The Effect of Resilience on Social and Environmental Sustainability and the Role of Digital Tools: Evidence from Bangladeshi Fashion Supply Chain

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Declaration of Originality

I hereby certify that this PhD dissertation, presented for examination at the PhD school of Management Engineering and Real Estate Economics in the University of Padova, is solely my own work, other than where I have clearly indicated that it is the work of others.

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Approval/Certification Page

This is to certify that the thesis entitled "**The Effect of Resilience on Social and Environmental Sustainability and the Role of Digital Tools: Evidence from Bangladeshi Fashion Supply Chain,"** submitted by **Awlad Hosen Sagar** in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Management Engineering and Real Estate Economics at the University of Padova, is an original work carried out by the candidate under our supervision and has been examined and approved by

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Preface

This dissertation has been submitted to the PhD school of Management Engineering and Real Estate Economics at the University of Padova, Italy, as a partial fulfillment of the requirements for a PhD. The research work was carried out under the supervision of Professor Laura Macchion and Rosanna Fornasiero, in the Department of Management Engineering, from October 2022 to September 2025. This research aimed to explore the effect of resilience practices on social and environmental sustainability in the fashion supply chain with the moderating effect of the application of digital tools. The following three manuscripts have been prepared based on the dissertation of the PhD. These three manuscripts have been submitted to three journals.

Manuscripts 1, 2 & 3:

1. Sagar, A. H., Laura Macchion and Rosanna Fornasiero (2024). Advancing Resilience, Digitalization, and Sustainability in Supply Chains: A Systematic Literature Review (Under review in a Q1 journal)
2. Sagar, A. H.**,** Laura Macchion and Rosanna Fornasiero (2025). Leveraging Resilience for Enhancing Social Sustainability and the Role of Digital Tools in the Fashion Supply Chain (Under review in a Q1 journal)
3. Sagar, A. H., Laura Macchion and Rosanna Fornasiero (2025). Resilience Practices and Environmental Sustainability in the Bangladeshi Fashion Supply Chain: The Moderating Role of Digital Tools (Published: https://onlinelibrary.wiley.com/doi/full/10.1002/csr.70208)

In addition, the findings of this research work are presented at the following scientific conferences:

1. Sagar, A.H., Macchion L. & Fornasiero R (2024). The relationship between sustainability, resilience, and digitalization in supply chain: A literature review, **EUROMA Forum (Hamburg), Germany 2024** (https://euroma-sustainabilityforum.org/about-euroma/)
2. Sagar, A.H., Macchion L. & Fornasiero R (2025). How Resilience Drives Social Sustainability and the Role of Digital Tools: Results from a Survey in the Fashion Supply Chain in Bangladesh, **EUROMA (Milan), Italy Conference 2025** (https://www.euroma2025.org/)
3. Sagar, A.H., Macchion L. & Fornasiero R (2025). The Moderating role of digital technologies in the relationship between Resilience and Social Sustainability in the Fashion Supply Chain, **IAMOT 2025 (Montreal), Canada** (https://www.iamot2025.com/)
4. Sagar, A.H., Macchion L. & Fornasiero R (2025). To what extent digital tools moderate in the relationship between resilience and environmental sustainability in fashion supply chain, **EDSI (Gothenburg), Sweden 2025** (https://edsi.decisionsciences.org/conference/)
5. Sagar, A.H., Macchion L. & Fornasiero R (2025). The effect of resilience practices on environmental sustainability and the moderating role of digital tools in the fashion supply chain, **NOFOMA (Copenhagen), Denmark 2025** (https://www.tilmeld.dk/nofoma2025/home)

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Abstract

There is increasing interest in examining the interplay between resilience, sustainability, and digital tools within supply chains (SC). However, finding an effective and equitable solution remains a concern. This thesis investigates the interplay between resilience, sustainability (social and environmental), and digital tools with the Bangladeshi fashion supply chain (FSC). This study considers four resilience constructs—visibility, agility, flexibility, and collaboration—and several digital tools: blockchain, internet of things, big data predictive analytics, artificial intelligence, and cloud-based platforms, which are commonly cited in the SC literature. Moreover, it focuses on internal and external social sustainability and waste management and pollution/emission of environmental sustainability that are critically important for SC actors. As a method, it employs a mixed methods approach, combining a systematic literature review (SLR) with empirical analysis based on survey data from 190 FSC actors, analyzed via structural equation modeling (SEM). The work is structured around three research questions focusing on best practices, the effects of resilience constructs, and the moderating role of digital tools. The results show that visibility, agility, and collaboration have a positive impact on social and environmental sustainability. Knowledge sharing, enhanced visibility, reduced intermediaries, and smart contracts facilitate the interaction between sustainability, resilience, and digital tools. Moreover, Bangladeshi FSC actors emphasize transparency in information flow, agile strategic planning, and collaboration that are more likely to achieve better social and environmental sustainability. Digital tools have been found to moderate the relationship with the positive effects of visibility for social and environmental sustainability. However, digital tools have amplified the negative effects of collaboration for social sustainability, and the negative effects of agility for the environmental sustainability model. This study makes a theoretical contribution and managerial insights with some new findings, including prioritizing resilience constructs and the extent of the digital tools needed to achieve sustainability. However, it focuses solely on the FSC sector in Bangladesh without considering economic sustainability and resource efficiency management of environmental sustainability.

Abstract (Italian)

Nell'ambito della gestione della Supply Chain, c'è un crescente interesse nel tipo di interazione che può esserci tra la capacità delle aziende di essere resilienti e la sostenibilità dei processi, tenendo conto anche del ruolo che possono avere gli strumenti digitali nel facilitare tale relazione. Questa tesi analizza l'interazione tra resilienza, sostenibilità (sociale e ambientale) e strumenti digitali nella filiera della moda del Bangladesh (FSC). In particolare, si indaga come i costrutti di resilienza influenzino la sostenibilità sociale e ambientale con il ruolo moderatore degli strumenti digitali. Per raggiungere questo obiettivo, è stata condotta prima di tutto una revisione sistematica della letteratura che ha portato alla mappatura delle dimensioni considerate e all'analisi dei concetti e delle pratiche che permettono di definire la sosteniblità sociale e ambientale, e a individuare quattro costrutti di resilienza - visibilità, agilità, flessibilità e collaborazione e diversi strumenti digitali: blockchain, Internet of Things, analisi predittiva dei big data, intelligenza artificiale e piattaforme basate su cloud. Sulla base di questa mappatura, è stato sviluppato un modello e definite delle ipotesi. Inoltre, si concentra sulla sostenibilità sociale e ambientale, che sono di fondamentale importanza per gli attori e le parti interessate della SC. Successivamente, sono stati condotti due studi trasversali attraverso la modellazione ad Equazioni Strutturali con dati provenienti da 190 aziende bengalesi del settore della moda. I risultati mostrano che la resilienza in termini di visibilità, agilità e collaborazione ha un impatto positivo sulla sostenibilità sociale e ambientale. Infatti, nei momenti di maggiore tensione per la gestione dei processi, la condivisione delle conoscenze, la maggiore visibilità sui processi, e la riduzione del numero di intermediari sono strumenti che facilitano il raggiungimento della sostenibilità attraverso pratiche di resilienza. Inoltre, l'analisi dei dati raccolti dalle aziende intervistate ha dimostrato come la trasparenza nel flusso di informazioni, la pianificazione strategica agile e la collaborazione siano fattori che hanno maggiori probabilità di raggiungere una migliore sostenibilità sociale e ambientale. È stato dimostrato che gli strumenti digitali attenuano la relazione tra visibilità e effetti positivi per la sostenibilità sociale e ambientale. Tuttavia, hanno amplificato gli effetti negativi della collaborazione per la sostenibilità sociale e quelli dell'agilità per il modello di sostenibilità ambientale. Questo studio fornisce un contributo teorico e manageriale molto utile per la gestione delle supply chain dal momento che aiuta ad individuare quali sono i costrutti di resilienza che maggiormente influenzano la sostenibilità ambientale e sociale e quale può essere il ruolo degli strumenti digitali necessari per raggiungere la sostenibilità. Tuttavia, si concentra esclusivamente sul settore FSC in Bangladesh, senza considerare la sostenibilità economica e la gestione efficiente delle risorse in termini di sostenibilità ambientale.

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List of Abbreviations

ADT	Application of Digital Tools
AGL	Agility
AI	Artificial Intelligence
AIIG	Italian Association of Management Engineering
AM	Additive Manufacturing
BDPA	Big Data and Predictive Analytics
BGMEA	Bangladesh Garment Manufacturers and Exporters Association
BLC	Blockchain
CB	Covariance Based
CBP	Cloud based Platform
COL	Collaboration
CUS	Customer
DT	Digital Technologies
DT	Digital Twin
EEA	European Environmental Agency
ENT	Environmental Sustainability
ERP	Enterprise Resource Planning,
EU	European Union
EXT	External Social Sustainability
FLE	Flexibility
FSC	Fashion Supply Chain
GIS	Green Information System
GVC	Global Value Chain
HRM	Human Resource Management
I4.0	Industry 4.0
INT	Internal Social Sustainability
IOT	Internet of Things
JPS	Joint Problem Solving
MGMT	Management
NBFI	Non-Banking Financial Institutions
NGO	Non-Governmental Organization
OSCM	Operations and Supply Chain Management
P/E	Reducing Pollution and Emission
PLS	Partial Least Square
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
REM	Resource Efficiency Management
RFID	Radio Frequency Identification
RMG	Ready-made-garments
RMSEA	Root Mean Square Error of Approximation
SC	Supply Chain
SCR	Supply Chain Resilience
SDG	Sustainable Development Goals

SEM	Structural Equation Model
SJR	Scimago Journal & Country Rank
SO	Society
SOSUS	Social Sustainability
SRMR	Standardized Root Mean Residual
SUP	Supplier
TLI	Tucker-Lewis Index
VCC	Value Co-Creation
VIS	Visibility
WOR	Worker
WOS	Web of Science

Chapter 1: Introduction

1.1 Background of the Study

Supply chain (SC) is an interconnected network of companies that facilitates the flow of products, information, and finance across and beyond organizational boundaries. It encompasses a broad spectrum of business operations, including logistics, but is increasingly confronted with sustainability challenges. Resilience has emerged as a parallel and complementary theme to sustainability within supply chain management. The two concepts are interrelated, generating both synergies and trade-offs (Rajesh, 2021). The combination of resilience and sustainability is needed (Ivanov D., 2018; Negri et al., 2021). The application of digital tools has introduced a new transformation to the relationship, influencing how supply chains respond to sustainability and resilience. As a result, the interplay among sustainability, resilience, and digital tools has become a growing area of research, driven by their synergistic benefits and complex interdependencies (Frederico et al., 2020; Bag et al., 2021). Addressing sustainability challenges, the adoption of digital tools and the strategic reconfiguration of supply chain resilience are needed (Wang et al., 2022). Accordingly, this study investigates the interactive study of the internal and external constructs of social sustainability, waste management and pollution/emission constructs of environmental sustainability, resilience constructs (i.e., visibility, agility, flexibility and collaboration), and digital tools (i.e., blockchain, Bigdata and Predictive Analytics, Internet of Things, Artificial Intelligence and Cloud Based Platform) in the supply chain.

Contextually, there is an increasing demand for sustainable fashion supply chains, propelled by customers, workers, and trade unions (Eggert & Hartmann, 2023). Besides, non-governmental organizations (NGOs) and regulatory bodies are exerting tremendous pressure on fashion brands to improve labor conditions, particularly among suppliers in developing countries (Miemczyk et al., 2012). The fashion industry of Bangladesh has undergone a significant transformation following the collapse of the Rana Plaza building in 2013. This tragic event prompted the implementation of government regulations and the adoption of sustainability policies by lead firms, alongside heightened stakeholder interest. Moreover, the fashion industry is a significant cause of environmental concern because of its production and wider supply chain. Solely garment and textile-based fashion accounts for around 10% of global CO_2 emission, which is more than all international flights and maritime shipping combined in a year (EU, 2020). About 8% of European microplastics released to oceans are from synthetic textiles, which are responsible for ocean acidity. Therefore, all SC stakeholders are concerned about the sustainability issues due to having social and environmental hazards. Accordingly, social and environmental sustainability is crucial, and its importance has been growing day by day (Govindan et al., 2014; Mastos et al., 2020; Eggert & Hartmann, 2023).

1.2 Main Concepts of the Study

1.2.1 Social Sustainability

Social sustainability, along with the economic and environmental dimensions, is one of the dimensions of the Triple Bottom Line (TBL) of sustainability. The prior literature has prioritized economic and environmental sustainability over social sustainability (Mani et al., 2016). Social sustainability is an imprecise concept and theoretically complex that is difficult to operationalization (Boström, 2012; Desiderio et al., 2022). However, social sustainability has become increasingly impactful but challenging due to the various flexibility in management approach, complexities in workplace safety, lack of compliance with regulations and enforcement (Sarker et al., 2021). The importance of social sustainability is further underscored through community resilience and resource resilience (Bag et al., 2022). Social sustainability is the overall process, structure, and relationships that support the capacity of current and future generations to create diverse, connected, and high-quality lives (Mckenzie, 2004). It focuses on upholding human rights, safe working conditions, community development, diversity, and ethical behaviour. Social sustainability also concerns preventing child labor, abuse, and harassment within companies and supply chain operations (Hannibal & Kauppi, 2019). Moreover, relationships with suppliers and mutual trust among stakeholders, referred to as 'relational capital' are also integral components of social sustainability (Benzidia et al., 2021).

From the demand side of the supply chain, 51% of EU consumers are ready to pay an additional 10% price for sustainably produced or transported products (RetailNext, 2023). Sustainable material is the main criterion of purchasing decisions for sixty-seven percent of EU consumers (Granskog et al., 2020). They assert that sustainability excels in acquiring durable products and consider social dynamics. Accordingly, supply chain actors reconcile the suppliers' issues, customer demand, and NGOs' expectations from internal and external social sustainability perspectives. Dempsey et al., (2011) described social sustainability as a multi-dimensional concept, including people, equity, health and safety, education and training, cultural diversity, an attractive public realm, job creation, and human rights. In the literature, there are some papers focused on social sustainability practices in terms of integrated human resource management practices (Nguyen et al., 2022), structured resource governance and a learning system (Eggert & Hartmann, 2023), health and safety of workers, and working conditions in the office and factory (Agarwal et al., 2022; Croom et al., 2018; Sharma et al., 2022), workers' satisfaction (Abdul-Hamid et al., 2022) and others. All these issues have been considered as practices related to internal social sustainability, meaning that they involve the departments, company management, and workers of each single company in the entire supply chain.

Other practices reported in the literature relate to upholding human rights (Aldrighetti et al., 2021), disclosing the supplier’s issues for customers (Grimm et al., 2014), child labor protection, upholding stakeholders' rights (Croom et al., 2018), employment opportunities for society (Agarwal et al., 2022), community governance and upholding cultural diversity (Grimm et al., 2014; Hussain et al., 2018), and protecting customer rights (Abdul-Hamid et al., 2022; Nayal et al., 2022). These practices have been considered as part of external social sustainability, meaning that they are related to external actors like suppliers, customers, and society in general. Accordingly, this study conceptualizes social sustainability practices from two perspectives, as represented in Figure 1.

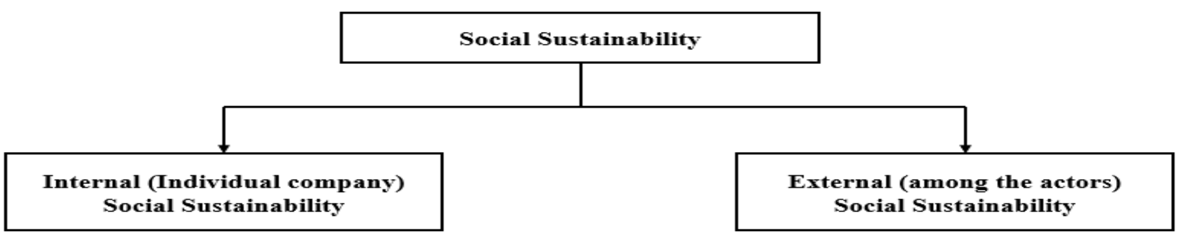

FIGURE 1: TWO CONSTRUCTS OF SOCIAL SUSTAINABILITY IN THE SUPPLY CHAIN

Moreover, Alghababsheh & Gallear, (2022) described social sustainability as the internal adoption of sustainability practices for management within the company and an external approach through supplier switching, customer collaboration, and social justice towards the external entities. Mani & Gunasekaran, (2018) address the issue by exploring how pressures from external entities (e.g., customers, sustainability culture, government, and external stakeholders, suppliers, and customers) act as primary constituents for social sustainability practices in SC. While Bechtsis et al., (2022) focused on the organizational practices through the integrated communication and hierarchical relationship within the company, and Agarwal et al., (2022) focused on health and safety of the workers within the factory and office. Lee & Choi, (2021) also described corporate social responsibility from internal and external social sustainability perspectives and showed how these are related to the firm's value performance.

