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ENHANCING ENVIRONMENTAL SUSTAINABILITY IN ASIAN TEXTILE SUPPLY CHAINS: INSIGHTS FROM AGILE PRACTICES AND MEDIATING VARIABLES

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Abstract. The objective of this research is to investigates how responsive systems and analytics, end-to-end collaboration, demand management and forecasting, design for agility, resilience and risk management, and process ownership affect agile supply chains, and enhancing environmental sustainability. This research also examines the impact of agile supply chains on supply chain resilience and environmental sustainability. This research further considers the mediations of real-time information and operational agility on the association between exogenous and endogenous constructs. The study used a structured questionnaire to collect responses from the textile sectors of Asian economies, including China, Pakistan, India, Bangladesh, and Vietnam. The study's findings indicate a positive and significant influence of independent variables on the agile supply chain, boosting supply chain resilience and enhancing environmental sustainability. The mediating variables, such as real-time information and operational agility, demonstrated the multiple serial mediations between exogenous and endogenous variables. The findings of the study have wider practical and theoretical implications. With informed decisions, organizations can use findings to enhance resilience and environmental sustainability in agile supply chain practices. Future researchers may replicate their studies using the modified conceptual framework in different industries and regions.

Keywords: environmental sustainability, agile supply chain, supply chain resilience, real-time information, operational agility, resilience and risk management, responsive systems and analytics.

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1. Introduction

According to the works of Ahmed and Huma (2021), the notion of an agile supply chain evolved to help organizations swiftly adjust to market shifts, customer needs and enhance environmental sustainability. A focus on flexibility, responsiveness, and collaboration characterizes the environmental sustainability in agile supply chain practices. According to Ahmed and Huma (2021), and Piya et al. (2020), it has made it possible for businesses to react fast to shifts in customer demand, technological advancements, and other environmental and operational issues. Agile supply chain (ASC) stresses iterative progress, collaborative project management, and continuous delivery systems (Oliveira-Dias et al., 2023). Environmentally friendly organizations form the ASC to rapidly identify and respond to shifts in supply chain management, including demand and supply changes (Abdelilah et al., 2023; Fayezi et al., 2017). As it helps businesses to recover from interruptions and retain their core activities swiftly, resilience is a critical component of the ASC (Kazancoglu et al., 2022; Han et al., 2020). Organizations must promptly detect, address, and adapt operations to disruptions and shifting circumstances to achieve resilience. In today's globalized and linked corporate world, where disruptions can swiftly spread throughout whole supply chains and harm many stakeholders, the agile supply chain and its resilience have become increasingly crucial for operation and environment (Shahed et al., 2021; Fadaki et al., 2020). According to Han et al. (2020) and Nguyen et al. (2018), adaptable, resilient supply chains enhance organizational performance during rapid, uncertain business settings.

The study analyzes multiple aspects influencing environmental sustainability in agile supply chains, for instance, responsive systems and analytics, end-to-end collaboration, demand management and forecasting, green design for agility, resilience and risk management, and process ownership. The study also examines how an agile supply chain affects the supply chain's resilience and environmental sustainability. This study also intends to investigate how real-time data and operational agility can mediate the link between exogenous and endogenous variables. To gather information from the textile industry throughout South Asian economies, the study used a standardized and modified questionnaire. Organizations can improve their resilience and agile supply chain standards by understanding these relationships (Ahmed & Huma, 2021; Piya et al., 2020). This research examines the dimensions of an agile supply chain, for instance, responsive systems and analytics, end-to-end collaboration, demand management and forecasting, design for agility, resilience and risk management, process ownership, and how they influence the environmental sustainability in ASC. Moreover, how ASC influences the supply chain's resilience, this research further analyzes the mediations of real-time information and operational agility between exogenous and endogenous variables.

The research adds to current knowledge by assessing how various factors affect environmental sustainability in agile supply chains and resilience (Shahed et al., 2021; Fadaki et al., 2020). The research explores the effects of responsive systems and analytics, end-to-end collaboration, demand management, and forecasting, green design for agility, resilience and risk management, and process ownership on environmental sustainability in agile supply chains. It also evaluates how agile supply chains influence resilience and explores the mediating role of real-time data and operational agility in linking external and internal factors. The study offers practical significance for the South Asian textile sector and understanding the impact of various factors on environmental sustainability in supply chain agility and resilience for informed decision-making (Kazancoglu et al., 2022; Han et al., 2020). Moreover, the study provides a theoretical framework that can guide future researchers in managing resilience in the environmental sustainability in agile supply chain. Empirical findings aid policymakers in developing nations to create policies fostering agile, resilient supply chain growth (Ahmed & Huma, 2021; Piya et al., 2020).

The study adds to existing literature on supply chain management in several areas. Responsive systems and analytics, end-to-end collaboration, demand management, forecasting, green agility design, resilience and risk management, and process ownership influence environmental sustainability in ASC (Oliveira-Dias et al., 2023). It also examines how agile supply chains affect supply chain resilience, significantly impacting controlling risks and disruptions. Thirdly, the outcomes illustrate the mediating influence of operational agility and real-time information in the link between exogenous and endogenous variables, offering insights into how these variables impact supply chain performance. Fourthly, conducting the study from the perspective of the textile industry in various South Asian economies to understand the ASC and SCR processes used in chosen economies. Consequently, the research outcomes furnish valuable insights to scholars and industry experts in agile supply chain management. According to Abdelilah et al. (2023) and Fayezi et al. (2017), this enhances environmental sustainability, adaptability and resilience against unexpected disruptions. The results aid decisions and improvise tactics and plans to enhance global supply chain performance, environmental sustainability, and competitiveness (Ahmad et al., 2023; Ahmed & Huma, 2021).

The remainder of the paper consists on previous literature and hypotheses development as Section 2, however, Section 3 contains on materials and methods. The Section 4 comprises on findings and data analyses, Section 5 discoursed the discussions on the results, finally Section 6 contains on conclusions and implications of the paper.

