: A mediation-moderation model', *Sustainability* 15(18), 13562. https://doi.org/10.3390/su151813562

Katsaliaki, K., Kumar, S. & Loulos, V., 2024, 'Supply chain coopetition: A review of structures, mechanisms and dynamics', *International Journal of Production Economics* 267, Article 109935. https://doi.org/10.1016/j.ijpe.2023.109057

Kessler, S.R., Nixon, A.E. & Nord, W.R., 2017, 'Examining organic and mechanistic structures: Do we know as much as we thought?', *International Journal of Management Reviews* 19(4), 531–555. https://doi.org/10.1111/ijmr.12109

Lawrence, P.R., & Lorsch, J.W., 1967, *Organization and environment: Managing differentiation and integration*, Division of Research, Graduate School of Business Administration, Harvard University, Boston MA.

Lee, K., Kim, J., Kwon, J. & Yeo, J., 2024, 'Maritime supply chain risk sentiment and the Korea trade volume: A news big-data analysis perspective', *The Asian Journal of Shipping and Logistics* 40, 42–51. https://doi.org/10.1016/j.ajsl.2024.01.001

Li, Z., Zhao, Q., Guo, H. & Huang, R., 2024, 'Impact of fossil fuel subsidies on energy-saving technological change in China', *Energy* 286, 129265. https://doi.org/10.1016/j.energy.2023.129265

Lu, D., Ding, Y., Asian, S. & Paul, S.K., 2018, 'From supply chain integration to operational performance: The moderating effect of market uncertainty', *Global Journal of Flexible Systems Management* 19(Suppl 1), 3–20. https://doi.org/10.1007/s40171-017-0161-9

Manhart, P., Summers, J.K. & Blackhurst, J., 2020, 'A meta-analytic review of supply chain risk management: Assessing buffering and bridging strategies and firm performance', *Journal of Supply Chain Management* 56(3), 66–87. https://doi.org/10.1111/jscm.12230

Meena, A., Dhir, S. & Sushil, S., 2023, 'A review of coopetition and future research agenda', *Journal of Business & Industrial Marketing* 38(1), 118–136. https://doi.org/10.1108/JBIM-09-2021-0443

Mwesiumo, D., Nujen, B.B. & Buvik, A., 2021, 'Driving collaborative supply risk mitigation in buyer-supplier relationships', *Supply Chain Forum: An International Journal* 22(4), 347–359. https://doi.org/10.1080/16258312.2021.1932567

Myers, S.C., 1977, 'Determinants of corporate borrowing', *Journal of Financial Economics* 5(2), 147–175. https://doi.org/10.1016/0304-405X(77)90015-0

Negi, S., 2021, 'Supply chain efficiency framework to improve business performance in a competitive era', *Management Research Review* 44(3), 477–508. https://doi.org/10.1108/MRR-05-2020-0272

Negi, S. & Anand, N., 2019, 'Wholesalers' perspectives on mango supply chain efficiency in India', *Journal of Agribusiness in Developing and Emerging Economies* 9(2), 175–200. https://doi.org/10.1108/JADEE-02-2018-0032

Oriani, R. & Sobrero, M., 2008, 'Uncertainty and the market valuation of R&D within a real options logic', *Strategic Management Journal* 29(3), 343–361. https://doi.org/10.1002/smj.657

Pero, M. & Sudy, I., 2014, 'Increasing security and efficiency in supply chains: A five-step approach', *International Journal of Shipping and Transport Logistics* 6(3), 257. https://doi.org/10.1504/ijstl.2014.060785

Pfeffer, J. & Salancik, G.R., 1978, *The external control of organizations: A resource dependence perspective*, Harper & Row, New York, NY.

Queiroz, M.M., Ivanov, D., Dolgui, A. & Wamba, S.F., 2022, 'Impacts of epidemic outbreaks on supply chains: Mapping a research agenda amid the COVID-19 pandemic through a structured literature review', *Annals of Operations Research* 319, 1159–1196. https://doi.org/10.1007/s10479-020-03685-7

Reitz, J.G., 2007, 'Immigrant employment success in Canada, Part I: Individual and contextual causes', *Journal of International Migration and Integration* 8, 11–36. https://doi.org/10.1007/s12134-007-0001-4

Sato, Y., Tse, Y.K. & Tan, K.H., 2020, 'Managers' risk perception of supply chain uncertainties', *Industrial Management & Data Systems* 120(9), 1617–1634. https://doi.org/10.1108/imds-01-2020-0049

Seepana, C., Paulraj, A. & Datar, A., 2025, 'Environmental uncertainties and reciprocal investments within coopetition: The contingent role of appropriability mechanisms', *International Journal of Production Economics* 290, 109811. https://doi.org/10.1016/j.ijpe.2025.109811

Shafiq, M. & Soratana, K., 2019a, 'Humanitarian logistics and supply chain management – A qualitative study', *LogForum* 15(1), 19–38.