1.2.2 Environmental Sustainability

One of this century's critical issues is maintaining environmental sustainability, which includes carbon emission due to the excessive use of carbon-based energy sources. The consequences of environmental pollution are not just a buzzword but hurt nature and livelihoods for all industries, including the fashion supply chain (FSC). It is estimated that 16-35% of the total between 200,000 and 500,000 tons of microplastics from textiles enter the global marine environment each year due to the fashion supply chain (EEA, 2022). 70% of the corporation's permanent agenda is on the environment, climate issues, and its mitigation policy (MIT, 2019). They emphasize the carbon footprint from production to supply chain. Environmental sustainability also matters in a transparent value chain system (Brun et al., 2020) that meets human needs without compromising the ecosystem.

Environmental sustainability encompasses the measures of reducing air, water, and carbon emission; solid waste management; efficient use of natural resources; and waste emission (Esfahbodi et al., 2023). It is a set of critical factors that act as the inception of green innovations, industrial symbiosis/synergy, pollution, and greenhouse gas reduction (Agarwal et al., 2022). Erhun et al., (2021) defined it as optimum water utilization, natural resource utilization, and carbon emission. In the literature, some of the authors highlighted environmental sustainability, focusing on waste reduction through waste management

(Abdul-Hamid et al., 2022; Hrouga et al., 2022), waste reuse and waste treatment (Agarwal et al., 2022), and optimum design of waste management (Del Giudice et al., 2020). Besides, other scholars gave importance to reducing pollution and emission, such as reducing water and air pollution (Chen & Chen, 2019; Dubey et al., 2019), greenhouse gas emission (López & Ruiz-Benítez, 2020; Mastrocinque et al., 2022), and decreasing consumption of hazardous/harmful materials (Dubey et al., 2019; Esfahbodi et al., 2023). Based on this, this study classifies environmental sustainability into three categories that are shown in Figure 2.

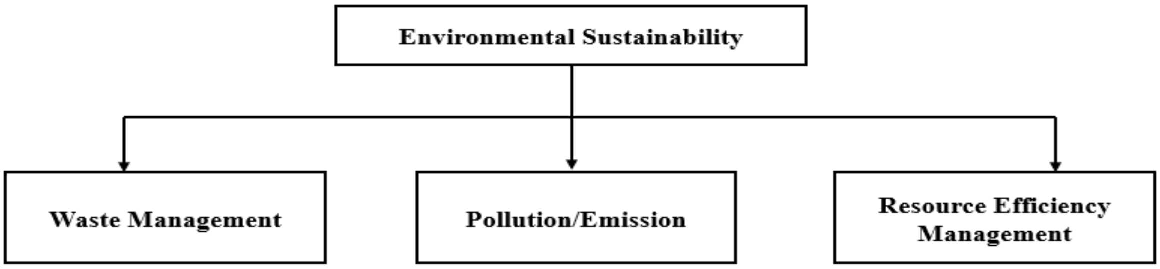

FIGURE 2: THREE CONSTRUCTS OF ENVIRONMENTAL SUSTAINABILITY IN THE SUPPLY CHAIN

Broadly, environmental sustainability refers to a balancing condition, resilience, and interconnection of human and nature that support ecosystems and economic regeneration without diminishing biological diversity (Morelli, 2011). There are five environmental sustainability factors: air, water, land, energy, and waste emission for assessment have been stated by Abdul-Hamid et al., (2022). After all, environmental sustainability means the magnitude of a company's taking care of nature, resources, and its surroundings and what proactive and reactive strategies have been taken to protect against environmental pollution with a wider aspect of the domain and constructs.

1.2.3 Resilience

Resilience is the ability to absorb, adapt, and recover from disruptions. It improves visibility, fosters collaboration, and develops disaster recovery plans (A.S & Ramanathan, 2021). Resilience is considered as both the prevention and cure for the supply chain (Hosseini et al., 2019; Pereira et al., 2020; Aldrighetti et al., 2021; Belhadi et al., 2022). Essentially, it signifies the ability to respond quickly, resulting from disruptions, and return to the original state (Holling, 1973; Christopher et al., 2004). Resilience is the capacity to provide operational stability, adaptability, and a balance between flexibility and redundancy (Rajesh, 2021). Previous literature categorizes resilience in multiple ways. Numerous studies emphasize proactive and reactive capabilities (Münch & Hartmann, 2023). Faruquee et al., (2021) classified agility, visibility, flexibility, and recovery plans as key drivers of resilience. While Ali et al., (2017) delineated thirteen critical resilience issues for SC, encompassing visibility, agility, adaptability, and collaboration. Hohenstein et al., (2015) stated flexibility, redundancy, collaboration, visibility, and agility are key constructs of resilience. Moreover, agility, visibility, adaptability, collaboration, and information sharing are considered as conceptual catalysts for resilience (Hosseini et al., 2019). Based on systematic literature review, this study focuses on some of the *most studied* resilience constructs (i.e., visibility, agility, flexibility, and collaboration) in the supply chain.

First, visibility allows SC actors to acquire essential information that determines the location and status through tracking and tracing during disruptions (McGrath et al., 2021). SC actors additionally guarantee visibility via physical mobility and the use of analytical tools (Zouari et al., 2021; Sharma et al., 2022). Visibility denotes the timely information system and transparency for product flow (Bechtsis et al., 2022). It also guarantees real-time information sharing (Frederico et al., 2021; Qader et al., 2022) and information governance throughout the SC to facilitate proactive strategies (Mol A.P.J., 2015).

Second, agility is the ability to detect and seize market opportunities and uncertainties (Erhun et al., 2021). It is a long-term strategic capability. Agility focuses on responding quickly to unforeseen disruptions and exploiting the advantage of change. Agility is the ability to strategically respond against changes in market demand or supply (Erhun et al., 2021; Irfan et al., 2022; Kazancoglu et al., 2022). SC actors enhance agility by leveraging supply networks (Reyes et al., 2021; Sarkis J., 2021) and frequently reconfiguring SC ahead of competitors (Croom et al., 2018; Bag et al., 2021). Agility also executes strategic supplier selection and segmentation during crises (Taleizadeh et al., 2022).

Third, flexibility is the ability to adjust changing conditions with minimal effort and time (Erol et al., 2010). It is an operational strategy including postponement to entail deferring the SC configuration (Becker et al., 2010). Flexibility encompasses the ability to modify SC processes, products, suppliers, or customers (Costa et al., 2022). It also facilitates rapid operational responses (Nayal et al., 2022). Moreover, it promotes tactical flexibility in operations to face sudden events in the SC (Abdelilah et al., 2018; Irfan et al., 2022; Silva et al., 2022).

Finally, collaboration is the capacity to work effectively with another party to achieve mutual advantages in disruptive situations (Costa et al., 2022). It includes networking, communication, and information dissemination among actors in the SC (A.S & Ramanathan, 2021; Silva et al., 2022). Collaboration pertains to stakeholder engagement and compliance agreements (Bechtsis et al., 2022; Münch & Hartmann, 2022). It also emphasizes human-machine collaboration and networking (McGrath et al., 2021). It helps managing partners, competitors, and knowledge-generating institutions for a sustainable SC (Han & Trimi, 2022). Resilience in supply chain management is therefore a multidimensional construct encompassing visibility, agility, flexibility, and collaboration. These constructs provide a foundational framework for understanding resilience in dynamic environments.

1.2.4 Digital Tools

Digitalization is a broader concept that encapsulates digital tools, applications, and systems. It is used for implementing an intelligent, customer-centric, system-integrated, globally connected, and data-driven mechanism to deliver valuable products and services that are more accessible and affordable (Seyedghorban et al., 2020). However, this study considers only the application of digital tools (e.g., blockchain application) in the SC rather than assessing the IT ecosystem, functional mechanism, or the comparative advantages or disadvantages. Accordingly, this study has gone through systematic literature review for digital tools connected to sustainability and resilience. From the systematic literature review, this study explored several digital tools (e.g., table 14-16) that are connected to sustainability and resilience in the supply chain, such as Blockchain, IOT, digital twin, additive manufacturing, ERP system, Industry 4.0 tools, Industry 5.0 tools and others. this study selects five of the most widely used and studied digital tools in the SC literature for analysis as a collective entity (i.e., blockchain, Internet of Things, Big Data and Predictive Analytics, Artificial Intelligence, and

Cloud Based Platform) and how these tools moderate the relationship between sustainability and resilience in the supply chain.

Firstly, *blockchain* is a cryptographically secure decentralized database. It generates a digital log of trusted and immutable transactions, which are encapsulated in blocks, a process known as mining, and can be shared between a public or private network (Asante et al., 2023). It is used in the SC for information governed by participants' consensus and secures real-time data sharing (Bechtsis et al., 2022). Blockchain has a positive impact on collaboration using smart contracts and creates a transparent data-transferring system in SC (Lohmer et al., 2020). It also enhances authentication through trust, quick reaction, and flexibility (Min H., 2019). Secondly, a*rtificial intelligence* is an advanced computer system that elaborates data and functions following human behavior in the SC. It influences social sustainability in terms of worker rights (Aldrighetti et al., 2021). Artificial intelligence communicates and imitates problem-solving capabilities with more accuracy and speed (Dirican C., 2015).

Thirdly, b*ig data and predictive analytics (BDPA)* collects, processes, and extracts meaningful insights from real-time data throughout the SC. It supports timely decision-making during disruptions. BDPA organizes and integrates information into a dynamic process for SC decisions. Bag et al., (2022) inferred that BDPA ensures community and resource resilience and visibility. It also guarantees robust SC through tracking-tracing, joint problem-solving, and communication (Ivanov & Dolgui, 2021). Fourthly, the *Internet of Things (IoT)* enables the connection of human, machines, and products for real-time data collection through networks. It enables continuous data collection, interconnection of the objects, and analytical autonomy (Bienhaus & Haddud, 2018). Finally, *cloud-based platforms (CBP)* often integrate data analytics that predict, optimize, and improve SC operations. It generates on-time SC indicators that identify the problem and resolve it quickly (Frederico et al., 2020). CBP responds promptly during disruption through data processing (Ivanov D., 2020). Digital tools have been recognized as a potential solution to enhance the interaction between sustainability and resilience. It entails the transformation of activities through the application of digital tools (Bressanelli et al., 2021). The benefits of digital tools are more pronounced in ensuring visibility, flexibility, agility and implementing recovery plans, outweighing concerns. It contributes as human substitution, trust mechanisms, and data security in SC through overarching information sharing and flexibility (Faruquee et al., 2021; Asokan et al., 2022).

1.3 Research Problem and Research Questions

There has been a growing interest among researchers in exploring the relationship between resilience and sustainability in the supply chain. For example, Carissimi et al., (2023) explored the relationship between sustainability and resilience from four perspectives (sustainability and resilience are two different concepts with separate and distinguishable goals, resilience is considered a component of sustainability, sustainability is considered a component of resilience, and they are considered as synonyms). Literature also shows that sustainability and resilience practices have been studied independently. Most of the existing models do not explicitly link social and environmental sustainability and resilience practices (Redman, 2014; Fahimnia & Jabbarzadeh, 2016). However, resilience has several interactions with sustainability (Chan et al., 2017). For example, the sustainability issue of waste reduction in the supply chain is generated by resilience for supply chain design and recovery actions (Ivanov D., 2018). Moreover, Rajesh, (2021) explained the relationship between sustainability and resilience from the variation in functional and strategical perspectives. He explained how an organizational supply chain goal has to tradeoff with the sustainability and resilience objectives but suggested for empirical validation.

Recognizing the interactive and multifaceted correspondence between sustainability and resilience (Sarkis, 2021), the adoption of digital tools is pivotal in facilitating and amplifying their dynamics and interplay. Digital tools offer holistic SCs management using blockchain, big data analytics, artificial intelligence (AI), and the Internet of Things (IoT), ensuring interconnectivity and real-time optimization (Asante et al., 2023). Digital tools also enhance sustainability through maximizing SC business value and insights for decisions (Bag et al., 2022). Besides, the literature presents varied perspectives, including both the moderating and mediating roles of digital tools on sustainability and resilience improvement in SCs. Moreover, the disparity in the application of digital tools to support sustainability and resilience diverges between developing and developed countries.

From the industry context, the fashion industry consumes a large amount of water and fossil-fueled energy (Peters et al., 2021). For example, 2700 liters of water are needed to produce a fashionable T-shirt (EPRS, 2020). Moreover, the fast fashion sector utilizes an estimated 79 trillion liters of water annually, contributing nearly 20% to the world's industrial wastewater production (Niinimäki et al., 2020). On the other hand, managing massive quantities of fashion items has become a social concern for international brands (Palm et al., 2021). Therefore, finding an effective and equitable solution for sustainability and resilience practices with the contingent effect of digital tools remains an interesting concern for researchers.

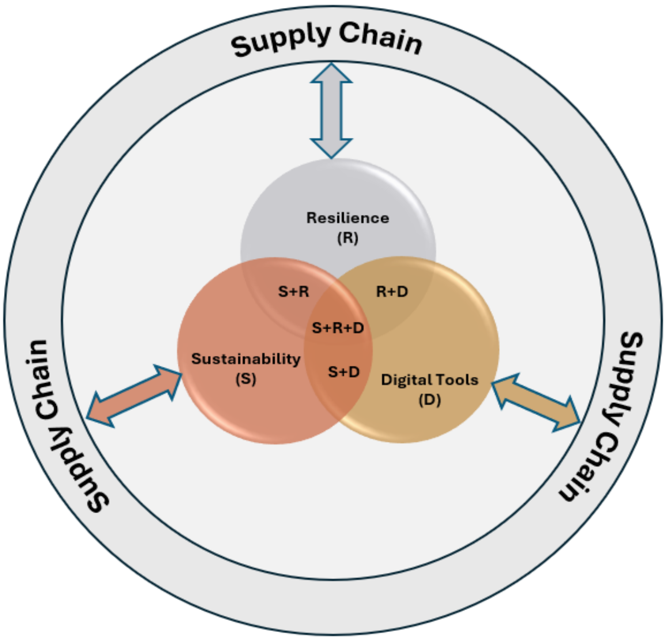

FIGURE 3: INTERACTIVE FRAMEWORK OF SUSTAINABILITY, RESILIENCE AND DIGITAL TOOLS IN THE SUPPLY CHAIN

The focal factor behind this academic interest is also the drive towards achieving Sustainable Development Goals (SDG). Hence, many studies have been commenced for social and environmental sustainability, but these are mostly theoretical and working papers. A comprehensive assessment of the Bangladeshi fashion supply chain (FSC) from social and environmental dimensions is well-timed. Despite the adoption of resilience-oriented practices aimed at enhancing social sustainability and managing environmental concerns, issues such as waste management, pollution, emissions, and climate-related impacts remain significant. Based on these considerations, this study investigates three research questions (RQs) that are explicitly shown in Table 1.

TABLE 1: LIST OF RESEARCH QUESTIONS AND SPECIFIC RESEARCH QUESTIONS

Research Questions (RQ)	Specific Research Questions (SRQ)
Research Question 1 (RQ1)	
What are the best practices used to manage supply chains that can combine sustainability, resilience and digital tools?	$SRQ_{1.1}$ What are the issues and constructs of sustainability, resilience, and digital tools influence in the supply chain?
	$SRQ_{1.2}$ How do the issues and constructs of sustainability, resilience, and digital tools interact with each other within SC?
	$SRQ_{1.3}$ What are the research gaps related to the interaction of the issues and constructs of sustainability, resilience, and digital tools in SC?
Research Question 2 (RQ2)	
How do various resilience constructs affect internal and external social sustainability, and what is the role of digital tools in the relationship between resilience and social sustainability in the FSC?	$SRQ_{2.1}$ How do various resilience constructs affect internal and external social sustainability practices in the FSC?
	$SRQ_{2.2}$ How does the application of digital tools strengthen the effects of various resilience constructs on internal and external social sustainability in the FSC?
Research Question 3 (RQ3)	
How do various resilience constructs affect waste management and emission-pollution of environmental sustainability and what is the role of digital tools in the relationship between environmental sustainability and resilience in the FSC?	$SRQ_{3.1}$ How do various resilience constructs affect environmental sustainability practices (i.e., waste management and emission/pollution) in the FSC?
	$SRQ_{3.2}$ How does the application of digital tools strengthen the effects of various resilience construct on environmental sustainability (i.e., waste management and pollution/emission) in the FSC?