2. Previous literature and hypotheses development

Two theories explain the agile supply chain and its resilience, such as resource-based theory (Nayak et al., 2023) and resilience engineering theory (Sadeghi et al., 2023). This research has integrated these two theories to explain and construct the study's conceptual framework.

The organization's competitive advantage comes from its resources and competencies (Wright et al., 2001). The resource-based view (RBV) theory demonstrates that tangible assets, for instance, financial, human, and physical assets, can characterize an organization's capital). Similarly, intangible capital could be considered brand reputation, knowledge, and patents; according to Lubis (2022) and Freeman et al. (2021), both capitals are vital for a competitive advantage, and environmental sustainability. The RBV theory postulates that an organization's capability to leverage exclusive assets and proficiencies to generate supreme customer value concludes its competitive superiority. The RBV theory helps organizations recognize and cultivate capabilities and resources for agile reactions to market swings and supply chain disruption (Nayak et al., 2023).

The resilience engineering (RE) theory is defined by Hickford et al. (2018) as targeting to found systems of performance, usually despite disruptions. According to Mosalam et al. (2018), the organization applies diverse strategies to cope with unforeseen incidents. The RE theory is grounded on the principle that resilient companies can modify and regain without failing their core functions (Hosseini et al., 2016). According to the RE theory, companies' processes should be flexible, redundant, and diverse to safeguard robustness and adaptability (Sadeghi et al., 2023; Pettit et al., 2019). Developing the ability to foresee and adapt to unforeseen events, learning from past mistakes, and consistently refining processes and procedures are all ways that organizations can become more resilient (Singh et al., 2019). According to McMaster et al. (2020), when utilized effectively, resilience engineering assists enterprises in recognizing and reducing supply chain vulnerabilities and formulating swift recovery strategies for disruptions within agile supply chain settings.

According to Shahed et al. (2021), and Mandal and Dubey (2021), supply chain resilience denotes a environmental sustainability in supply chain's capability to survive and rebound from unexpected disruptions, for instance, political unrest, shortages, and natural catastrophes. Resilient supply chains can quickly adjust to changes and continue providing goods or services to clients without substantial delays or interruptions (Ribeiro & Barbosa-Povoa, 2018; Alfalla-Luque et al., 2017). The ability of a company to lessen its reliance on any one supplier or manufacturing site and to better survive interruptions is pivotal for supply chain resilience (Han et al., 2020). Companies should thoroughly understand potential risks to their environmental sustainability in supply chains and develop plans to mitigate them (Hsu et al., 2021). SCR is vital due to probable disturbances in today's interconnected world. Hence, environmental sustainability in ASC addresses flexibility and receptiveness. ASC creates a robust supply chain mechanism, which expertly circumnavigates variations in demand, technology, and other variables (Reyna-Castillo et al., 2022). According to Alfalla-Luque et al. (2023), agile supply chains must be adaptable enough to accommodate planned and unanticipated changes in demand and supply. A comprehensive strategy involving all facets of the supply chain, from sourcing and purchasing to production, logistics, and customer support, is needed to implement an environmental sustainability in ASC (Gruchmann et al., 2022; Samdantsoodol et al., 2017). Thus, we frame the hypothesis as follows:

H1: The agile supply chain has a significant and positive relationship with supply chain resilience.

Demand management and forecasting are critical factors for an ASC to proactively respond to changes in customer demand (Hsu et al., 2022). An agile supply chain has some key demand management and forecasting aspects. For example, in an agile supply chain, demand planning should be a collaborative effort between all parties involved in the supply chain, including suppliers, manufacturers, distributors, and customers for environmental sustainability (Alzoubi & Yanamandra, 2020). For stakeholders to immediately spot changes in demand patterns and adapt supply accordingly, an agile supply chain needs real-time visibility into demand data (Gruchmann et al., 2022). In order to collect data, it might be necessary to use sensors, RFID, and other tools (Mackay et al., 2020). Instead of depending on sporadic projections, an agile supply chain needs continuous forecasting. Stakeholders should, therefore, continuously assess trends in demand and make necessary adjustments. Contingency plans for various circumstances, such as unexpected spikes or reductions in demand, must be in place in an agile supply chain (Aldhaheri & Ahmad, 2023). In an agile supply chain, predictive analytics can be a helpful tool for better demand forecasting and trend identification (Reyna-Castillo et al., 2022). The ASC can swiftly and effectively react to variations in demand while minimizing waste and maximizing efficiency by applying effective demand management and forecasting practices (Hsu et al., 2022; Sharma et al., 2021). Thus, researchers hypothesized the following relationship:

H2: Demand management and forecasting have a significant and positive relationship with agile supply chains.

End-to-end collaboration is essential for an agile supply chain since it brings all parties together to achieve shared objectives (Oliveira-Dias et al., 2023). Vital components of end-to-end collaboration within an agile supply chain encompass shared planning among all stakeholders: suppliers, manufacturers, distributors, and customers (Battistella et al., 2017).

It helps ensure that everyone understands the plan and can work together to achieve the desired outcomes. According to Korucuk et al. (2023), an agile supply chain requires real-time data sharing so stakeholders can quickly identify demand, supply, or other factors that may impact the supply chain's resilience. In an agile supply chain, joint problem-solving is essential to resolving issues quickly and efficiently (Alzoubi & Yanamandra, 2020). It could entail bringing together representatives from diverse supply chain segments to address issues promptly. Agile supply chains also demand collective decision-making involving all relevant stakeholders. End-to-end collaboration in an ASC involves a commitment to continuous improvement in operations and environmental sustainability. It means stakeholders constantly seek ways to improve processes, reduce waste, and optimize efficiency (Mackay et al., 2020; Battistella et al., 2017). Hence, researchers hypothesize the following relationship:

H3: End-to-end collaboration has a significant and positive relationship with the agile supply chain.