Shafiq, M. & Soratana, K., 2019b, 'Lean and Agile paradigms in humanitarian organizations' logistics and supply chain management', *LogForum* 15(1), 139–153. https://doi.org/10.17270/J.LOG.2019.294

Shafiq, M. & Soratana, K., 2020, 'Lean readiness assessment model – A tool for Humanitarian Organizations' social and economic sustainability', *Journal of Humanitarian Logistics and Supply Chain Management* 10(2), 77–99. https://doi.org/10.1108/JHLSCM-01-2019-0002

Shafique, M., Shafiq, M. & Saleem, H.M.N., 2025, 'Role of climate change mitigation strategies in responsive green humanitarian supply chains', *NUST Business Review* 7(2), 181–204. https://doi.org/10.37435/nbr.v7i2.135

Shen, X., Xu, Q., Liu, Q. & Leibercht, M., 2023, 'The relationship between supply chain resilience, supply chain integration, and supply chain performance: A MASEM analysis', *Journal of Intelligent & Fuzzy Systems: Applications in Engineering and Technology* 45(2), 3361–3377. https://doi.org/10.3233/jifs-220649

Silvestri, C., Silvestri, L., Piccarozzi, M. & Ruggieri, A., 2024, 'Toward a framework for selecting indicators of measuring sustainability and circular economy in the agri-food sector: A systematic literature review', *International Journal of Life Cycle Assessment* 29(8), 1446–1484. https://doi.org/10.1007/s11367-022-02032-1

Suryawanshi, P. & Dutta, P., 2023, 'Distribution planning problem of a supply chain of perishable products under disruptions and demand stochasticity', *International Journal of Productivity and Performance Management* 72(1), 246–278. https://doi.org/10.1108/IJPPM-12-2020-0674

Tang, C.-H., Liu, H.-C., Lee, Y.-H. & Hsu, Y.-T., 2024, 'ESG risk, economic policy uncertainty, and the downside risk: Evidence from US firms', *The North American Journal of Economics and Finance* 75, 102293. https://doi.org/10.1016/j.najef.2023.102293

Thompson, J.D., 1967, *Organizations in action: Social science bases of administrative theory*, McGraw-Hill, New York, NY.

Tong, X., Lai, K., Lo, C.K. & Cheng, T., 2022, 'Supply chain security certification and operational performance: The role of upstream complexity', *International Journal of Production Economics* 247, 108433. https://doi.org/10.1016/j.ijpe.2022.108433

United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2025, Sudan: Humanitarian Needs and Response Plan 2025 - Overview, viewed 07 November 2025, from https://www.unocha.org/publications/report/sudan/sudan-humanitarian-needs-and-response-plan-2025-overview.

Urciuoli, L. & Ekwall, D., 2015, 'The perceived impacts of AEO security certifications on supply chain efficiency – A survey study using structural equation modelling', *International Journal of Shipping and Transport Logistics* 7(1), 1. https://doi.org/10.1504/ijstl.2015.065886

Vilko, J., Ritala, P. & Edelmann, J., 2014, 'On uncertainty in supply chain risk management', *The International Journal of Logistics Management* 25(1), 3–19. https://doi.org/10.1108/IJLM-10-2012-0126

Wang, W., Huang, H. & Fu, X., 2025, 'Does regional AI development improve corporate supply chain efficiency? Evidence from China', *International Review of Economics and Finance* 103, 104597. https://doi.org/10.1016/j.iref.2025.104597

Woodhead, A. & Cotter, J., 2017, *Murray darling basin regional economic diversification program: Horticultural supply chain and exports*, University of Southern Queensland, Queensland government publication, Queensland.

World Bank Group, 2024, *Economy: Sudan Data360,* viewed n.d., from https://data360.worldbank.org/en/economy/SDN.

World Food Programme (WFP), 2025, *Situation report Sudan regional crisis*, viewed 30 December 2025, from https://www.wfp.org/publications/sudan-crisis.

World Health Organization (WHO), 2024, *Sudan situation report,* viewed 10 January 2026, from https://www.emro.who.int/images/stories/sudan/situation-report-october-2024.pdf.

World Trade Organization (WTO), 2023, *Panel explores role of trade in addressing global fragility and conflict*, viewed 30 December 2025, from https://www.wto.org/english/news_e/news23_e/tfp_20jul23_e.htm.

Wu, D., 2024, 'Text-based measure of supply chain risk exposure', *Management Science* 70(7), 4781–4801. https://doi.org/10.1287/mnsc.2023.4927

Zhao, X., Li, Z. & Liu, J., 2024, 'Optimal timing of phasing out producer subsidies towards carbon neutrality: Interaction between fossil energy extraction and environmental uncertainties', *Energy Strategy Reviews* 56, 101598. https://doi.org/10.1016/j.esr.2024.101598

Zheng, L.J., Islam, N., Zhang, J.Z., Behl, A., Wang, X. & Papadopoulos, T., 2025, 'Aligning risk and value creation: A process model of supply chain risk management in geopolitical disruptions', *International Journal of Operations & Production Management* 45(5), 1178–1210. https://doi.org/10.1108/IJOPM-03-2024-0271

Zhu, X., Zhu, J., Regan, D. & Wen, Z., 2026, 'Exploring cascading failures in supply chain risk management: A systematic review, 2013–2024', *Journal of Safety Science and Resilience* 7(2), 100234. https://doi.org/10.1016/j.jnlssr.2025.100234

Zhu, Z., Huang, L., & Huang, W., 2025, 'Managers' perception of supply chain risk and total factor productivity of enterprises: Opportunity-seeking or loss-aversive?', *International Journal of Production Economics* 294, 109822. https://doi.org/10.1016/j.ijpe.2025.109822