1.4 Research Objectives

This study is grounded on several primary milestones with some specific research objectives. First, reviewing and identifying the key issues of social and environmental sustainability, resilience, and digital tools from existing literature. Second, analyzing and classifying the integrated literature on sustainability, resilience, and digital tools. Third, identifying potential research gaps in the current literature, encompassing both ongoing and forthcoming research. Moreover, it aims to clearly identify the relationship and conflicting outcomes among sustainability, resilience constructs, and notable digital tools of SCs. From a contextual perspective, this study assesses the effect of resilience practices on social sustainability (i.e., internal and external) and environmental sustainability (i.e., waste management and emission/pollution). Furthermore, how digital tools moderate the relationship between social and environmental sustainability and various resilience constructs in the fashion supply chain.

1.5 Scope of the Study

The scope of this study is the fashion supply chain in Bangladesh. The choice of selecting Bangladesh was motivated by the significant role of Bangladesh in the global FSC, particularly in garments, knitwear, and woven wear. Bangladesh is the second largest ready-made garments (RMG) exporting country in the world. FSC actors in Bangladesh maintain direct links with downstream fashion outlets in developed countries, making the country an ideal context for this study. In fact, the Bangladeshi fashion supply chain covers a wide range of the global fashion supply chain. The complex SC dynamics due to local and imported inputs for the supply chain is another reason for selecting Bangladesh. Moreover, the critical assessment of 4 million workers involvement, including the concern of child labor practices are also reasons for selecting Bangladeshi fashion supply chain. The upholding of human rights and ethical sourcing issues of sustainability in the chain level is also important reason for selecting the Bangladeshi fashion supply chain.

Besides, many global brands make pledges about social and environmental sustainability at present. Some of the lead firms have also pretended to have keen interest in human rights and carbon emission since the atmosphere has been electrified by the emergence of SDG. Moreover, most of the supplies of the major fashion brands (e.g., Prada, H&M, Zara, Uniqlo, Mango, Pull & Bear and Walmart) are from Bangladesh, and therefore, it is considered as an ideal context for the study of fashion supply chains. The sample frame was drawn from the member directory of the Bangladesh Garment Manufacturers and Exporters Association (BGMEA), the apex trade body for the RMG sector in Bangladesh. The overall goal is the execution of social and environmental sustainability in operations and distribution through resilience practices and digital tools in Bangladeshi FSC.

1.6 Significance of the Study

This study signifies addressing the state-of-the-art conceptual gap of the relationship between sustainability, resilience, and digital tools with the empirical study (Ivanov D., 2021; Sarkis J., 2021; Nayal et al., 2022). There is limited research in the specific fashion supply chain industry for developing countries' perspectives. Besides, there is no quantitative and survey-based study on the Bangladeshi fashion supply chain considering sustainability issues, resilience constructs, and digital tools in the contemporary period. From the reviewed literature, this study finds only some case studies that showed the international ACCORD case of the garments industry in Bangladesh (Sodhi & Tang, 2021). The previous studies on the integration of sustainability, resilience, and digital tools are qualitative case studies for apparel industry (Hohn & Durach, 2021), the automotive case study (Ivanov D., 2021), the African mining industry (Bag et al., 2021) and the footwear industry in Bangladesh (Sarker et al., 2021). Therefore, this study signifies the appropriate contextual research gap related to resilience practices, sustainability, and digital tools application in the Bangladeshi fashion supply chain.

This study has theoretical and practical implications that contribute to sustainability in supply chain literature. The findings could be input for the appropriate decision in the fashion supply chain. By addressing the gaps and embracing the interactive framework, stakeholders can improve their understanding of sustainability, resilience, and digital tools in the supply chain. Moreover, the mixed findings from previous literature create the disagreement gap, and this study signifies this gap with empirical evidence. For example, Frederico et al., (2021) explained the impact of disruptive technologies and the interoperability of sustainability (i.e., efficiency) and resilience to improve supply chain performance. They inferred no moderating role of disruptive technologies in the relationship between sustainability and resilience. However, their study negates the previous findings of Cabral & Grilo, (2018). The application of Industry 4.0 has a positive effect on operational supply chain performance with the moderating effect of flexible orientation and controlled orientation (Bag et al., 2022).

Besides, the data-driven supply chain ensures a secured, sustainable and end-to-end visible supply chain by continuous tracking & tracing and sharing knowledge of physical and informational SC structures (Belhadi et al., 2022). This various finding in different industries approaches to the scope for further research due to the disagreement gap/contrasting and contradictory findings in the relationship between sustainability, resilience, and digital tools.

Finally, this study signifies the coverage of the consensus of the supply chain practicing gap, policy implication, and practical evaluation in the fashion supply chain. As outcome, the result prioritizes resilience constructs and determines the extent of the digital tools to achieve internal and external social sustainability and waste management and reduce pollution/emission of environmental sustainability. This study revealed that visibility, agility and collaboration have a positive effect on social and environmental sustainability. Digital tools moderate both positively and negatively in connection with resilience and sustainability. This study also argues for the uniform adoption of digital tools to maintain consistency and foster collaboration among all actors in the supply chain. Furthermore, an isolated focus on agility or flexibility may not always yield a sustainable fashion supply chain, emphasizing the necessity of a more integrated, visible, and collaborative approach.

1.7 Structure of the Thesis

This study is structured into seven chapters; chapter 2 encompasses a systematic literature review. Chapter 3 presents the hypothesis development and theoretical framework. Chapter 4 delineates the methodology. Chapter 5 shows the analysis and results. Chapter 6 constitutes the discussion. Finally, Chapter 7 presents the conclusion and future research directions.

Chapter 2: Systematic Literature Review

2.1 Introduction

Systematic literature review (SLR) is a rigorous methodical approach to synthesizing existing literature on a specific topic that reduces errors, prevents redundancy, and maintains publication standards (Moher et al., 2009). It systematically identifies and evaluates relevant studies, providing a comprehensive understanding of the current state of knowledge for a specific topic (Wang & Chugh, 2015; Tricco et al., 2018). SLR also maps and assesses the relevant intellectual territory and has been used as a complement to the traditional narrative of literature. It is more structured compared to general narrative and guides the specification of research questions, which further create and develop knowledge (Tranfield et al., 2003). Moreover, SLR helps to identify gaps and inconsistencies (Grant & Booth, 2009). From the practical implication, it also ensures quality assessment and helps to take evidence-based decisions (Popay et al., 2006; Mihalache & Mihalache, 2016; Munn et al., 2020). As evidence, SLR could be applied in various fields such as I4.0 and circular economy (Bressanelli et al., 2021; Abdul-Hamid et al., 2022), lean management (Danese et al., 2018), and financial literacy (Goyal & Kumar, 2021).

The supply chain sustainability, resilience, and digital tools have expanded quickly and now form a highly interdisciplinary research space involving operations management, informational ecosystem, environment, and social science. Due to the accelerated development and the increasing synergistic importance of these three concepts within supply chains, the existing knowledge has become both crucial and highly fragmented, characterized by diverse constructs, methods, and theoretical perspectives across disciplines. Conducting a systematic literature review (SLR) integrates these themes allows to consolidate this dispersed body of knowledge through a rigorous, transparent, and replicable process for identifying, evaluating, and synthesizing relevant and state-of-the-art literature. As the first objective, SLR with these keywords is necessary to map the evolution of sustainability, resilience and digital tools (e.g., IoT, AI, blockchain, and cloud-based platform) and assess how they connect each other's in different supply-chain contexts. Since the use of digital tools is constantly emerging and changing, a systematic review enables to assess current evidence, identify technological gaps, and avoid inconsistent or outdated conclusions in the domain of supply chain.

Second, the relationship between sustainability and resilience remains conceptually complex, with some studies viewing them as complementary and others as competing priorities. An SLR using the selected search *strings* helps to clarify these conceptual boundaries. It also reveals how digital tools mediate or moderate this relationship by synthesizing empirical findings across sectors and methodological approaches. Third, an SLR in the supply chain supports theoretical advancement by integrating key constructs (e.g., visibility, agility, flexibility, collaboration) and linking them with theoretical frameworks such as dynamic capability theory, socio-technical systems, and the resource-based view. Such theoretical consolidation is critical to assess the subsequent empirical research questions 2 and 3. Finally, the field continues to suffer from inconsistent measurement of sustainability, resilience, and digital tools constructs. By systematically examining the metrics and methodologies employed, this SLR helps to identify methodological limitations, advance standardized frameworks, and highlight underexplored areas—especially social and environmental sustainability, which remain less developed compared to economic sustainability. Accordingly, the three steps of SLR employed by Xia et al., (2018) this study describes the subsequent sections of systematic literature review-

I. Planning and Computer Search
II. Visual Examination
III. Content Analysis

2.1.1 Planning and Computer Search

This stage involves planning and searching articles related to sustainability, resilience, and digital tools in the supply chain from an academic database. The planning of SLR consists of creating keywords and a research protocol (Xia et al., 2018). Research keywords are derived from the stated research questions, and the research protocol has been established in several steps with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. The three concepts are sustainability, resilience, and digital tools, and their selected 'synonym' is explained in Table 2.

TABLE 2: LIST OF CONCEPTS AND SYNONYMS FOR SYSTEMATIC LITERATURE REVIEW

SL. No.	Concept	Synonyms of the Concepts
1	Digital tools	Digital, industry 4.0, industry 5.0, cyber, automat*, smart manufac*
2	Sustainability	Green, environmentally, responsible, and social
3	Resilience	robust, flexible, adaptable;
Domain	Supply chain	Value chain, supply network

For the computer search of the keywords, the authors use the "Scopus" database due to having a reputation and a wider range of data sources than the Web of Science (Falagas et al., 2008). The search rule was conducted in the title/abstract/keyword for 'combined literature' for sustainability, resilience, and digital tools. The search strings of the Scopus database are:
(sustainab or green* or environmental* or responsib* or social*) and (resilien*or robu st* or flexibl* or adaptab*) and ("supply chain" or "value chain" or "supply network") or (sustainab* or green* or environmental* or responsib* or social*) and (digi tal* or"industry4.0" or "industry5.0" or cyber* or automat* or "smart manufact*) and ("supply chain" or "value chain" or "supply network") or (digital* or "industry 4.0" or "industry5.0" or cyber* or automat* or "smart manufact*) and ("supply chain" or "value chain" or "supply network") and (resilien* or robust* or flexibl* or adaptab*).*

The reasonable exclusion criteria have been adjusted. Articles published only in English and in the subject areas of business and management, economics, econometrics, and finance have initially been considered. This study used PRISMA as SLR protocol to obtain-

a) Insights into the interaction of the concepts

b) Transparency of the research design and procedure

c) Subsequent quality assessments

d) Methodological robustness

e) Critical appraisal

f) Replicability of the research

The PRISMA as SLR protocol has been shown in Figure 4 and the details of each step have been discussed in the subsequent sections.

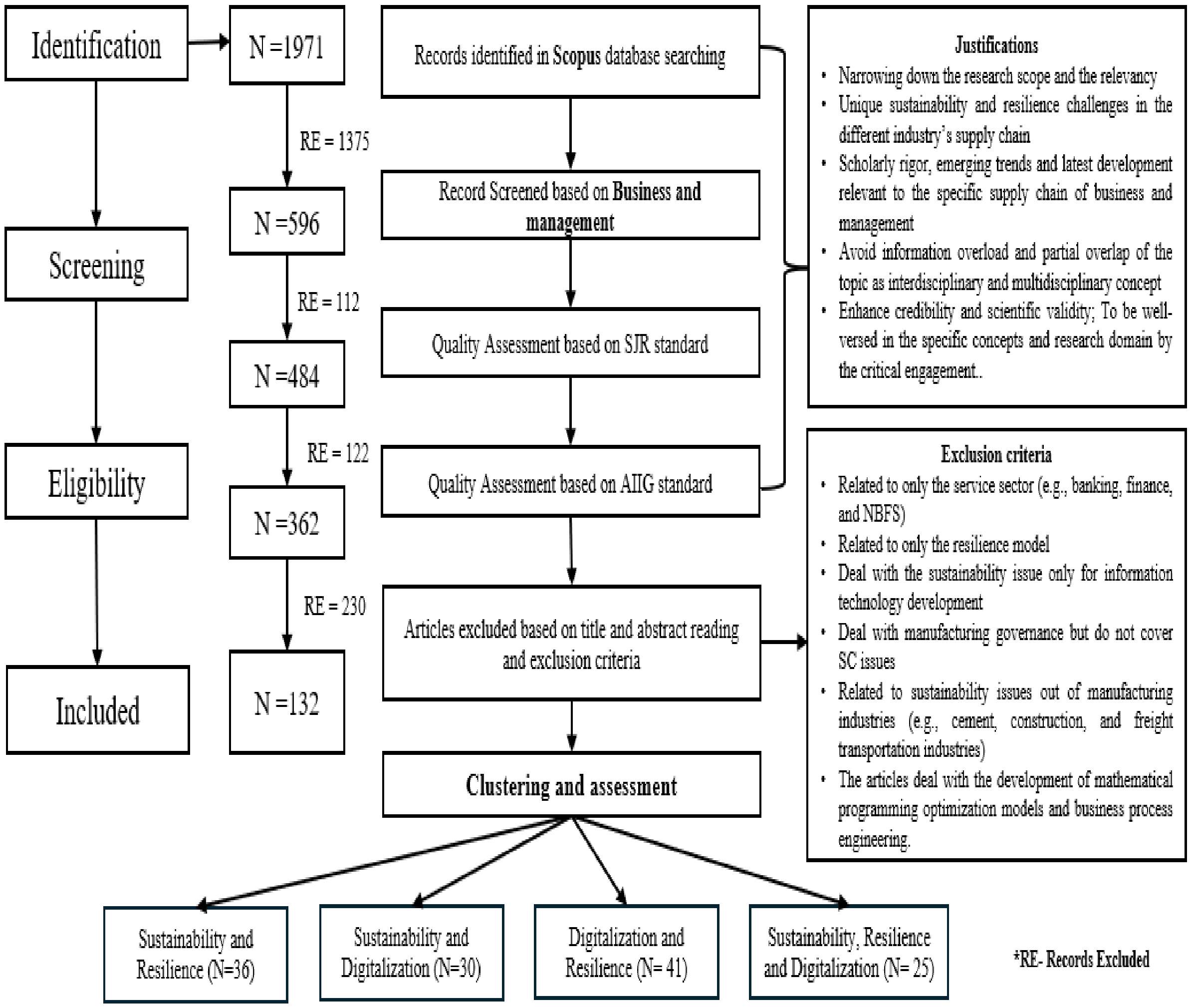

FIGURE 4: PRISMA PROTOCOL OF THE SYSTEMATIC LITERATURE REVIEW

2.1.2 Visual Examination

Visual Examination is related to removing irrelevant papers and the consideration of various filtration standards. At this stage, the quality of the journals has been graded by the presence in the Scimago journal and the country ranking (SJR). The respective quantities of SJR ranking have been displayed in Table 3.

TABLE 3: CLASSIFICATION OF JOURNALS BASED ON THE SCIMAGO JOURNAL AND COUNTRY RANKING (SJR)

Sl. No.	Ranked	Quantity
1	Q_1	375
2	Q_2	109
3	Q_3	52
4	Q_4	36
5	Non-SJR	24
Total		596

From this ranking, this study considers the articles belonging only to Q_1 and Q_2 and the total number of articles reduces to 484 (i.e., 375 + 109). As a subsequent quality assessment, this study also proceeds with the standard of the Italian Association of Management Engineering (AIIG) and considers only the articles belonging to the Gold-Star, Gold, and Silver rankings of AIIG. Afterward, the number of articles dropped to 362 (i.e., 16 + 235 + 111). The respective quantities of AIIG ranking have been displayed in Table 4.