According to Kittisak et al. (2019), responsive systems and analytics are essential components of an agile supply chain. An agile supply chain swiftly responds to changing customer needs, disruptions, environmental sustainability, and uncertainties (Mackay et al., 2020). Responsive systems in an agile supply chain use technology, processes, and systems that enable quick and effective decision-making (Aldhaheri & Ahmad, 2023). According to Oliverira-Dia et al. (2023), these systems must be capable of gathering, analyzing, and interpreting real-time data from various sources, including customers, retailers, distributors, and suppliers. Analytics give an understanding of how the supply chain functions, help spot potential bottlenecks, and forecast changes in demand (Al Humdan et al., 2023; Ku, 2022). Supply chain managers can decide on inventory levels, transportation routes, and supplier relationships by carefully analyzing data from various sources (Ahmad et al., 2023). Respondent systems and analytics offer real-time visibility into the supply chain in an agile supply chain, allowing managers to act swiftly on data-driven choices (Alfalla-Luque et al., 2023). Hence, researchers hypothesize the following relationship:

H4: Responsive systems and analytics have a significant and positive relationship with the agile supply chain.

According to Sharma et al. (2021), agile supply chain management entails incorporating flexibility and adaptation throughout the supply chain for swift response to varying demand, supply, or other factors. An agile supply chain means being resilient and prone to the risk of encountering disruptions and environmental sustainability. There are a few ways that risk management and resilience can be incorporated into an agile supply chain. For instance, first recognize risks that the supply chain may be exposed to, such as supply chain disruptions, demand fluctuations, or natural disasters (Oliverira-Dia et al., 2023). Risk assessment entails classifying each risk according to its likelihood and effect on the supply chain. The next step is to create strategies to manage the risks once identified and evaluated (Alzoubi & Yanamandra, 2020; Liu & Lee, 2018). It entails establishing a monitoring system that monitors essential indicators like supplier performance, demand trends, and inventory levels. The organization must act swiftly and effectively to mitigate the impact of any disruptions that occur, a flexible supply chain constantly improves and changes (Wong et al., 2020). Generally, resilience and risk management are essential components of an agile supply chain and environmental sustainability (Aldhaheri & Ahmad, 2023; Tarigan et al., 2021). Thus, we framed the hypothesis as follows:

H5: Resilience and risk management have a significant and positive relationship with agile supply chain.

Designing for agility in the supply chain involves drafting an adaptable system that responds rapidly to fluctuations in demand, supply, or other disruptions (Zhu et al., 2020). There are some ways in which green design agility in an ASC might be achieved, such as a modular design allows for customization and flexibility by breaking down the supply chain into smaller, independent components that can be reconfigured easily (Nguyen et al., 2018). Design for agility permits an organization to swiftly adjust to variations in customer demand, supplier availability, or manufacturing capacity. A solid and varied supplier network that can accommodate sudden variations in demand is necessary for an agile supply chain and environmental sustainability (Sood & Jain, 2022). According to Al Humdan et al. (2023), it is necessary to use accurate forecasting, real-time demand monitoring, and effective inventory management systems to optimize inventory levels for agility (Piya et al., 2020). Conclusively, continuous improvement is required for an agile supply chain. Regularly reviewing and updating supply chain processes, systems, and strategies is required to ensure that businesses remain effective and competitive in the business arena (Sood & Jain, 2022; Mandal, 2017). Thus, we framed the hypothesis as follows:

H6: Green Design for agility has a significant and positive relationship with the agile supply chain.

In an agile supply chain, process ownership refers to the accountability and responsibility for the successful execution of a particular process within the supply chain. It involves identifying and assigning specific individuals or teams responsible for overseeing each process and ensuring it is carried out efficiently and effectively (Dubey et al., 2018). Process ownership is vital in an agile supply chain, fostering accountability and collaboration throughout the supply network (Queiroz et al., 2022). Assigning ownership of specific processes to individuals or teams makes it easier to identify who is responsible for each process step and who can be held accountable for any issues (Oliverira-Dia et al., 2023). In an agile supply chain, the ownership of processes may be assigned to cross-functional teams responsible for delivering specific products or services (Alzoubi & Yanamandra, 2020). According to Rahimi et al. (2020), assigning ownership of processes to cross-functional teams makes it easier to promote collaboration and communication across different functions within the supply chain. Various steps could be taken to establish process ownership in an agile supply chain for sustainability. For instance, identify the critical processes within the supply chain that need to be owned and managed. Assign ownership of each process to a specific individual or cross-functional team (Alzoubi & Yanamandra, 2020). Thus, we framed the hypothesis as follows:

H7: Process ownership has a significant and positive relationship with the agile supply chain.

According to Oliveira-Dias et al. (2023) and Najar (2022), real-time information is vital for an environmental sustainability in agile supply chain by providing immediate and up-to-date data that enables efficient decision-making, responsiveness, and adaptability. Real-time data helps them accurately track and manage inventory, enabling timely reordering, production adjustments, or stock redistribution to meet changing demand patterns (Aldhaheri & Ahmad, 2023; Najar, 2022). Organizations can identify potential bottlenecks or disruptions in the supply chain by having real-time visibility into supplier performance, lead times, and order status. According to Singh et al. (2019) and Pettit et al. (2019), monitoring equipment and lines in real-time is essential for efficient production. Agile supply chains can execute proactive risk mitigation methods, such as alternative sourcing, safety stock changes, or supply chain rerouting, with the help of real-time analytics in order to reduce disruptions and maintain continuity (Pettit et al., 2019). Organizations can monitor and track the performance of their supply chain in real time using real-time analytics and key performance indicators (KPIs). Real-time data collection, integration, and analysis from diverse sources are made possible by these technologies, boosting supply chain agility and supplying valuable insights for decision-making. Several studies have employed real-time data as a mediating variable (Chatterjee et al., 2022; Raji et al., 2021).

Operational agility, which can swiftly and efficiently adapt to changing conditions and needs, is a crucial element of agile supply chain management and environmental sustainability (Korucuk et al., 2023; Ribeiro & Barbosa-Povoa, 2018). It entails having the adaptability and flexibility to change operational strategies, resources, and procedures in real time. Organizations may quickly identify and address bottlenecks, disturbances, and inefficiencies thanks to operational agility in an agile supply chain (Piya et al., 2020). This agility is attained by streamlined and effective procedures, successful supplier and partner engagement, and cutting-edge technologies (Sharma et al., 2021). Through operational agility, organizations ensure minimum disruptions in inventory management, production, and logistics operations. Operational agility enables proactive risk mitigation, such as alternative sourcing or rerouting supply chains, to minimize disruptions and maintain continuity (Panigrahi et al., 2023; Kazancoglu et al., 2022). Thus, operational agility in agile supply chain management empowers organizations to stay ahead in a dynamic and competitive business environment, enhancing customer satisfaction, environmental sustainability, and driving business success (Sood & Jain, 2022). Several research studies have used operational agility as a mediating variable, for instance, Pettit et al. (2019), and Fayezi et al. (2017).

The study additionally assesses how agile supply chains affect supply chain resilience. It also investigates how real-time information and operational agility mediate between external and internal variables. Thus, the researchers have formulated the mediation hypotheses:

H8: Real-time information significantly mediates between agile supply chain and supply chain resilience.

H9: Operational agility significantly mediates between agile supply chain and supply chain resilience.

H10: Real-time information and operational agility significantly mediate between agile supply chains and supply chain resilience.

The proposed conceptual framework of this study is grounded on previous studies and two theories, such as Resource-based view theory (Nayak et al., 2023) and Resilience engineering theory (Sadeghi et al., 2023). The researchers have taken operational variables from previous studies to modify the conceptual framework of the study. Figure 1 represents the proposed modified conceptual model of the existing research.

3. Materials and methods

The study's research design comprised a quantitative approach; the researchers used a deducted approach with a cross-sectional design (Ahmed et al., 2023; Al Humdan et al., 2023) of the study. A structured but modified five-point Likert-scaled questionnaire was employed to gather datasets from the textile sectors of various economies of Asian countries, for instance,

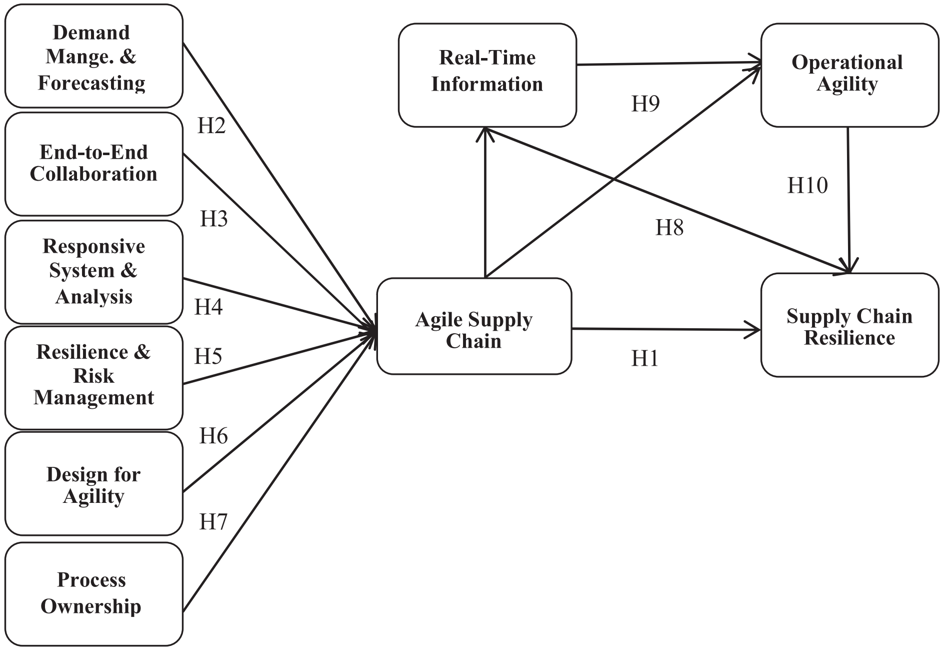

Figure 1. Proposed modified conceptual model of the research

India, China, Pakistan, Vietnam, and Bangladesh. The undertaken study's indicators examined how responsive systems and analytics, end-to-end collaboration, demand management, and forecasting, green design for agility, resilience and risk management, and process ownership impact the ASC and environmental sustainability. It also looked at how the agile supply chain affected supply chain resilience. The study took real-time information and operational agility as mediating variables between exogenous and endogenous variables.

The researchers have employed a purposive sampling technique to collect the responses from the supply chain managers and decision-makers of an organization from the textile sectors of Asian economies such as China, India, Pakistan, Vietnam, and Bangladesh (Hair et al., 2014). The responses from the participants were gathered using a standardized but modified five-point Likert scale questionnaire. Participants were given the questionnaire, and information was collected in person and online via personal email, Google Docs, LinkedIn, and company websites. The questionnaire had to be filled out and returned by the participants within a specific time. Data was collected over six months, from January 2022 to June 2022, from respondents with knowledge and expertise in supply chain management. Out of 400 survey forms sent for data collection, 345 were returned, thus resulting in a response rate of 86.25%.