TABLE 4: CLASSIFICATION OF JOURNALS BASED ON THE ITALIAN ASSOCIATION OF MANAGEMENT ENGINEERING

Sl. No.	Rank	Quantity
1	Gold-star	16
2	Gold	235
3	Silver	111
4	Bronze	43
5	Copper	28
6	Out of the list	51
	Total	484

The next step is the reading of distinct titles, abstracts and the assessment of these 362 articles (16+235+111). During the final selection process, the following exclusion criteria have been used to reach the final number of articles (i.e., 132 articles) for full article reading. The exclusion criteria are

- Articles deal with only service flow (e.g., banking, finance, and non-bank financial institutions) for sustainable supply chains
- Articles deal with only the resilience model (e.g., risk management model and the network model) in the supply chain
- Articles deal with the sustainability issue only for information technology development (e.g., mobile applications, platforms, and design tools)
- Articles related only to sustainable production or manufacturing activities without supply chain implication
- Articles deal with governance issues in manufacturing but do not cover supply chain issues.
- Articles deal with sustainability issues only out of manufacturing industries (e.g., cement, construction, and freight transportation industries)
- Articles deal with the development of mathematical programming optimization models and business process engineering.

These 132 articles are fully reviewed from a thematic perspective and classified into four groups. The VOS-viewer application has been used to visualize keywords from the reviewed literature. A total of 727 keywords is indexed across the 132 selected articles. This study used a threshold of a minimum of five occurrences, resulting in a reduction to 25 keywords. However, there are three keywords (i.e., manufacture, cost, and manufacturing) that are directly related to economic sustainability. Therefore, 22 keywords have been displayed in Figure 5 from the output of Vos viewers. From these numbers, it is evident that the most common keywords are “supply chain” (79 times), “sustainability” (42), “resilience” (31), “industry 4.0” (21) and “blockchain” (12) as obvious from research orientation and research question. As such, the output of the final filtering stage still reflects the consistency of the keywords that were initially adopted. The generated output of selected keywords is shown in Figure 5.

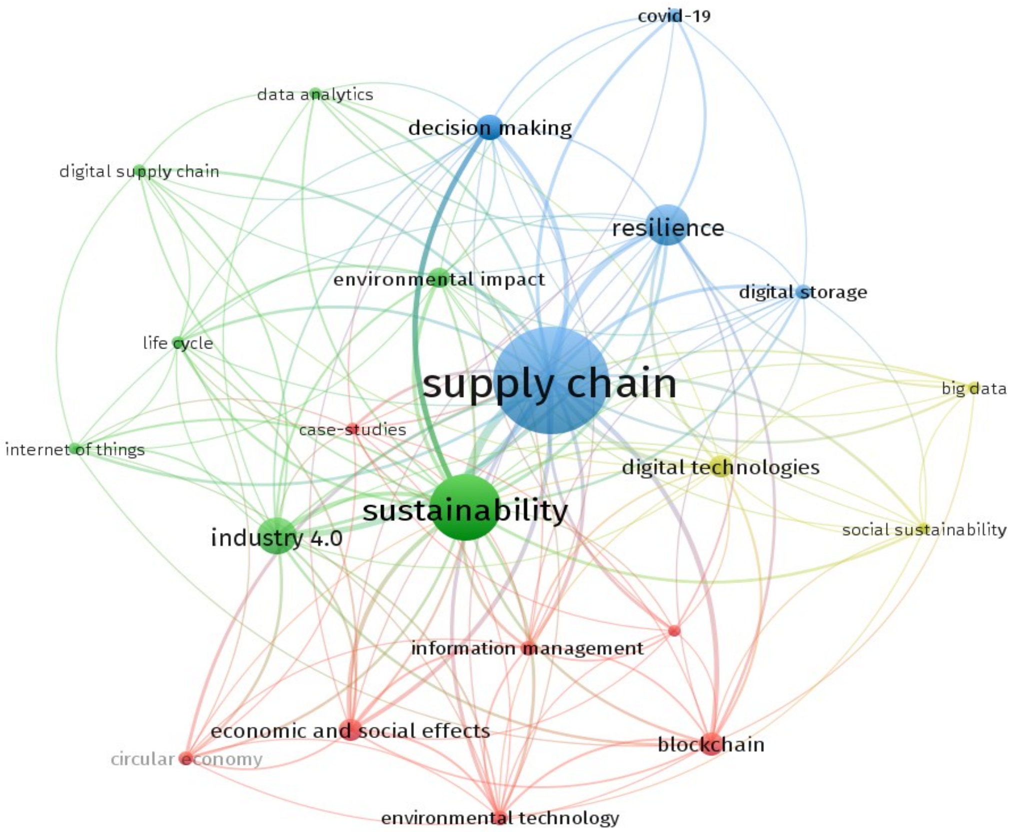

FIGURE 5: OUTPUT OF KEYWORD VISUALIZATION THROUGH VOS-VIEWER

2.1.3 Content Analysis

The content analysis is carried out to identify and analyze the finally selected papers based on the topic and the theoretical lens. It is also carried out to detect and classify literature based on geographical areas, interaction, and research trends of sustainability, resilience, and digital tools in the supply chain. For this identification and analysis, this study organizes a comprehensive Excel Sheet of review with the codebook for content analysis. Based on the study of Xia et al., (2018), this process has two parts-

a) Descriptive Part

b) Thematic Part

2.1.3.1 Descriptive Part

As the descriptive part, this study deliberately goes through 132 papers to detect and organize the necessary information, for example, year of publication, country-based study, articles sources, and methodology. The selected articles have been separated according to the year of publication to know the relevance and periodical context (Elo & Kyngäs, 2008). Most of the studies are very recent. The most reviewed articles have been published in 2022 and following years. More than 80% of articles have been published in the last three years. Therefore, this study covers updated outcomes of the interaction among sustainability, resilience, and digital tools.

This study also classifies the selected articles based on the country-specific data to explore the contribution and significance of respective countries in research on the combination of resilience, sustainability, and digital tools in the supply chain. Figure 6 shows the status of the top twelve countries, making an outstanding contribution in the field.

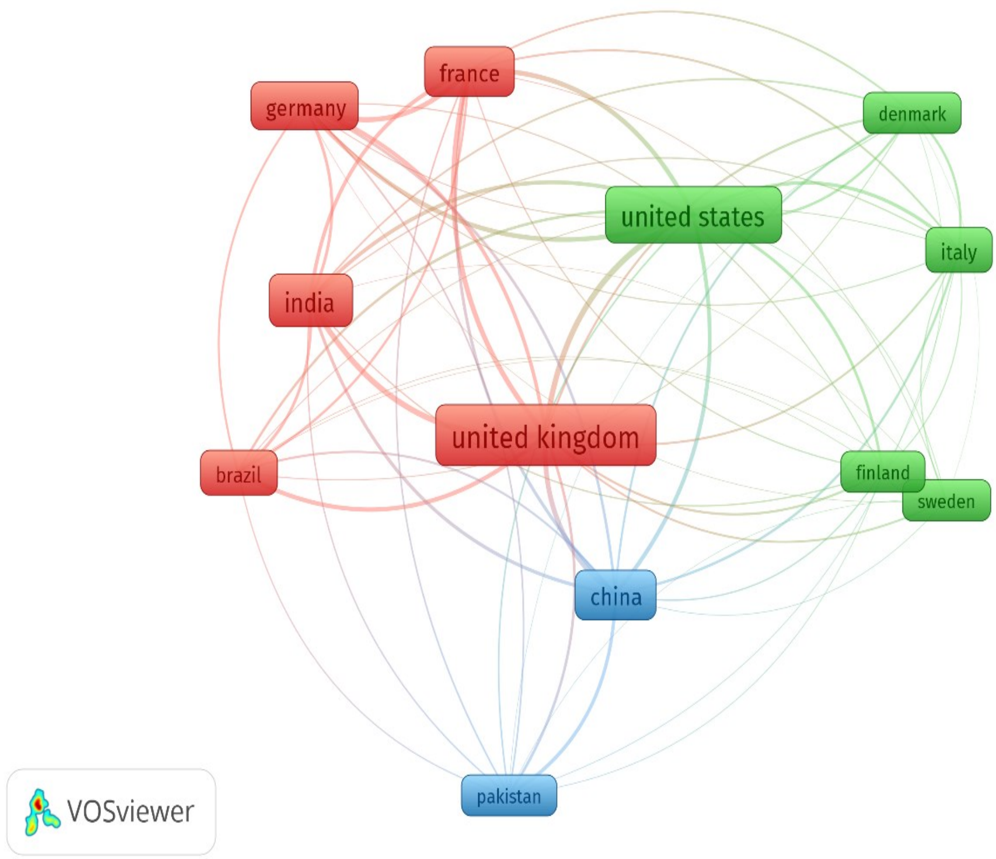

FIGURE 6: COUNTRY BASED RESEARCH CONTRIBUTION

In this case, the United Kingdom (UK) was positioned top scoring 52 authors and 1601 citations. The USA holds the second position with 31 authors scoring 2438 citations. The overall output of total authors and citations has been stated in Table 5.

Table 5: Country-based scientific authors and respective citation scores

Country	Authors	Citations
United Kingdom	52	1601
United States	31	2438
India	25	985
China	19	606
France	17	2023
Germany	15	2591
Italy	10	499
Brazil	9	197
Denmark	6	887
Finland	6	506
Other countries	89	3258

Besides, the selected 132 articles have been classified based on the methodology used. There are 59 articles that used quantitative methods, and the remaining 73 articles used qualitative methods. In the case of specific methodology, the case study and structural equation method (SEM) is the most used methods for qualitative and quantitative studies. An overview of methods has been stated in Figure 7.

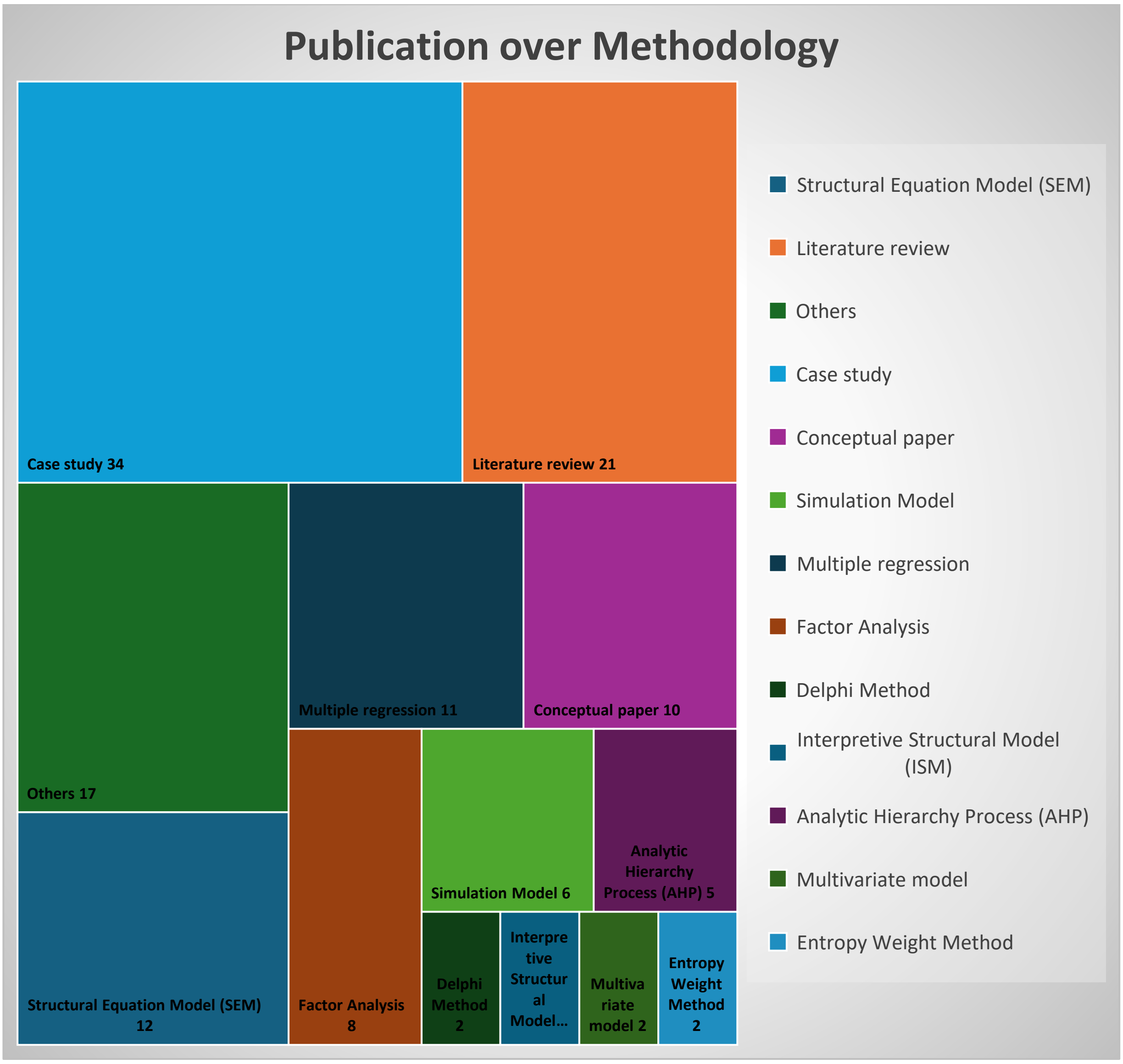

FIGURE 7: MOST USED METHODS IN THE REVIEWED LITERATURE

This study has also identified the most published journals by authors. These 132 articles have been published in 29 journals. There are 11 journals published with a minimum of five articles, and the top three publishing journals are the Journal of Cleaner Production (23 articles and 1690 citations), International Journal of Production Economics (11 articles and 545 citations) and International Journal of Operations and Production Management (10 articles and 378 citations). The Vos viewer output has been shown in Figure 8.

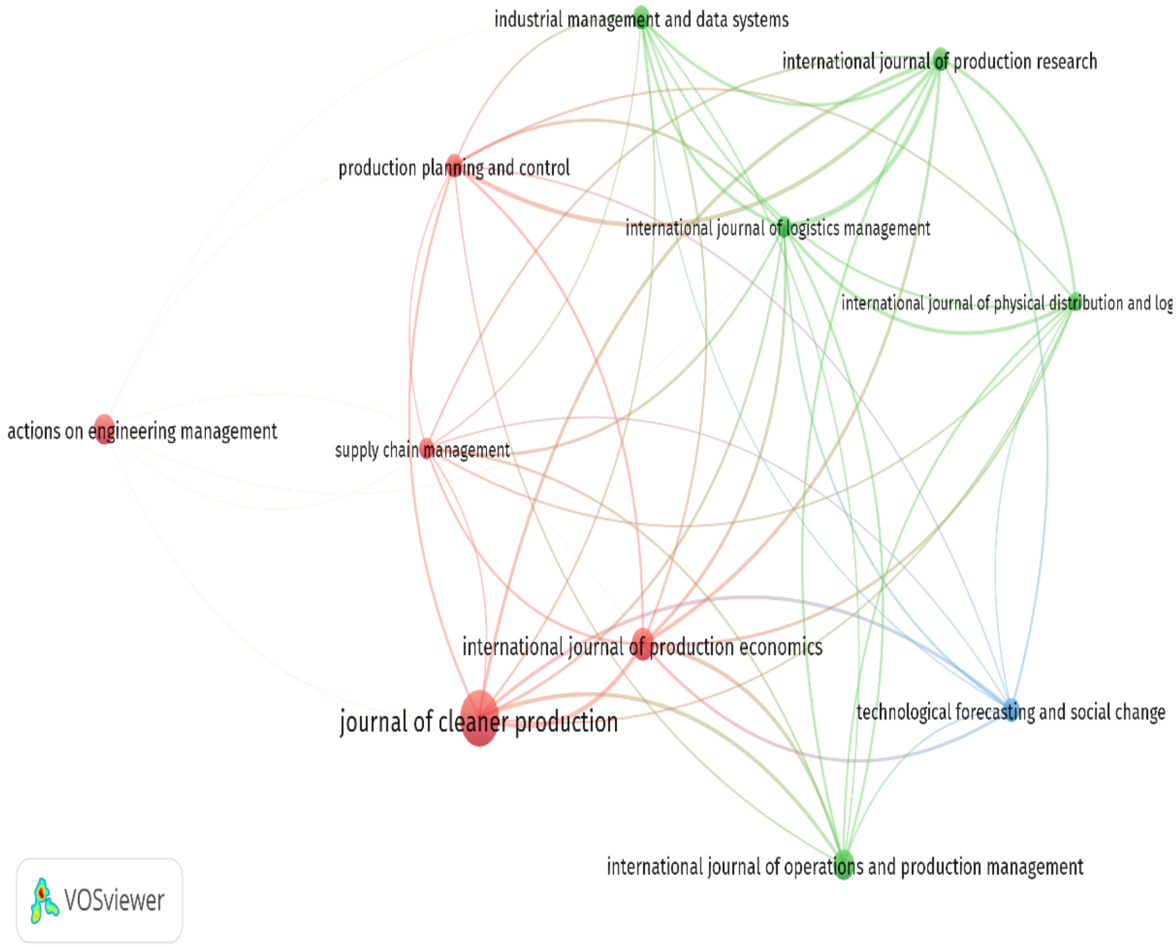

FIGURE 8: TOP ELEVEN JOURNALS FROM TWENTY-NINE JOURNALS

2.1.3.2 Thematic Analysis

This section describes how the constructs of sustainability, resilience, and the issues of digital tools derived from the created Excel sheet. Each of the constructs has been designed based on the three main themes:

a) Conceptual theme of the explored issues

b) Mapping the issues into the reflective construct (Jarvis et al., 2003)

c) True representation of the construct (Coltman et al., 2008)

Firstly, this study explores the issues described from each of the articles in an inductive approach and makes a pool of issues. Secondly, it put similar issues into a common construct to generate 1st-order category of the explored issues. For example, the resilience issues have been classified into four constructs (i.e., visibility, agility, flexibility, and collaboration). Then, since the categorization was still including too many issues, it was decided to further aggregate to a 2^{nd}-order category to obtain the final items for the subsequent research. This was held in an iterative way. Likewise, the issues- integrated human resource management, leadership, and knowledge management- have been named by the ‘management’ construct of social sustainability. Subsequently, all social sustainability issues have been classified into five constructs and broadly internal and external social sustainability construct (Alghababsheh & Gallear, 2022). The environmental sustainability issues are classified into three constructs (i.e., waste management, emission/pollution, and resource efficiency management). As an example, the extracted issues for visibility have been shown in Table 6.