Sacles were modified to suit researchers' needs and objectives of the study. Items for supply chain resilience were borrowed from the works of Mandal and Dubey (2021). The adapted items for the dimensions of ASC, for instance, demand management and forecasting, were taken from previous literature (Mackay et al., 2020; Richey Jr. et al., 2016); modified measures of End-to-end Collaboration were adapted from Battistella et al. (2017), and Alzoubi and Yanamandra (2020). The modified measurement scales of Responsive systems and analytics were taken from previous literature (Oliveira-Dia et al., 2023; Mackay et al., 2020; Kittisak et al., 2019), adapted items of Resilience and Risk management were taken from preceding literature, such as Sharma et al. (2021), Wong et al. (2020), and Liu and Lee (2018). Similarly, the modified items of green Design for Agility were obtained from preceding literature (Zhu et al., 2020; Nguyen et al., 2018; Mandal, 2017), and adapted items for Process ownership were extorted from earlier studies, for instance, Queiroz et al. (2022), Alzoubi and Yanamandra (2020), and Dubey et al. (2018). The researchers have incorporated two mediating variables, Real-time information and Operational Agility; the adapted indicators of Real-time information were obtained from preceding literature (Najar, 2022; Nguyen et al., 2018; Dubey et al., 2018), and adapted measures of Operational Agility were extracted from previous studies such as Pettit et al. (2019), Ribeiro and Barbosa-Povoa (2018), and Fayezi et al. (2017).

The study employs the PLS-SEM approach as the primary statistical technique; PLS-SEM is a variance-based SEM modeling that analyzes complex relationships between multiple variables (Hair et al., 2022; Williams et al., 2009). Measurement and structural models were validated through PLS-SEM modeling (Sarstedt et al., 2019). According to Ahmed et al. (2023), for measurement model's validation, researchers used outer loading, composite reliability, Cronbach's alpha, and average variance extracted to validate the reliabilities and convergent validities of variables and items. Similarly, the HTMT matrix and Fornnel-Lacker criterion are used to substantiate the discriminant validities of constructs; thus, in this way, the measurement model is endorsed. Secondly, for the substantiation of the structural model, researchers (Gefen et al., 2000; Rigdon et al., 2017) employed several statistical techniques, for instance, R-square values, f-square values, path coefficient analysis, Blindfolding, Predictive Relevance (Q^2), and overall model fitness of the hypothesized model (Ahmed et al., 2024; Hair et al., 2022).

The researchers have selected diverse demographics from different cultural economies; for instance, they selected senior and middle management employees of the textile industry from China, India, Pakistan, Bangladesh, and Vietnam. They received complete responses from 345 candidates, 211 (61.15%) males and 134 (38.84%) females. The detailed demographic statistics are shown in Table 1.

Table 1. Demographics of respondents

Demographics		Frequency	Percent
Gender	Male	211	61.15%
	Female	134	38.84%
Education	Higher Diploma	94	27.24%
	Bachelor's degree	174	50.43%
	Master's degree	77	22.31%
Experience (In Years)	1–5	85	24.63%
	5–10	121	35.07%
	More than 10 years	139	40.28%
Income (In USD 000/ Month)	2K–2.5K	202	58.55%
	2.5K–3K	91	26.37%
	3K–3.5K	52	15.07%
Total – N		345	

4. Findings and data analyses

4.1. Assessment of measurement model

Figure 2 displays the factor loading diagram that shows each indicator has a value higher than 0.70 that validated the reliability and validity of each item (Gefen et al., 2000). Table 2 and Figure 2 present the reliability and validity analysis results for a survey that measures six constructs linked to ASC and SCR and two mediating variables, for instance, real-time information and operational agility. The Cronbach's Alpha (CA) examines indicators' reliability or internal consistency within each construct (Ahmed et al., 2024). According to Sarstedt et al. (2019), the CA readings above 0.70 are generally acceptable. The current study exhibited that all constructs have high levels of reliability with ranges from 0.679 to 0.965 (Kamis et al., 2021). With rho_a and rho_c values ranging from 0.722 to 0.968 in this investigation, all constructs have excellent levels of composite dependability (Hair et al., 2022). The AVE is a convergent validity metric that gauges how closely related each construct's items are to one another (Fornell & Larcker, 1981). The AVE scales from 0 to 1, with values over 0.5 considered acceptable. With AVE ranging from 0.571 to 0.713 in this investigation, all variables have a satisfactory level of convergent validity (Dos-Santos & Cirillo, 2023; Fornell & Larcker, 1981).

Table 2. Convergent validity and reliability

Constructs	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	The average variance extracted (AVE)
Agile Supply Chain	0.965	0.968	0.968	0.571
Demand Management & Forecasting	0.757	0.763	0.846	0.580
Design for Agility	0.841	0.851	0.895	0.682
End-to-end Collaboration	0.720	0.736	0.842	0.641
Operational Agility	0.797	0.819	0.881	0.713
Process Ownership	0.679	0.722	0.819	0.604
Real-Time Information	0.856	0.897	0.888	0.571
Resilience & Risk Management	0.829	0.838	0.888	0.666
Responsive Systems & Analytics	0.875	0.883	0.909	0.666
Supply Chain Resilience	0.936	0.947	0.952	0.801

Ahmed et al. (2024) claims that the HTMT matrix is a statistical tool for evaluating a measurement model's discriminant validity. It is accomplished by contrasting each pair of components' heterotrait-monotrait (HTMT) ratios. The HTMT ratio contrasts the average correlation between items within each construct with the correlation between two factors (Afthanorhan et al., 2021). The HTMT matrix was employed in this work to evaluate the measurement model's discriminant validity. According to Hair et al. (2014), Table 3's findings demonstrated that each construct perfectly correlated with itself because all of the matrix's diagonal values were 1.0. The off-diagonal readings represented the HTMT ratios between different constructs. The HTMT values were below 0.85, the recommended threshold for assessing discriminant validity. It indicates sufficient evidence of discriminant validity among the factors in the measurement model. Hence, the HTMT matrix suggests no evidence of construct overlap or redundancy in the measurement model (Yusoff et al., 2020; Kamis et al., 2021).