TABLE 6: EXPLORATION PROCEDURE OF ISSUES AND ITEMS FOR VISIBILITY CONSTRUCT

<table>
<tr><td>Explored issues of visibility from literature as a reflective construct</td><td>1^{st} order category of explored issues</td><td>2^{nd} ordered issues (Summarized Items of the questionnaire)</td></tr>
<tr><td rowspan="3">▪ Tracking and tracing (Luthra et al., 2020; Asante et al., 2021; Ivanov D., 2021; McGrath et al., 2021; Bechtsis et al., 2022; Münch & Hartmann, 2022; Silva & Ruel, 2022)
▪ Adoption of innovative analytical tools for visibility (Ahmed et al., 2021; Razak et al., 2021; Sharma et al., 2022)
▪ Assessment of the demand level transparency (Bag et al., 2021; Dev et al., 2021; Mubarik et al., 2021; Sauer et al., 2022)
▪ Visibility through physical transportation (Rothwell et al., 2016; Ivanov D., 2019; Faruquee et al., 2021; Zouari et al., 2021;</td><td>▪ Tracking and tracing
▪ Visibility at demand level
▪ Localization</td><td>Tracking, tracing, and localization system</td></tr>
<tr><td>▪ Visibility through physical transportation
▪ Adoption of innovative analytical tools</td><td>Use of physical transportation and innovative analytical tools</td></tr>
<tr><td>▪ Real-time information sharing, disclosure, data</td><td>Real-time information sharing and disclosure</td></tr>
</table>

<table>
<tr>
<td rowspan="3">Abdul-Hamid et al., 2022; Irfan et al., 2022; Küffner et al., 2022)
▪ Dynamic capabilities through resource resilience (Bag et al., 2021; Faruquee et al., 2021; Münch & Hartmann, 2022; Qader et al., 2022)
▪ Real-time information sharing, disclosure, data location, and process control (Erhun et al., 2021; Frederico et al., 2021; Ivanov D., 2022)
▪ Sensing capability (Belhadi et al., 2022; Silva et al., 2022; Yadav et al., 2022)
▪ Reduction of intermediary for transparency (Köhler & Pizzol, 2020)
▪ Trust and information governance (Grimm et al., 2014; Mol A.P.J., 2015)
▪ Localization strategy for quick visibility (Nandi et al., 2021)</td>
<td>location, and process control
▪ Velocity of information system</td>
<td></td>
</tr>
<tr>
<td>▪ Reduction of intermediary</td>
<td>Reduce intermediaries in the supply chain</td>
</tr>
<tr>
<td>▪ Trust and information governance</td>
<td>Trustworthy information governance system</td>
</tr>
</table>

This exploration and classification have been done to emphasize the key themes (Webster & Watson, 2002; Ridley D., 2012), for a holistic understanding of the concepts (Fink A., 2014) and the coherent structure of the articles (Boell & Cecez-Kecmanovic, 2015). Besides, this study has identified the notable adopted theories for the interactive study. An overview of the most common applied theories is given in Table 7.

TABLE 7: MOST USED THEORETICAL LENS IN THE REVIEWED ARTICLES

Name of the Theory	Sources
Information Processing Theory	Bag et al., (2021); Akhtar et al., (2022); Enrique et al., (2022); Modgil et al., (2022); Qader et al., (2022)
Stakeholder theory	Hussain et al., (2018); Sarkis et al., (2021); Tsolakis et al., (2021)
Contingency theory	Kazancoglu et al., (2022); Song et al., (2022); Tortorella et al., (2022)
Dynamic Capability theory	Li et al., (2022); Silva et al., (2022); Silva et al., (2022)
Panarchy based theory	Mirzabeiki & Aitken, (2022)
Dynamic Capabilities and Relational Capabilities View	Münch & Hartmann, (2022); Nayal et al., (2022)
Resource-based view (RBV) theory	Pereira et al., (2020); Nayal et al., (2022); Sarkis et al., (2021); Tsolakis et al., (2021)
Transaction cost theory	Tsolakis et al., (2021); Nayal et al., (2022)
Grey prediction theory	Rajesh R., (2016)
Behavioral reasoning theory	Yadav et al., (2022)

Finally, the study classifies all the articles into four interactive groups based on their interaction. These four interactions are

I. Sustainability and resilience: the articles that only focus on the issues of sustainability and resilience
II. Sustainability and digital tools: the articles that only focus on the issues of digital tools and sustainability

III. Resilience and digital tools: articles that only focus on the issues of digital tools and resilience
IV. Sustainability, resilience, and digital tools: the articles that focused on the issues related to three concepts: sustainability, resilience and digital tools in SC.

This thematic analysis has been done to identify the common theme across the systematic literature review and make a qualitative assessment of the study. It also assists to figure out the conceptual framework, and know the research pattern, trends, and future direction. Finally, this thematic analysis section leads to the findings of the study and begins to answer the research questions.

2.2 Findings from Systematic Literature Review

This section aims to answer SRQ_1 and SRQ_2 of the research question 1. The issues explored in the literature are collected and aggregated according to their constructs. To answer SRQ_1 of the research question 1, the issues of social and environmental sustainability, resilience, and digital tools have been classified based on their respective constructs. This process has been performed through the full-text reading, the identification of explored issues and the assigning of them to the respective concepts. Subsequently, the issues inside the concepts have been clustered along specific constructs that could represent all the issues included. Accordingly, all explored issues of the social sustainability concept have been clustered along with the constructs of management, workers, customers, suppliers, and overall society.

These five constructs are also classified into two major constructs of social sustainability (i.e., internal social sustainability and external social sustainability). The internal social sustainability consists of two constructs (management and workers) that are within the company. Besides, external social sustainability is associated with the customers, suppliers, and overall society that are externally connected to the supply chain actors. Successively, environmental sustainability has been classified into three constructs: waste management, pollution/emission, and resource efficiency management. The constructs of resilience have also been clustered into visibility, agility, flexibility and collaboration. Moreover, the digitalization through the use of various digital tools has been identified, and five notable digital tools have been highlighted. Figure 9 shows the summary of the overall scheme of the issues explored.

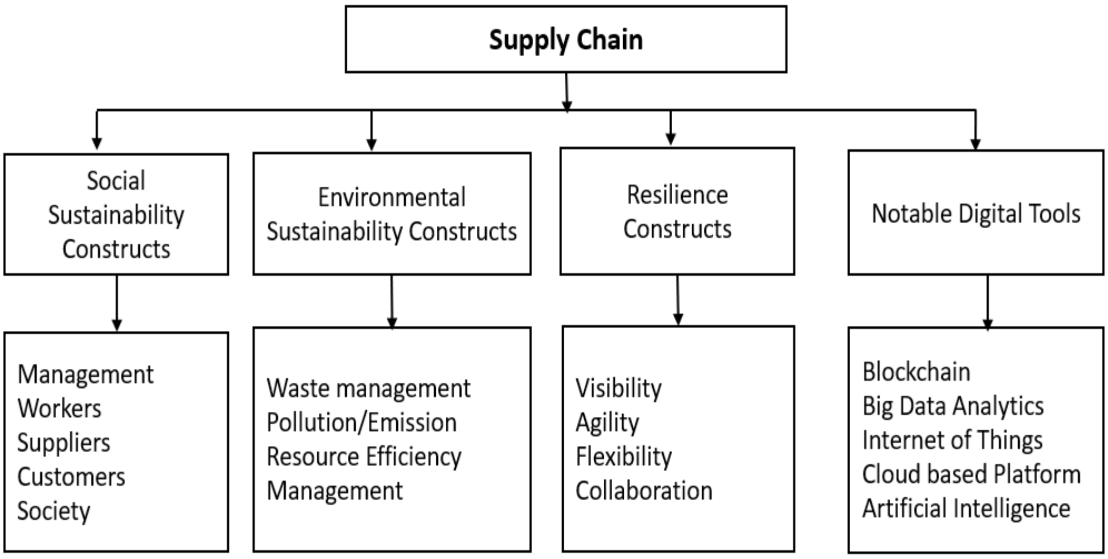

FIGURE 9: LIST OF EXPLORED CONSTRUCTS AND NOTABLE DIGITAL TOOLS IN THE SUPPLY CHAIN

2.2.1 Social Sustainability Issues in Supply Chain

Sustainability in the supply chain contributes to the effective use of social, economic and environmental resources. It consists of reducing unemployment, consumption, waste, and transforming waste into resources. Social sustainability reveals employee and customer satisfaction through sustainable governance, sustainable management, educational campaigns, social gain, relationships with suppliers and mutual trust among actors (Benzidia et al., 2021; Bressanelli et al., 2021). The explored issues related to internal and external social sustainability emerging from literature have been outlined in Table 8 and Table 9.

TABLE 8: ISSUES OF INTERNAL SOCIAL SUSTAINABILITY AND REFERENCES

Issues of Management (MGMT) Construct	References
• Relationship within the hierarchy and departments	(Del Giudice et al., 2020; McGrath et al., 2021; Tsolakis et al., 2021; Bechtsis et al., 2022; Han & Trimi, 2022)
• Resource management and governance	(Govindan et al., 2014; Koh et al., 2017; Luthra et al., 2020; Dev et al., 2021; Rajesh R., 2021; Reyes et al., 2021; Kazancoglu et al., 2022; Nayal et al., 2022; Belhadi et al., 2022; Silva & Ruel, 2022)
• Integrated human resource development practices	(Becker et al., 2010; Govindan et al., 2014; Silva et al., 2022)
• Leadership	(Frederico et al., 2020; Münch & Hartmann, 2022; Van Nguyen et al., 2022; Yang et al., 2022)
• Knowledge management	(Jena & Ghadge, 2021; Köhler & Pizzol, 2021; Silva et al., 2022; Zhao et al., 2023)
Issues of Workers (WO) Construct	
• Health and safety	(Luthra et al., 2017; Croom et al., 2018; Mastos et al., 2020; Sarker et al., 2021; Agarwal et al., 2022; Sauer et al., 2022; Sharma et al., 2022)
• Working condition for workers	(Luthra et al., 2017; Croom et al., 2018; Kolotzek et al., 2018; Chen & Chen, 2019; López & Ruiz-Benítez, 2019; Sarker et al., 2021; Sarkis J., 2021; Mangla et al., 2022; Strandhagen et al., 2022)
• Worker satisfaction	(Chen & Chen, 2019; López & Ruiz-Benítez, 2020; Abdul-Hamid et al., 2022)

• Education and training for workers	(Frederico et al., 2020; López & Ruiz-Benítez, 2020; Raut et al., 2021; Mangla et al., 2022; Münch & Hartmann, 2022; Chari et al., 2022)

TABLE 9: ISSUES OF EXTERNAL SOCIAL SUSTAINABILITY AND REFERENCES

Explored Issues of Customer (CUS)	References
• Customer satisfaction	(Abdul-Hamid et al., 2022; Kayikci et al., 2022; Nayal et al., 2022)
• Customer loyalty and retention	(Bag et al., 2021; Ahmad et al., 2022)
• Responsiveness to customer preference	(Ali et al., 2021; Mubarik et al., 2021; Sodhi & Tang, 2021; Kazancoglu et al., 2022; Lin et al., 2023)
• Customer interaction and relationship	(Frederico et al., 2020; Sarkis J., 2021; Yang et al., 2021; Agarwal et al., 2022; Han & Trimi, 2022; Münch & Hartmann, 2022)
Explored Issues of Suppliers (SUP)	
• Supplier relationship	(Becker et al., 2010; Croom et al., 2018; Pereira et al., 2020; Bag et al., 2021; Jena & Ghadge, 2021; Han & Trimi, 2022; Münch & Hartmann, 2022)
• Benefits and improvement program for suppliers	(Eggert & Hartmann, 2023)
• Disclosure of supplier issue	(Grimm et al., 2014)
• Supplier responsiveness to sustainability practices	(Kazancoglu et al., 2022)
• Relational capital of suppliers	(Benzidia et al., 2021; McGrath et al., 2021; Münch & Hartmann, 2022)
• Child labour practices	(Croom et al., 2018; Kolotzeks et al., 2018; Hannibal & Kauppi, 2019; Aldrighetti et al., 2021)
Explored issues of Society (SO)	

• Job creation	(Bressanelli et al., 2021; Agarwal et al., 2022; Mastrocinque et al., 2022)
• Human rights	(Koh et al., 2017; Kolotzek et al., 2018; Croom et al., 2018; Hannibal & Kauppi, 2019; Aldrighetti et al., 2021; Upadhyay et al., 2021; Eggert & Hartmann, 2023)
• Social education and well-being program	(Kolotzek et al., 2018; Aldrighetti et al., 2021; Rajesh R., 2021; Asokan et al., 2022; Eggert & Hartmann, 2023)
• Rational consumption and social health	(Agarwal et al., 2022; Strandhagen et al., 2022)
• Ethics and community commitment	(Koh et al., 2017; Chen & Chen, 2019; Lu et al., 2020; Cristiano S., 2021; Amin-Chaudhry et al., 2022; Asokan et al., 2022; Costa et al., 2022)
• Social governance	(Mol A.P.J, 2015; Rothwell et al., 2016; Hohn & Durach, 2021; Asokan et al., 2022; Eggert & Hartmann, 2023)
• Regulatory compliance	(Hussain et al., 2018; Rajesh R., 2019; Sarker et al., 2019; Kittipanya-ngam & Tan, 2020; Luthra et al., 2020)
• Cultural value and diversity	(Grimm et al., 2014; Hussain et al., 2018; Kolotzek et al., 2018)
• Stakeholder rights and Non-Governmental Organisation (NGO) role	(Luthra et al., 2017; Rajesh R., 2019, Raut et al., 2021; Sodhi & Tang, 2021; Hrouga et al., 2022)

2.2.2 Environmental Sustainability Issues in Supply Chain

Environmental sustainability covers the initiative of reducing air and water pollution, carbon emission and solid waste management and improving the environmental situation (Erhun et al., 2021; Esfahbodi et al., 2023). The extracted issues of environmental sustainability have also been extensively described in literature. This study categorizes all the environmental sustainability issues by three constructs: waste management, pollution/emission, and resource efficiency management. The issues highlighted of each of the constructs are stated in Table 10.