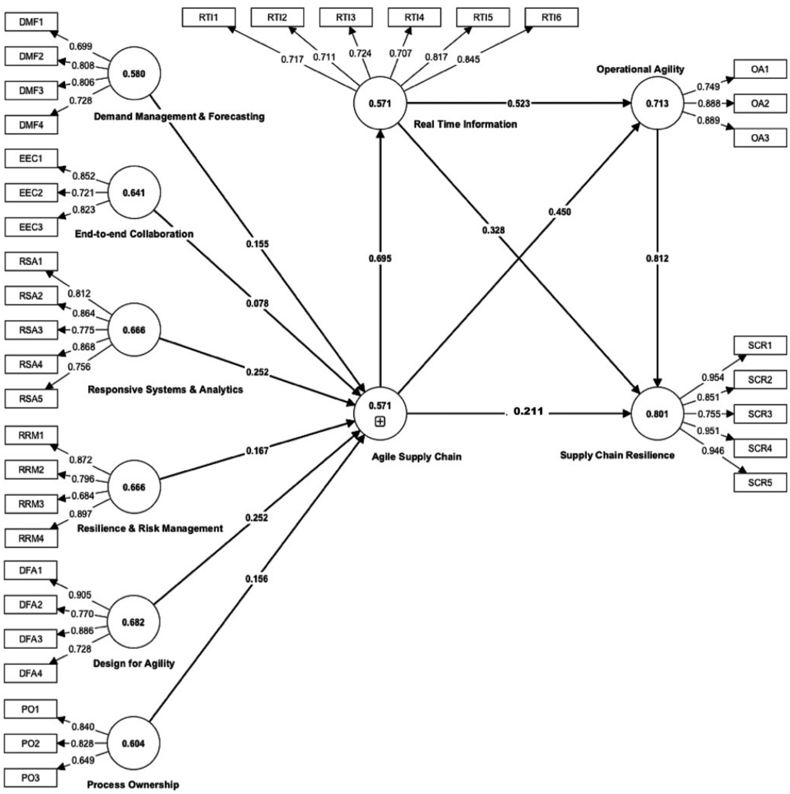

Figure 2. Measurement model of the study

Table 3. HTMT – discriminant validity

Constructs	ASC	DMF	DFA	EEC	OA	PO	RTI	RRM	RSA	SCR
Agile Supply Chain	1.000									
Demand Management & Forecasting	0.812	1.000								
Design for Agility	0.826	0.821	1.000							
End-to-end Collaboration	0.863	0.818	0.838	1.000						
Operational Agility	0.735	0.746	0.815	0.819	1.000					
Process Ownership	0.695	0.630	0.737	0.755	0.757	1.000				
Real-Time Information	0.730	0.733	0.812	0.717	0.826	0.752	1.000			
Resilience & Risk Management	0.780	0.634	0.790	0.699	0.733	0.832	0.726	1.000		
Responsive Systems & Analytics	0.610	0.714	0.783	0.766	0.603	0.740	0.614	0.802	1.000	
Supply Chain Resilience	0.698	0.685	0.648	0.715	0.732	0.802	0.774	0.697	0.626	1.000

4.2. Assessment of structural model

According to Hair et al. (2014), R-square is a statistical gauge demonstrating the variance ratio in the endogenous construct explicated by the exogenous constructs in a regression model. In this case, R-squared is used to examine the goodness of fit for the model and exogenous constructs' predictive power on the endogenous construct. The outcomes of Figure 3 and Table 4 exhibited that the R-square value for agile supply chain management is 1.000, which indicates that the model explains all the variation in this construct. For operational agility, the R^2 reading is 0.802, which indicates the exogenous constructs explicit 80.2% of the variation in this construct (Hussain et al., 2021; Kamis et al., 2021). The R-squared values for real-time information and SCR are 0.483 and 0.882, respectively.

Table 4. Coefficient of variation (R^2)

Constructs	R-square	R-square adjusted
Agile Supply Chain	1.000	1.000
Operational Agility	0.802	0.801
Real-Time Information	0.483	0.482
Supply Chain Resilience	0.882	0.881

According to Ahmed et al. (2023), f-square examines the effect size of independent variables vis-à-vis dependent construct in a regression model. It signifies the ratio of the variance in the endogenous construct described by the exogenous constructs (Sarstedt et al., 2019). According to Hair et al. (2014) and Urbach and Ahlemann (2010), the f-square values shown in Table 6 measures of effect size that denote the power of association among overall constructs and every construct. The findings of Table 5 demonstrated that the constructs green designed for agility (17.638), process ownership (11.804), and responsive systems and analytics (19.163) have the highest F-square values, indicating that these constructs have the most substantial relationships with the overall construct of agile supply chain.

Table 5. f-square (f^2) values (effect size)

Constructs	ASC	DMF	DFA	EEC	OA	PO	RTI	RRM	RSA	SCR
Agile Supply Chain					0.529		0.935			0.127
Demand Management & Forecasting	8.565									
Design for Agility	17.638									
End-to-end Collaboration	1.025									
Operational Agility										1.100
Process Ownership	11.804									
Real-Time Information					0.715					0.274
Resilience & Risk Management	7.428									
Responsive Systems & Analytics	19.163									
Supply Chain Resilience										

According to Ahmed et al. (2024), the hypothesized direct relationship demonstrated the direction and strength of association between the variables in the hypothesized model. According to Hair et al. (2022), a more significant coefficient value exhibited a greater association between the two variables. The findings of Table 6 and Figure 3 demonstrated that the path coefficients suggest that ASC showed a positive and cogent association with the SCR ($\beta = 0.216$, T = 5.086, and P = 0.000). The findings of Table 6 further demonstrated that demand management & forecasting ($\beta = 0.163$, T = 35.472 and P = 0.000), green design for agility ($\beta = 0.216$, T = 34.550 and P = 0.000), end-to-end collaboration ($\beta = 0.119$, T = 24.516 and P = 0.000), process ownership ($\beta = 0.138$, T = 27.720 and P = 0.000), resilience & risk management ($\beta = 0.186$, T = 33.429 & P = 0.000), and responsive systems & analytics ($\beta = 0.237$, T = 32.369 & P = 0.000) have significant and affirmative association with ASC. Hence, it is decisively established that hypotheses H1–H7 are validated. The individual impact of Responsive Systems and analytics demonstrated that it has the highest impact of 0.237 on the ASC, followed by the ASC with 0.216 and design for agility with 0.215.