TABLE 10: EXPLORED ISSUES AND CONSTRUCTS OF ENVIRONMENTAL SUSTAINABILITY

Issues of Environmental Sustainability	References
Waste Management (WST) construct	
• Waste reduction	(Govindan et al., 2014; Dubey et al., 2019; Abdul- Erhun et al., 2021; Reyes et al., 2021; Hrouga et al., 2022; Hamid et al., 2022; Nayal et al., 2022)
• Waste reuse and treatment	(Zhong et al., 2017; Sodhi & Tang, 2021; Agarwal et al., 2022; Hrouga et al., 2022)
• Circular economy	(Del Giudice et al., 2020; Mastos et al., 2020; Khan et al., 2021; Mastos et al., 2021; Sarkis J., 2021; Bressanelli et al., 2021; Agarwal et al., 2022; Chari et al., 2022)
• Natural conservation and ecological balance	(Chen & Chen, 2019; Kittipanya-ngam & Tan, 2020; Köhler & Pizzol, 2020; Raut et al., 2021; Mangla et al., 2022; Yang et al., 2022; Sauer et al., 2022)
Pollution/Emission (P/E) construct	
• Water and air pollution level	(Chen & Chen, 2019; Dubey et al., 2019; Abdul-Hamid et al., 2022)
• Greenhouse gas reduction	(López & Ruiz-Benítez, 2020; Agarwal et al., 2022; Mastrocinque et al., 2022; Nayal et al., 2022)
• Carbon emission rate and reporting	(Koh et al., 2017; Bag et al., 2021; Esfahbodi et al., 2023)
• Solid waste emission	(Dubey et al., 2019; López & Ruiz-Benítez, 2020; Esfahbodi et al., 2023)
• Emission from the supplier’s perspective	(Erhun et al., 2021)

• Global warming and monitoring emission	(Mastos et al., 2020; Esfahbodi et al., 2023)
Resource Efficiency Management (REM) construct	
• Reduce the consumption of natural resources	(Chen & Chen, 2019; Ali et al., 2021; Strandhagen et al., 2022)
• Reverse logistics	(Govindan et al., 2014; Agarwal et al., 2022)
• Efficient resource utilization	(Tsolakis et al., 2021; Chari et al., 2022; Costa et al., 2022; Sharma et al., 2022)
• Energy management	(Chen & Chen, 2019; López & Ruiz-Benítez, 2020; Mastos et al., 2020; Sharma et al., 2021; Abdul-Hamid et al., 2022; Kamble et al., 2022; Strandhagen et al., 2022)
• Green design and innovation	(Luthra et al., 2017; Bechtsis et al., 2022; Mastrocinque et al., 2022)
• Environmental accounting and reporting	(Koh et al., 2017)
• Environmental awareness	(Sarkis et al., 2021)

2.2.3 Resilience Issues in the Supply Chain

Resilience is defined as the ability to manage performance variability and demonstrate adaptive capacity for rapid response and recovery (Akhtar et al., 2022). Its connection with sustainability has been explored from multiple theoretical perspectives, including the Resource-Based View (Tsolakis et al., 2021; Nayal et al., 2022), Information Processing Theory (Bag et al., 2021; Enrique et al., 2022), and Stakeholder Theory (Hussain et al., 2018). However, a recurring theme in the literature is the application of the Dynamic Capabilities Theory, which has gained prominence due to limitations in the resource-based view theory for explaining resilience in dynamic environments (Pereira et al., 2021; Silva & Ruel, 2022; Li et al., 2022; Yang et al., 2022; Münch & Hartmann, 2022). For instance, Pettit et al., (2010) identified fourteen critical dynamic capabilities for resilience, such as visibility, flexibility, and collaboration—all vital for achieving sustainability. Furthermore, agility is also increasingly recognized as a key resilience construct that supports sustainable practices (Patrucco &

Kahkonen, 2021; Akhtar et al., 2022). Based on patterns observed in recent literature, this study focuses on four frequently studied constructs of resilience (visibility, agility, flexibility and collaboration) that are closely associated with sustainability (Belhadi et al., 2021; Aldrighetti et al., 2021; Faruquee et al., 2021). The explored issues of resilience and their respective references have been stated in Table 11.

TABLE 11: RESILIENCE ISSUES, CONSTRUCTS AND REFERENCES

Explored Issues of Resilience	References
Visibility (VIS) construct	
• Tracking and tracing	(Luthra et al., 2017; Luthra et al., 2020; Asante et al., 2021; Ivanov D., 2021; McGrath et al., 2021; Bechtsis et al., 2022; Silva & Ruel, 2022)
• Visibility through physical transportation	(Rothwell et al., 2016; Ivanov D, 2019; Lohmer et al., 2020; Zouari et al., 2021; Faruquee et al., 2021; Abdul-Hamid et al., 2022; Irfan et al., 2022; Küffner et al., 2022)
• Adoption of innovative analytical tools for visibility	(Ahmed et al., 2021; Razak et al., 2021; Sharma et al., 2022)
• Visibility at the demand level	(Bag et al., 2021; Dev et al., 2021; Mubarik et al., 2021; Sauer et al., 2022)
• Real-time information sharing, disclosure, data location and process control	(Erhun et al., 2021; Frederico et al., 2021; Ivanov D., 2022; Lv et al., 2022; Qader et al., 2022;)
• Sensing capacity	(Belhadi et al., 2022; Silva et al., 2022; Yadav et al., 2022)
• Reduction of intermediary	(Köhler & Pizzol, 2020)
• Velocity of the information system	(Tsolakis et al., 2021; Li et al., 2022)
• Trust and information governance	(Grimm et al., 2014; Mol A.P.J., 2015)
• Localization	(Nandi et al., 2021)
Agility (AGL) construct	
• Leverage supply network	(Reyes et al., 2021; Sarkis J., 2021)

• Rapid response capacity to market	(Grimm et al., 2014; Kolotzek et al., 2018; Erhun et al., 2021; Faruquee et al., 2021; Rajesh R., 2021; Sodhi & Tang, 2021; Irfan et al., 2022; Kazancoglu et al., 2022)
• Supplier segmentation based on crisis	(Taleizadeh et al., 2022)
• Frequency of remanufactured services before competitor	(Croom et al., 2018; Bag et al., 2021; Mubarik et al., 2021)
• Human capital recruitment or acquisition strategy	(Becker et al., 2010; Silva & Ruel, 2022)
Flexibility (FLE) construct	
• Flexible capacity in uncertain demand and disparity	(Aldrighetti et al., 2021; Faruquee et al., 2021; Ahmad et al., 2022; Kazancoglu et al., 2022; Tortorella et al., 2023)
• Flexible sources and supplier orientation	(Govindan et al., 2014; Bag et al., 2021; Sarkis J., 2021)
• Flexible operations and management	(López & Ruiz-Benítez, 2020; Pereira et al., 2020; Reyes et al., 2021; Gupta et al., 2021; Irfan et al., 2022; Silva et al., 2022)
• Flexibility for competitive advantages	(Hussain et al., 2018)
• Postponement, automated factory, and omnichannel SC	(Ivanov D., 2021)
• Rapid operational response	(Nayal et al., 2022)
Collaboration (COL) construct	
• Coordination with actors through information sharing	(Ivanov et al., 2019; A.S & Ramanathan, 2021; Erhun et al., 2021; Mastos et al., 2021; Küffner et al., 2022; Silva et al., 2022; Yang et al., 2022)
• Horizontal and vertical integration with suppliers and others	(Koh et al., 2017; Croom et al., 2018; Mastos et al., 2020; Jena & Ghadge, 2021; Bag et al., 2021;

	Chari et al., 2022; Belhadi et al., 2022; Eggert & Hartmann, 2023)
• Stakeholder interaction and compliance agreement	(Pereira et al., 2020; Bechtsis et al., 2022; Münch & Hartmann, 2022)
• In-firm integration and empowerment	(Becker et al., 2010; Costa et al., 2022; Silva & Ruel, 2022)
• Collaborative planning, forecasting, and replenishment	(Frederico et al., 2021; Golan et al., 2021; Ivanov & Dolgui, 2021; Razak et al., 2021)
• Human-machine collaboration and networking	(McGrath et al., 2021; Tsolakis et al., 2021; Ivanov D., 2022)

2.2.4 Issues of Digital Tools in the Supply Chain

Digitalization in the supply chain research is defined as a set of practices of digital tools that allow the supply chain to be intelligent, customer-centric, system-integrated, globally connected, and data-driven (A.S & Ramanathan, 2021; Aldrighetti et al., 2023). The application of I4.0 is one of the disruptive innovations in the digital supply chain, which was initiated by Germany in 2011, mostly the application of digital tools in the manufacturing and service industry, namely, artificial intelligence, blockchain, the Internet of Things, big data analytics and others. The notable digital tools have been explained here.

Blockchain is a cryptographically secure decentralized database that generates a digital log of trusted and immutable transactions, which are encapsulated in blocks, a process known as mining, and can be shared between a public or private network. The cloud-based platform is a technological ecosystem used for collecting and managing information across the SC to handle data streams in SC operations (Bechtsis et al., 2022). Artificial intelligence is an advanced computer system that elaborates data and functions following human behavior (Aldrighetti et al., 2023). Big Data Analytics (BDA) capabilities are the technology to collect, process, and extract meaningful insights from real-time data to support appropriate and timely decision-making (Belhadi et al., 2022). The Internet of Things (IoT) enables the connection of human, machines, products, and equipment for real-time data collection through interconnected networks and analytical autonomy (A.S & Ramanathan, 2021). The most frequently used digital tools and the issues explored related to sustainability and resilience have been listed with respective references in Table 12.

TABLE 12: ROLE OF DIGITAL TOOLS FOR SUSTAINABILITY AND RESILIENCE IN THE SUPPLY CHAIN

Role of digital tools for sustainability and resilience	References
Blockchain (BLC)	
• Customer satisfaction	(Quayson et al., 2021; Abdul-Hamid et al., 2022; Kayikci et al., 2022)
• Circular purchase and design	(Khan et al., 2021; Mastos et al., 2021; Tsolakis et al., 2021)
• Knowledge management and resource sharing	(Köhler & Pizzol, 2020; Tsolakis et al., 2021; Mangla et al., 2022)
• Employee satisfaction	(Abdul-Hamid et al., 2022; Asokan et al., 2022)
• Supplier relationship	(McGrath et al., 2021)
• Transparency and decentralization	(Min H., 2019; Asante et al., 2021; McGrath et al., 2021; Nandi et al., 2021; Razak et al., 2021; Tsolakis et al., 2021)
• Collaboration through the trust	(Lohmer et al., 2020; Mastos et al., 2021)
Big Data and Predictive Analysis (BDPA)	
• Communication and information sharing	(Raut et al., 2021; Bag et al., 2022; Nayal et al., 2022)
• Circular design and HR development	(Dubey et al., 2019; Del Giudice et al., 2020; Nayal et al., 2022)
• Flexible supply chain	(Rajesh R., 2016)
• Customer satisfaction	(Raut et al., 2021)
Internet of Things (IOT)	
• Improve visibility tracking system	(A.S & Ramanathan, 2021; Mubarik et al., 2021; Irfan et al., 2022; Küffner et al., 2022; Yadav et al., 2022)
• Collaborative planning	(Sharma et al., 2022)
• Information sharing	(Yadav et al., 2022)
Cloud-based Platform (CBP)	

• Customer satisfaction and employee satisfaction	(Abdul-Hamid et al., 2022; Mastrocinque et al., 2022)
• Social network and circular supply chain design	(Bressanelli et al., 2021; Kamble et al., 2021)
• Analytics and warning capability	(Faruquee et al., 2021; Liu & Wei, 2022)
• Trust-based relationship and information sharing	(Ivanov et al., 2019; Han & Trimi, 2022; Nayal et al., 2022; Van Nguyen et al., 2022)
Artificial Intelligence (AI)	
• Operations management	(Deiva et al., 2022)
• Strategic planning and recovery management	(Golan et al., 2021; Gupta et al., 2021; Irfan et al., 2022; Kamble et al., 2022)
• Real-time information sharing	(Mubarik et al., 2021; Ivanov D., 2021; Zouari et al., 2021; Lv et al., 2022; Modgil et al., 2022; Nayal et al., 2022)
• Adaptability, alignment, and agile supply chain	(Mak & Max., 2021)
• Customer satisfaction	(Nayal et al., 2022)

2.3 Interaction among Sustainability, Resilience and Digital Tools in the Supply Chain

To answer SRQ_2 of the research question 1, this section explains how the concepts of sustainability, resilience and digital tools are connected and what are the combined issues that have been discussed in literature. There are four interactions identified from three concepts. These four interactions have been displayed and explained in Figure 10 and following sections.

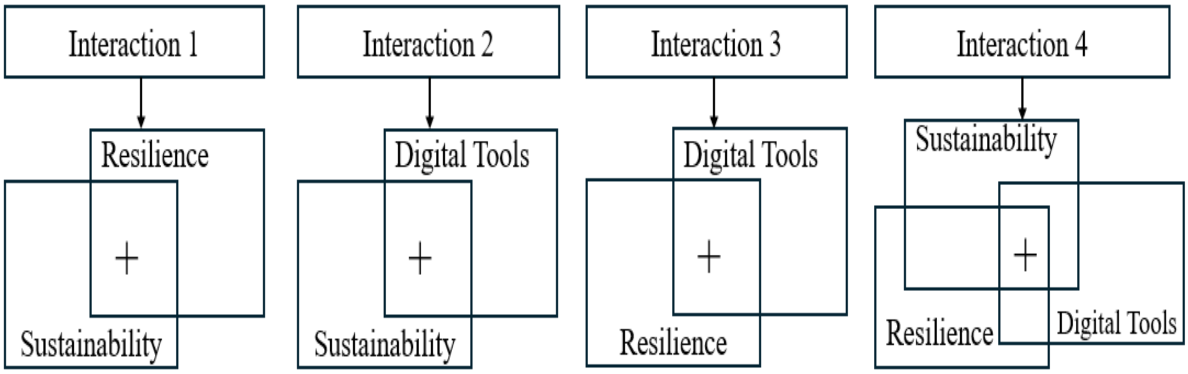

FIGURE 10: FOUR INTERACTIONS OF THREE CONCEPTS IN THE SUPPLY CHAIN

2.3.1 Interaction 1: Sustainability and Resilience

This interaction outlines the comprehensive overview of 36 articles that study the various constructs and issues of social and environmental sustainability and resilience. It inferred that sustainability and resilience are interdependent and influence one another. Their interaction generates both synergies and trade-offs within supply chains. Several studies suggest that sustainability practices enhance SC resilience. For instance, customer relationships, employee safety, and intra-organizational management have been shown to foster transparency, collaboration, and flexibility in supply chains. Besides, practices of social sustainability—such as knowledge management, supplier empowerment, and a supportive organizational culture—promote collaboration and visibility through socially responsible and inclusive procurement strategies and ethical sourcing. Subsequently, it creates a strong buyer–supplier relationship. Furthermore, social sustainability efforts also improve agility and visibility by facilitating intensive information exchange among supply chain stakeholders on policy compliance, human rights, and health and safety issues (Eggert & Hartmann, 2023).

Conversely, resilience practices play a critical role in promoting sustainability in supply chains. Such agile and flexible capabilities of resilience positively influence responsible supply chain performance by enabling rapid logistic responses to demand variability and supporting strategic planning. Moreover, practices such as flexible sourcing and transportation positively affect environmental sustainability by reducing lead time and facilitating greener SC operations. Collaboration, a key dimension of resilience, also serves as a catalyst for sustainability by reducing waste and promoting circularity. Collaboration also ensures sustainability by securing rational consumption and reversed logistics in the supply chain. It further strengthens social sustainability by enabling more effective monitoring and reporting of social capital and resource mapping. In summary, existing literature predominantly emphasizes the 'management' construct of social sustainability and highlights collaboration as a central construct of resilience over visibility, agility, and flexibility. However, there is limited research concerning the governance and information disclosure of suppliers, particularly in relation to agility and flexibility constructs of resilience. Furthermore, visibility is frequently examined in the context of pollution/emission reduction; other resilience constructs—such as agility and flexibility—remain underexplored in their contributions to the broader sustainability and resilience nexus. The list of interconnected constructs of sustainability and resilience is displayed in Table 13.

TABLE 13: LIST OF SUSTAINABILITY AND RESILIENCE CONSTRUCTS WITH RESPECTIVE LITERATURE

Authors	Social	Environmental	Resilience
	Sustainability		
Agarwal et al., (2022)	MGMT, CUS, SO	WM, EM	COL
Ahmad et al., (2022)	CUS		FLE
Aldrighetti et al., (2021)	MGMT, SO		AGL, FLE
Ali et al., (2021)	CUS	REFF	COL
Amin-Chaudhry et al., (2022)	SO		COL
Becker et al., (2010)	MGMT, CUS, SO		FLE
Chen & Chen, (2019)	MGMT, SO	P, REFF	COL
Costa et al., (2022)	SO	WM	AGL, COL
Cristiano, (2021)	SO	REFF	RES
Croom et al., (2018)	MGMT		AGL, COL
Eggert & Hartmann, (2023)	SO, SUF	REFF	COL
Erhun et al., (2021)	MGMT,	WM, EM	AGL, COL
Fagundes et al., (2020)	MGMT, CUS, SUP		FLE
Govindan et al., (2014)	MGMT	WM, REFF	AGL, FLE
Grimm et al., (2014)	CUS, SUP, SO		AGL
Hosseini et al., (2019)	SUP		AGL, FLE, COL

Hussain et al., (2018)	SO		FLE
Jena & Ghadge, (2021)	MGMT, SUP		AGL, COL
Kazancoglu et al., (2022)	MGMT, CUS, SUP		FLE
Koh et al., (2017)	MGMT, SO	EM, REFF	COL
Kolotzek et al., (2018)	WOR, SO	WM	AGL, COL
López & Ruiz-Benítez, (2020)	WOR	WM, EM	AGL, FLE
Luthra et al., (2017)	WOR, SO	WM	VIS
Mol A.P.J, (2015)	SO	REFF	VIS
Münch & Hartmann, (2023)	WOR, CUS, SUP		VIS, AGL, FLE, COL
Pereira et al., (2020)	MGMT, SUP		FLE, COL
Rajesh R., (2019)	MGMT, WOR, SO		AGL
Rajesh R., (2021)	MGMT, SO		AGL
Rothwell et al., (2016)	SO	EM	VIS
Sarker et al., (2021)	WOR, SO		FLE
Sauer et al., (2022)	MGMT, SO	WM	VIS, FLE
Silva et al., (2023)	MGMT		VIS, FLE, COL
Silva & Ruel, (2022)	MGMT, SUP		VIS, FLE, COL
Sodhi & Tang, (2021)	SO	REFF	AGL
Taleizadeh et al., (2022)	SO	EM	AGL
Wang et al., (2022)	CUS, SUP		COL

MGMT= Management, WOR = Worker, CUS = Customer, SUP = Supplier, SO = Society, WM = Waste Management, EM = Emission P = Pollution, REFF = Resource Efficiency, VIS = Visibility, AGL = Agility, FLE = Flexibility, COL = Collaboration.

2.3.2 Interaction 2: Sustainability and Digital Tools

This section synthesizes the findings of 30 articles that examine the intersection of digital tools and sustainability within supply chains. Most of the research indicates that data-driven supply chains enabled by I4.0 digital tools have a positive influence on both environmental and social sustainability. Specifically, digital tools enhance organizational and social performance by fostering responsible relationships, promoting the health and safety of actors, supporting social welfare, and advancing social governance. As an example, Big Data and Predictive Analytics (BDPA) is shown to improve organizational culture and reduce emission by enhancing technological competencies, managerial capabilities, organizational learning, and operational flexibility (Dubey et al., 2019). Besides, digital tools often serve a moderating and mediating role in the relationship between sustainability and resilience. The I4.0 tools have been found to moderate the relationship between closed-loop supply chains and social and environmental sustainability by reinforcing waste management and recycling initiatives (Aldrighetti et al., 2022). Furthermore, the IoT supports supplier sustainability through enhanced partnerships and the sharing of strategic resources and information. As a digital technology, blockchain contributes to circular supply chain practices—such as sustainable purchasing, design, and recycling—while improving environmental performance. It also reduces the reliance on third-party certification by smart contract mechanism.

However, the literature remains limited regarding how I4.0 tools contribute to social stakeholder engagement, social value creation, and the impact of I4.0 on broader supply chain community development. To address these limitations, Acioli et al., (2021) advocate for the adoption of Society 5.0 principles. They suggested public awareness, collaborative stakeholder management, technological readiness, and regulatory frameworks to facilitate the transition to a digitalized and sustainable supply chain. A comprehensive list of interconnected constructs of sustainability and digital tools is provided in Table 14.

TABLE 14: LIST OF SUSTAINABILITY CONSTRUCTS AND DIGITAL TOOLS WITH THE RESPECTIVE LITERATURE

Authors	Digital tools	Sustainability	
		Social	Environmental
Abdul-Hamid et al., (2022)	BLC, AI, IoT, CBP, BDPA	WOR, CUS	P, EM
Acioli et al., (2021)	CBP, BLC, BDPA	CUS, SO	
Aldrighetti et al., (2023)	BDPA, AM	MGMT, WOR	EM, WM
Asokan et al., (2022)	BLC, BDPA, IoT, AI	SO	
Benzidia et al., (2021)	BLC	SUP	
Bressanelli et al., (2021)	BLC, IoT, CBP, BDPA	SO	REFF
Del Giudice et al., (2020)	BDPA	MGMT	WM
Dubey et al., (2019)	BDPA	WOR	P, EM
Esfahbodi et al., (2023)	BLC		WM, P, EM

Frederico et al., (2020)	BLC, BDPA, AI, IoT, CBP	MGMT, SUP, CUS	
Han & Trimi, (2022)	IoT, BDPA, CBP	SO	
Hannibal & Kauppi, (2019)	I4.0	SO	
Hohn & Durach, (2021)	AM	MGMT, SO	
Hrouga et al., (2022)	BLC, IoT	SO,	WM
Kamble et al., (2022)	BLC, IoT, AI, CBP		WM, REFF
Kauffman & Riggins, (2012)	I4.0	SO	
Kayikci et al., (2022)	BLC	WOR, CUS	
Khan et al., (2021)	BLC		WM, REFF
Kittipanya-ngam & Tan, (2020)	BLC, IoT	SO	WM, P
Li et al., (2020)	AI, BDPA	SO	
Lu et al., (2020)	I4.0	SO	
Mangla et al., (2022)	BLC	MGMT, WOR	EM
Mastrocinque et al., (2022)	AI, IoT, CBP, BDPA	WOR, SO	EM, REFF
Nguyen et al., (2022)	DT	MGMT	
Quayson et al., (2021)	BLC	SO	
Sarkis et al., (2021)	BLC, IoT, CBP	MGMT, SO	REFF
Sharma et al., (2021)	I4.0	SO	WM, REFF
Strandhagen et al., (2022)	IoT, BDPA, AM	WOR, SO	REFF, WM, EM
Upadhyay et al., (2021)	BLC	SO	
Zhong et al., (2017)	IoT		WM

BLC = Blockchain, IoT = Internet of Things, AI = Artificial Intelligence, BDPA = Bigdata and Predictive Analytics, DT = Digital Twin, AM = Additive Manufacturing, CBP = Cloud based platform, DT = Digital Technology, I4.0 = Industry 4.0, ERP = Enterprise Resource Planning, RFID = Radio Frequency Identification, MGMT= Management, WOR = Worker, CUS = Customer, SUP = Supplier, SO = Society, WM = Waste Management, EM = Emission P = Pollution, REFF = Resource Efficiency.

2.3.3 Interaction 3: Resilience and Digital Tools

The application of digital tools has been extensively examined in relation to the visibility and collaboration constructs of resilience in the supply chains. Empirical evidence suggests that BDPA enhances community and resource resilience by improving responsiveness, transparency among SC actors, managerial capabilities, and competitive advantage (Bag et al., 2022). It also fosters resilient supply chains through dynamic capabilities, particularly joint problem-solving and effective communication. Similarly, blockchain technology positively influences collaboration by enabling trust, rapid response, and flexibility. It also facilitates a secure and transparent supply chain through smart contracts. Moreover, digital tools emphasize integrating localization, agility, and resilience during disruptions. Besides, Song et al., (2022) argue that digital supply chains enhance resilience by strengthening logistic capabilities, innovativeness, and modularization. The long-term improvements in SC performance are more effectively achieved through the integration of digital tools and the collaboration construct of resilience instead of actor-centric optimization efforts. However, the impact of these digital interventions is significantly influenced by the digital maturity of supply chain actors. A detailed list of interconnected constructs linking resilience and digital tools of 41 articles is presented in Table 15.

TABLE 15: LIST OF RESILIENCE CONSTRUCTS AND DIGITAL TOOLS WITH RESPECTIVE LITERATURE

Authors	Digital Tools	Resilience
A.S & Ramanathan (2021)	IoT	COL
Ahmed Khan et al., (2021)	ATM	VIS, AGL, FLE, COL
Akhtar et al., (2022)	I4.0	AGL, FLE
Asante et al., (2023)	BLC	VIS
Bag et al., (2022)	BDPA	VIS, COL
Belhadi et al., (2021)	BDPA	COL
Burgos & Ivanov, (2021)	DT	AGL
Colicchia et al., (2019)	CI	FLE
Creazza et al., (2022)	ERP	VIS
Deiva & Kalpana, (2022)	AI	VIS
Enrique et al., (2022)	SSC	FLE
Faruquee et al., (2021)	BLC, CBP, AI	VIS, AGL, FLE
Golan et al., (2021)	AI	COL
Gupta et al., (2021)	BLC, AI	VIS, FLE
Irfan et al., (2022)	IoT, AI	VIS, AGL, FLE
Ivanov et al., (2020)	TI	VIS

Ivanov D., (2022)	BDPA	FLE
Ivanov D., (2021)	BLC, AI	VIS
Ivanov & Dolgui, (2021)	BDPA, RFID, ERP, ML	VIS, COL
Hosseini et al., (2019)	BLC, AM, CBP, BDPA	VIS, AGL, FLE, COL
Ju et al., (2021)	I4.0	COL
Küffner et al., (2022)	BLC, IoT	VIS, AGL, COL
Kumar & Mallipeddi, (2022)	BLC, IoT, BDPA, CBP, AI	AGL
Li et al., (2022)	BLC, IoT	VIS
Liu & Wei, (2022)	CBP	AGL
Lohmer et al., (2020)	BLC	VIS, AGL, COL
Lv et al., (2022)	AI, DT	COL
Mak & Max, (2021)	BDPA	AGL
Min H., (2019)	BLC	VIS, FLE
Modgil et al., (2022)	AI	VIS
Nandi et al., (2021)	BLC	VIS, AGL, FLE
Qader et al., (2022)	BLC, IoT	VIS
Rajesh R, (2016)	BDPA	FLE
Ralston & Blackhurst, (2020)	I4.0	AGL
Razak et al., (2023)	BLC	VIS, AGL, COL
Shashi et al., (2020)	IoT, BDPA	AGL, FLE, COL
Song et al., (2022)	BLC, IoT, CBP	AGL
Tortorella et al., (2023)	BLC, IoT, BDPA, CBP, AI	FLE
Vanany et al., (2021)	DT	AGL
Rapaccini et al., (2020)	BLC	AGL
Zouari et al., (2021)	BLC, IoT, AI	VIS, FLE, Col

BLC = Blockchain, IoT = Internet of Things, AI = Artificial Intelligence, BDPA = Big Data and Predictive Analytics, DT = Digital Twin, AM = Additive Manufacturing, CBP = Cloud based platform, DT = Digital Technology, I4.0 = Industry 4.0, ERP = Enterprise Resource Planning, RFID = Radio Frequency Identification, VIS= Visibility, AGL = Agility, FLE = Flexibility, COL = Collaboration, CI = Cyber Intelligence, ERP = Enterprise Resource Planning, SSC = Smart SC, TI = Technological Innovation, DT = Digital Tools

2.3.4 Interaction 4: Sustainability, Resilience and Digital Tools

The intersection of sustainability, resilience, and digital tools remains in its early stages of academic exploration. Most of the existing research comprises literature reviews, conceptual papers, and case studies, rather than empirical and large-scale investigations. A general pattern in the literature reveals that digital tools are predominantly aligned with the management construct of social sustainability, as well as the visibility and collaboration constructs of resilience. However, there is comparatively limited focus on the supplier- and worker-related construct of social sustainability, as well as on the flexibility construct of resilience—areas that warrant further empirical attention.

Digital tools significantly have a positive impact on sustainability performance, responsiveness, and visibility through smart contracts, relational orientation, resource sharing, coordinating alignment, and human-machine cooperation. However, the cost of technological innovation is also a contrasting issue for sustainability and resilience goals. Blockchain stands out as the most extensively utilized tool for enabling real-time transparency and information sharing in supply chains. It contributes positively to both social sustainability and resilience by facilitating information sharing, enhancing product visibility, and improving knowledge management processes. Furthermore, blockchain technology plays a pivotal role in transforming traditional supply chains into closed-loop systems by promoting automation, visibility, and traceability (Mastos et al., 2021). However, the extent to which blockchain empirically moderates the relationship between sustainability and resilience remains underexplored in current research.

Big Data and Predictive Analytics also positively influence social sustainability and resilience. It enables real-time assessment of customer satisfaction, monitors resource consumption, and facilitates tracking and tracing activities. Besides, the IoT contributes to environmental sustainability by continuously monitoring CO_2 emission, enhancing customer responsiveness, and supporting joint logistics and collaboration within supply chains. IoT further promotes operational flexibility and supports backup supplier strategies, thereby reinforcing both customer relationship management and environmental performance (Dev et al., 2021; Yang et al., 2022). In fact, data-driven SC applications foster sustainable and resilient supply chain practices through continuous intra-organizational information flow and data monetization. However, these digital applications are predominantly limited to internal data sharing, but their potential for broader social and environmental sustainability across external supply chain actors remains underutilized. The interconnected constructs from twenty-five reviewed articles on sustainability, resilience, and digital tools are detailed in Table 16.

TABLE 16: LIST OF SUSTAINABILITY, RESILIENCE CONSTRUCTS AND DIGITAL TOOLS WITH RESPECTIVE LITERATURE

Author	Digital tools	Sustainability		Resilience
		Social	Environmental	
Bag et al., (2023)	IoT, BDPA	CUS	WM,	VIS, AGL, FLE, COL
Bechtsis et al., (2022)	BLC, CBP, AI	MGMT, WOR	REFF	VIS, AGL
Belhadi et al., (2022)	AM	MGMT	WM	VIS, AGL, COL
Chari et al., (2022)	IoT	WOR	WM	AGL, COL
Dev et al., (2021)	AM	MGMT	REFF	AGL
Frederico et al., (2023)	IoT, BDPA, CBP	MGMT		VIS, COL
Giotopoulos et al., (2022)	ICT	MGMT, WOR, SO		FLE
Ivanov D., (2023)	BLC, AM, BDPA, I5.0	WOR, MGMT	EM, REFF	VIS, COL
Köhler & Pizzol, (2020)	BLC	MGMT	REFF	VIS, COL
Lin et al., (2023)	DT	MGMT, CUS, SO	REFF	VIS, COL
Luthra et al., (2020)	IoT, BDPA	MGMT, WOR	WM	VIS, COL
Mastos et al., (2021)	BLC		WM, REFF	COL
Mastos et al., (2020)	IoT, BDPA	WOR, SO	P, EM	COL
McGrath et al., (2021)	BLC	MGMT, CUS, SUP		VIS, COL

Mirzabeiki & Aitken, (2023)	BLC	MGMT, WOR	WM	COL
Mubarik et al., (2021)	IoT, BDPA, CBP, AI	CUS, WOR, SUP		VIS, AGL
Nayal et al., (2022)	AM, BDPA, AI, CBP	CUS, SO	WM, EM	FLE, COL
Raut et al., (2021)	BDPA	CUS	REFF	AGL, COL
Reyes et al., (2023)	BLC, IoT, BDPA, CBP	SO	WM	AGL, FLE
Sarkis J, (2021)	BLC, IoT, AM, BDPA	MGMT, WOR, CUS	WM	AGL, FLE
Sharma et al., (2022)	IoT, BDPA	MGMT, CUS, WOR	REFF	VIS, FLE, COL
Tsolakis et al., (2021)	BLC	WOR, SUP	P, REFF	VIS, COL
Van Nguyen et al., (2022)	BDPA, CBP	MGMT		COL
Yadav et al., (2023)	IoT	CUS, SO	REFF	VIS, FLE, COL
Yang et al., (2022)	BLC, IoT, AM, BDPA, CBP, AI	CUS, SUP, MGMT	WM, REFF	FLE, COL

BLC = Blockchain, IoT = Internet of Things, AI = Artificial Intelligence, BDPA = Bigdata and Predictive Analytics, DT = Digital Twin, AM = Additive Manufacturing, CBP = Cloud based platform, DT = Digital Technology, I4.0 = Industry 4.0, ERP = Enterprise Resource Planning, RFID = Radio Frequency Identification, VIS= Visibility, AGL = Agility, FLE = Flexibility, COL = Collaboration, CI = Cyber Intelligence, ERP = Enterprise Resource Planning, SSC = Smart SC, TI = Technological Innovation, DT = Digital Tools MGMT= Management, WOR = Worker, CUS = Customer, SUP = Supplier, SO = Society, WM = Waste Management, EM = Emission P = Pollution, REFF = Resource Efficiency

2.4 Discussion based on the Systematic Literature Review

Based on a critical systematic literature review, this chapter answers research question 1. It identifies which are the best practices used to manage supply chains that combine sustainability, resilience, and digital tools. For concerns about $SRQ_{1.1}$, this SLR identifies the influencing issues of sustainability, resilience and digital tools in supply chain management. From the 132 reviewed articles, most of the articles are qualitative and descriptive, broadly due to the newness of the interaction among these concepts. Additionally, there is limited literature addressing the interplay of these three concepts in the context of performance evaluation within supply chains. This gap approaches the challenge to study more quantitative research on empirical evidence (Bechtsis et al., 2022; McGrath et al., 2021). Chapter 2 explains the possible interactions of the issues and constructs related to sustainability, resilience and digital tools answering $SRQ_{1.2}$. Considering this interaction, subsequently this chapter shows a conceptual research framework to facilitate the interlink between the constructs of the three concepts. Specifically, section 2.3 explained the possible interactions of the issues and constructs related to sustainability, resilience and digital tools, answering $SRQ_{1.2}$.