Table 7 and Figure 3 have provided the statistical analysis of a hypothesized multiple serial mediation model. The findings showed that real-time information significantly mediates between agile supply chain and supply chain resilience ($\beta = 0.231$, T = 6.613 & P = 0.000). Likewise, operational agility was a potent mediator between agile supply and supply chains ($\beta = 0.363$, T = 9.488 & P = 0.000). The findings of multiple serial mediations showed that real-time information and operational agility have acted as cogent mediators between ASC and SCR ($\beta = 0.047$, T = 7.490 & P = 0.000) (Tarigan et al., 2021). Lastly, the results of multiple serial mediations demonstrated that the real-time information, and operational agility significantly mediate between an agile supply chain, resilience in the supply chain, and supply chain resilience. The detailed results of multiple serial mediations are reported in Table 8, showing that all the hypotheses are substantiated.

Table 6. Hypothesized direct relationship

Hypothesized Direct Relationship	Original sample (O)	Standard deviation	T statistics	P values
Agile Supply Chain -> Supply Chain Resilience	0.216	0.043	5.086	0.000
Demand Management & Forecasting -> Agile Supply Chain	0.163	0.005	35.472	0.000
Design for agility -> Agile Supply Chain	0.215	0.006	34.550	0.000
End-to-end Collaboration -> Agile Supply Chain	0.119	0.005	24.516	0.000
Process Ownership -> Agile Supply Chain	0.138	0.005	27.720	0.000
Resilience & Risk Management -> Agile Supply Chain	0.186	0.006	33.429	0.000
Responsive Systems & Analytics -> Agile Supply Chain	0.237	0.007	32.369	0.000

Table 7. Hypothesized mediation and multiple serial mediation

Hypothesized Mediation Relationship	Original sample (O)	Standard deviation	T statistics	P values
ASC -> RTI -> SCR	0.231	0.035	6.613	0.000
ASC -> OA -> SCR	0.363	0.038	9.488	0.000
ASC -> RTI -> OA -> SCR	0.287	0.038	7.645	0.000

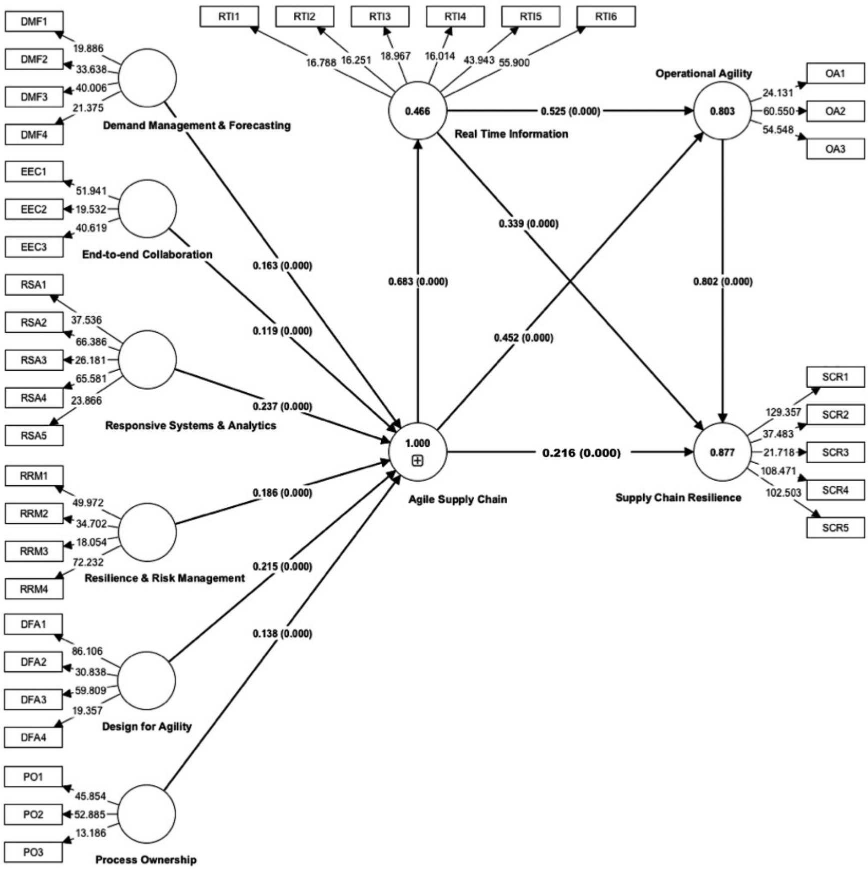

Figure 3. Structural model of the study

Table 8. The blindfolding and predictive relevance (Q^2)

Constructs	SSO	SSE	Q^2 (=1-SSE/SSO)
Agile Supply Chain	7981.000	3821.625	0.521
Demand Management & Forecasting	1388.000	966.492	0.304
Design for Agility	1388.000	736.072	0.470
End-to-end Collaboration	1041.000	734.813	0.294
Operational Agility	1041.000	601.086	0.423
Process Ownership	1041.000	789.154	0.242
Real-Time Information	2082.000	1238.570	0.405
Resilience & Risk Management	1388.000	768.072	0.447
Responsive Systems & Analytics	1735.000	871.296	0.498
Supply Chain Resilience	1735.000	521.791	0.699

According to Hair et al. (2022), and Urbach and Ahlemann (2010), the Blindfolding and Predictive Relevance (Q^2) value for each variable represents the proportion of variance in a particular construct, which is accounted for underlying constructs after cross-validation. The findings of Table 8 exhibited that supply chain resilience has the highest Q^2 value of 0.699, indicating that it is strongly related to the underlying constructs (Hair et al., 2022). Agile supply chain (0.521), green design for agility (0.470), responsive systems and analytics (0.498), and real-time information (0.405) also have relatively high Q^2 values, indicating that they are strongly related to the underlying constructs. However, Demand management and forecasting (0.304), end-to-end collaboration (0.294), and process ownership (0.242) have lower Q^2 values, indicating that they may be less strongly related to the underlying constructs. Hence, the Q^2 values suggested that the underlying variables have moderate to predictive solid Relevance of variables (Ahmed et al., 2023).

5. Discussions

This research examines the impact of an agile supply chain and its dimensions on supply chain resilience and environmental sustainability in the context of textile industry of Asian economies including China, India, Pakistan, Vietnam, and Bangladesh. Furthermore, the current research also examined the multiple mediations of operational agility and real-time information between the exogenous and endogenous variables. The findings showed that agile supply chain (ASC) has a potent and affirmative impact on supply chain resilience in the textile industry of selected Asian countries. These outcomes are in line with the previous literature, for instance, Mandal and Dubey (2021), Mackay et al. (2020), and Richey Jr. et al. (2016). The results show that responsive systems and analytics have a significant and affirmative influence on the agile supply chain (ASC) in manufacturing industry including textile industry. The outcomes of previous literature demonstrated similar results (Oliveira-Dia et al., 2023; Mackay et al., 2020; Kittisak et al., 2019). The dimension of end-to-end collaboration has a cogent and positive impact on ASC, which is also coherent with the outcomes of previous studies, for example, Battistella et al. (2017), and Alzoubi and Yanamandra (2020). Similarly, demand management and forecasting and green design for agility have a significant and positive impact on ASC in the textile sector of China, India, Pakistan, Vietnam, and Bangladesh; previous literature also demonstrated similar outcomes (Zhu et al., 2020; Mandal & Dubey, 2021; Nguyen et al., 2018; Mandal, 2017; Richey Jr. et al., 2016). Finally, resilience, risk management, and process ownership have a cogent and affirmative impact on ASC in the perspective of textile industry; these results are also consistent with the previous studies, such as Queiroz et al. (2022), Sharma et al. (2021), Wong et al. (2020), Alzoubi and Yanamandra (2020), Liu and Lee (2018), and Dubey et al. (2018), which have also demonstrated that resilience, risk management, and process ownership have a significant and positive influence on ASC for manufacturing sectors including textile industry. Operational Agility and Real-time Time Information have significant multiple serial mediations between agile supply chain, and supply chain resilience in perspective of textile industry of Asian economies. These outcomes are in line with the previous studies, which also demonstrated that operational Agility and real-time Information are the potent mediators between the exogenous and endogenous variables (Oliveira-Dias et al., 2023; Najar, 2022; Chatterjee et al., 2022; Raji et al., 2021).

6. Conclusions

The current study examined the importance of an agile supply chain and dimensions, for instance, responsive systems and analytics, end-to-end collaboration, demand management and forecasting, green design for agility, resilience and risk management, and process ownership. The empirical findings from the study highlighted that demand management, end-to-end collaboration, process systems, resilience, design, and ownership exhibit substantial positive links with the agile supply chain. Furthermore, an agile supply chain was found to significantly and positively correlate with the supply chain resilience, and environmental sustainability in case of Asian textile economies. Thus, in this way, hypotheses H1 to H7 are substantiated. This research also examines the multiple serial mediations of operational agility and real-time information between agile supply chain, and supply chain resilience. Hence, hypotheses H8 to H10 are also substantiated, and it is concluded that operational agility and real-time information are vigorous mediating factors among exogenous and outcome variables. The study's findings highlight the need for organizations to establish robust systems in areas like demand management, end-to-end collaboration, responsive systems, resilience, green design, and ownership for effective and agile supply chain management. Additionally, the outcomes stress the pivotal role of agile supply chains in enhancing supply chain resilience, and environmental sustainability within the Asian textile industry context. Furthermore, the results indicate that adopting advanced technologies, such as AI, data analytics, real-time data, and operational agility, is vital for long-term competitive supply chain resilience.

Theoretical implications stemming from this research are paramount, contributing significantly to supply chain management. The study adds value to the existing literature by meticulously pinpointing the pivotal factors in bolstering supply chain resilience. Thus, the future researchers may replicate their studies in different manufacturing sectors using this modified conceptual framework. The empirical evidence presented in the study strongly aligns with the concept that cultivating supply chain resilience necessitates a blend of agility, real-time data integration, as well as effective demand management and forecasting. Therefore, the undertaken study has some significant industrial implications. The results underscore that supply chain resilience is instrumental in mitigating the impact of disruptive events and elevating the supply network's overall efficacy, and environmental sustainability using influencing factors such as demand management, end-to-end collaboration, responsive systems, resilience, green design, and ownership. Crucially, the research also highlights the intricate interplay of multiple elements essential for comprehending the complex landscape of supply chain resilience. The organizations should adopt the process of real-time and information and operational agility to overcome the uncertainly and wastages in procurement and production. The research findings encourage organizations to adopt a holistic view that accounts for the interconnectedness of diverse components to enhance supply chain resilience and environmental sustainability. These findings offer a strategic compass for managers to devise plans that optimize their supply chain resilience, aiding in prioritizing investments in various capabilities based on their impact.

This research has certain limitations, firstly, the cross-sectional survey of this study restricts the identification of the causality between the variables. Thus, it is recommended that future researchers use the longitudinal survey method to explore the links between the constructs over time and establish causation. Secondly, this research has taken only the textile industry, thus, the findings cannot be generalizable. It would be intriguing to reproduce this study in other sectors to see if the results are the same across industries. This study offers insightful information about the connections between several constructs linked to supply chain resilience.

Future research, however, might expand on these findings to improve the knowledge of supply chain resilience and its causes.

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