As evident from some papers (Lebel et al., 2006; Faruquee et al., 2021; Singh et al., 2023) through visibility, agility, flexibility, and collaboration, both social and environmental sustainability constructs can effectively be managed in the supply chain (Interlink-1). Conversely, other approaches show that it is possible to manage sustainability at the supply chain level to foster resilience by leveraging strong customer-supplier relationships, trust mechanism and transparent processes. This approach mitigates social and environmental risks while enhancing capabilities of visibility and collaboration. It ultimately contributes to a resilient supply chain (Interlink-2). Moreover, for what concerns digital tools, they can have an ambivalent role: on one side they play a moderating role in the bidirectional relationship between resilience and sustainability, as demonstrated in Interlinks 3 and 4 *(I3&4).* On the other hand, digital tools also serve as mediators in relationships, as highlighted in Interlink 5 *(I5).* This illustrates how digital tools can both influence and strengthen the connection between sustainability and resilience in the supply chain.

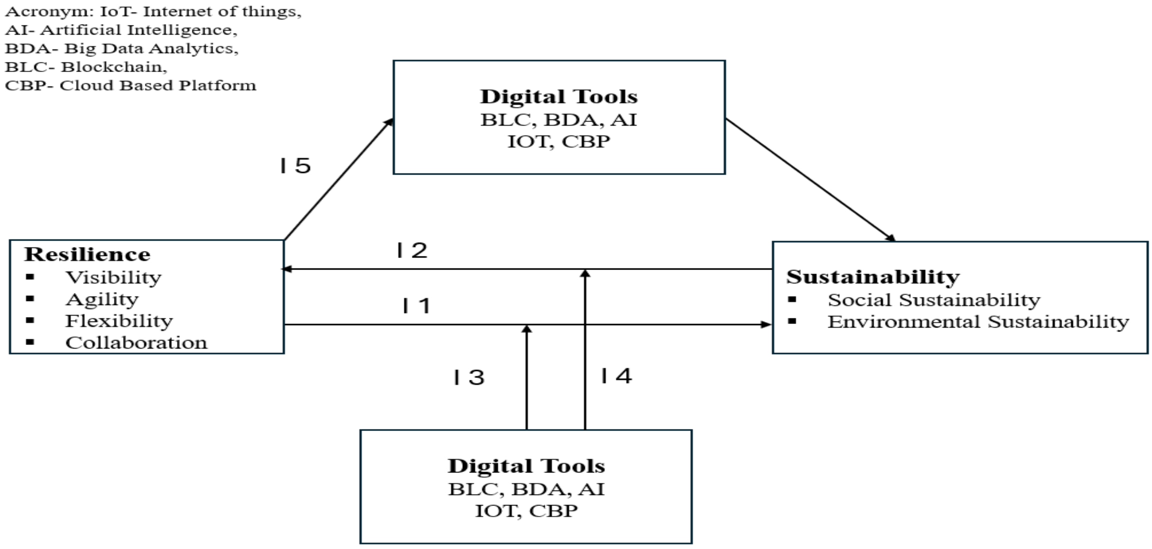

FIGURE 11: CONCEPTUAL FRAMEWORK FROM SLR ON SUSTAINABILITY, RESILIENCE AND DIGITAL TOOLS

However, there are some issues that have been studied less in literature. The reason behind less study could be for global disparity in SC, and complex relationships within the SC actors. Moreover, how digital tools accelerate these complex relationships is also a new research agenda. This study identifies several critical gaps in answering $SRQ_{1.3}$.

- In terms of scope, most prior studies have concentrated on supply chains within specific industries—such as automotive (Ivanov D., 2021), energy (Mastos et al., 2021), and mining (Bag et al., 2022). However, there is a noticeable gap in research focusing on the global fashion industry's supply chain, despite its significant impact on social and environmental sustainability. The fashion industry is responsible for 10% of global carbon emission. This industry is also increasingly under scrutiny for its social implications, particularly concerning labor practices and ethical sourcing that are all related to social and environmental sustainability and resilience practices. Given this context, future research could explore how different resilience constructs influence social and environmental sustainability in the fashion supply chain, considering the contingent role of digital tools.
- The existing literature lacks a unified perspective on the dynamic interplay among sustainability, resilience, and digital tools in supply chain contexts. Moreover, there is a scarcity of comparative evaluations that identify which specific constructs most effectively contribute to jointly enhancing supply chain sustainability and resilience.
- Regarding the impact of digital tools on sustainability and resilience, various approaches have been applied, yielding heterogeneous results. In this context, a confirmatory and

theory-testing study could be a new research direction through empirical validation for the resilience-digital tools-sustainability nexus. In particular, the moderating role of digital tools applications in connection to resilience and sustainability in supply chains could be new empirical research from a developing country perspective.

- Although there is extensive research on the broader concept of resilience, the influence of specific resilience constructs and particular digital tools on sustainability outcomes remains underexplored. For example, the role of collaboration construct in enhancing waste management within environmental sustainability, particularly when moderated by blockchain technology, has not been sufficiently investigated. This presents a promising avenue for future research.
- Environmental and social accounting, reporting, and disclosure practices and digital tools remain underexplored in supply chain literature. How these practices could effectively be managed through resilience and digital innovations could also be a new research avenue.
- An empirical study on the effect of resilience on social and environmental sustainability based on information processing theory, resource-based theory, or dynamic capability theory for a specific industry's global supply chain could also be a new theory-testing study for sustainable supply chains.

This chapter advances the existing literature by detecting the main thematic areas of sustainability, resilience and digital tools and their interactions in the supply chain. It proposes an innovative view of categorizing contributions based on different inter-relational perspectives and the rationale behind them. Specifically, the developed framework can be used to test different hypotheses to be built upon the 3 concepts and upon the research gaps described. The explored and summarized issues of different constructs can benefit decision-makers in choosing appropriate SC decisions. Furthermore, the clustering of studies organizes, synthesizes, and coheres research in a structured way. These strategically support SC actors to identify what sustainability and resilience constructs and digital tools should be proposed for long-term SC performance. Moreover, this chapter identifies several unraveling research works on specific issues. SC stakeholders and academicians can come forward to work on the stated gaps.

Chapter 3: Hypothesis Development and Research Framework

3.1 Background

Based on the foundational understanding of resilience constructs, it is essential to explore their direct effect on social and environmental sustainability within supply chains. Resilience does not only enhance operational continuity but also fosters sustainable business practices. It ensures robustness and recoverability in the supply chain that have positive effects on workers, suppliers, and customers (Rai et al., 2021). Since the volatility is growing in the global supply chains, the integration of resilience strategies becomes imperative for maintaining ethical labor practices, workplace safety, and equitable stakeholder relationships. The interconnected nature of resilience and social and environmental sustainability underscores the need for a deeper investigation. How specific resilience constructs—visibility, agility, flexibility, and collaboration- shape both internal and external social sustainability outcomes and waste management and pollution/emission of environmental sustainability. The following sections delve into these relationships providing empirical insights. It develops necessary propositions and hypotheses to know how resilience practices contribute to the broader sustainability agenda within the fashion supply chain. Basically, a hypothesis is a logical and conjectural relationship between variables that could be expressed as a testable statement. In the subsequent sections this study considers the directional hypothesis.

3.2 Leveraging Resilience for Enhancing Social Sustainability in Supply Chains

Due to complexity and uncertainty within global supply chains, understanding how resilience can be leveraged to promote sustainability has become increasingly critical. Resilience practices are critical for sustainability under the turbulent supply chain. There are various resilience constructs as prominent determinants for social sustainability that strengthen social sustainability during disruption (Lebel et al., 2006; Singh et al., 2023). Without resilience, the supply chain is exposed to various social challenges that affect management, workers, suppliers, and customers (Rai et al., 2021; Silva & Ruel, 2022). Therefore, the study of resilience and social sustainability within supply chains has become an emerging research area due to their synergistic importance and interaction (Frederico et al., 2020; Rajesh, 2021). The importance of studying the relationship between resilience constructs and internal and external social sustainability in the supply chain has been stated in the following sub-sections.

End-to-end transparency enhances visibility, which in turn contributes to the development of human resources and improves managerial efficiency within the supply chain (Münch & Hartmann, 2023). Moreover, visibility achieved through localization and diversified sourcing positively influences ethical behavior and information governance (Barbieri et al., 2020). Agility, as a key construct of resilience, also positively impacts the trust mechanism, relationship management, and sustainability performance in supply chains during disruptions through interdependent logistics and contingency planning (Faruquee et al., 2021). In addition, flexibility serves as the basis for an expedited human capital recruitment strategy through increasing operational efficiency (Becker et al., 2010; Silva & Ruel, 2022). Zhu & Wu, (2022) inferred that flexibility as a construct of resilience, along with risk management and recovery management, has a positive effect on social sustainability. Flexibility practice through adjusted and reliable delivery system, and adoptive strategies against demand variability resolve labor issues, ethical standards and social issues in the supply chain. It is related to health and safety in the workplace because a better working environment facilitates workers' rapid adaptability and prompt responses to unforeseen events (Hosseini et al., 2019; Sarker et al., 2021). Singh et al., (2023) studied the effect of the resilience construct on social sustainability in Indian automotive industry. They inferred that collaboration is the top resilience construct of dynamic capability theory under uncertainty. It has a positive effect on social sustainability through ensuring work safety and health. Moreover, Faruquee et al., (2021) focused on the role of dependable relationships and the ability to make contingency plans. They also showed that agile practices have a positive effect on overall supply chain relationships and trust among actors. Based on these evidences, the following hypotheses have been developed:

H1a–H1d: Resilience practices, (a) Visibility, (b) Agility, (c) Flexibility and (d) Collaboration are positively associated with the internal social sustainability in the fashion supply chain.

On the other hand, visibility positively influences customer satisfaction and a long-term relationship through real-time information sharing (Qader et al., 2022). It improves sustainable supplier relationships by introducing physical and innovative analytical tools for demand and supply level transparency (Faruquee et al., 2021). Visibility through local and diversified sourcing also has a positive effect on social sustainability to ensure necessary employment opportunities and social value gain (Barbieri et al., 2020). Besides, agility has a positive effect on the responsible supply chain through strategic changes in the market, people, and technology (Kazancoglu et al., 2022). Wieland & Wallenburg, (2013) asserted that agility as a resilience construct positively influences value creation for customers by leveraging supply chain relationships. *Flexibility* enables effective responses and abrupt interruptions through advanced operational models to ensure customer satisfaction (Ahmad et al., 2022). It ensures social sustainability through operational flexibility in supplier selection and relationship development and change during the crisis (Bag et al., 2022).

Finally, collaboration represents a core resilience construct that enables effective relationships with suppliers, customers, competitors, and knowledge-generating institutions (Han & Trimi, 2022). It plays a crucial role in promoting sustainable supplier selection, segmentation, and relationship management, thereby reducing supply chain disruptions (Hosseini et al., 2019). Additionally, collaboration supports the protection of human rights and reinforces moral responsibility across the supply chain (Koh et al., 2017). Singh et al., (2023) examined the influence of resilience constructs on social sustainability within the Indian automotive sector. Their findings identified collaboration as the most influential resilience construct, grounded in dynamic capability theory, which positively impacts social sustainability by advancing social welfare and fostering community development in uncertainty. Moreover, collaboration strengthens sustainability efforts by nurturing interdependent relationships, facilitating networks, and encouraging education and training among supply chain stakeholders. Based on these evidence, the following hypotheses have been developed-

H2a–H2d: Resilience practices, (a) Visibility, (b) Agility, (c) Flexibility and (d) Collaboration are positively associated with the external social sustainability in the fashion supply chain.

3.3 Moderating Role of Digital Tools in Enhancing Resilience and Social Sustainability

In the previous chapter we have found several approaches proposing digital tools with both a mediating and moderating role. As the global supply chain landscape continues to evolve, the role of digital tools in enhancing resilience and sustainability has garnered significant attention. Digital tools have emerged as pivotal enablers that not only rationalize operations but also facilitate the achievement of sustainability goals during disruption. The integration of digital tools such as blockchain, Internet of Things (IoT), Artificial Intelligence (AI), Big Data Predictive Analytics (BDPA), and Cloud-based Platforms have been shown to have a moderating effect on the relationship between resilience practices and sustainability outcomes. These digital tools improve operational efficiency, enhance information sharing, and strengthen relationships across the supply chain. Previous research has underscored the positive impact of digital tools in different sectors. For example, A. S & Ramanathan, (2021) demonstrated the moderating effect of blockchain, IoT, AI, BDPA, and Cloud-based Platforms on the relationship between SC resilience practices and sustainability in the automobile sector. They inferred that digital tools moderate social sustainability by improving customer satisfaction, sustainable operations, and quick response. They suggested further empirical studies for other industries from developing countries as a theory testing study. Digital tools also enhance the relationship through reliable, secure, and timely information sharing within the supply chain during disruption. Aldrighetti et al., (2023) used digital tools as a moderating variable on the effect of the closed-loop supply chain (CLSC) and sustainability. They classified digital tools into data-driven and process-driven technology perspectives. Finally, they inferred that data-driven digital tools positively moderate the relationship between CLSC and social sustainability by improving reputation and skilled manpower.

In particular, Bag et al., (2022) highlighted the moderating effect of the BDPA on the firm's dynamic capabilities and community/resource resilience. They stressed the optimal allocation of SC resources and supplier development programs through the moderating role of BDPA.

Del Giudice et al., (2020) explored that a big-data-driven supply chain moderates the positive relationship between circular economy HR management and firm performance through improving supply chain service and advanced demand forecasting to avoid market shocks. Faruquee et al., (2021) also explored the moderating role of digital transformation (DT) between joint problem solving (JPS) and supply chain resilience through increasing trust and communication among actors in the SC. Aligned with these, Ju et al., (2021) investigated that digital technology has a positive moderating effect on the relationship between integrated quality (IQ) and value chain co-creation (VCC) through immediate reaction, efficiency, and collaboration. Furthermore, Ivanov D., (2022) and Luthra et al., (2020) theoretically discussed the interaction among social sustainability, flexibility, agility, collaboration, blockchain, and BDPA. Based on these, the following hypotheses have been developed:

H3a–H3d: The relationship between resilience practices, (a) Visibility, (b) Agility, (c) Flexibility and (d) Collaboration and internal social sustainability are stronger when actors of the supply chain adopt the application of digital tools.

H4a – H4d: The relationship between resilience practices, (a) Visibility, (b) Agility, (c) Flexibility and (d) Collaboration and external social sustainability are stronger when actors of the supply chain adopt the application of digital tools.

3.4 Leveraging Resilience for Enhancing Environmental Sustainability in Supply Chains

Literature shows that environmental sustainability and resilience practices have been studied independently, and most of the existing models do not explicitly link environmental sustainability and resilience practices (Redman, 2014; Fahimnia & Jabbarzadeh, 2016). However, resilience has several interactions with environmental sustainability (Chan et al., 2017). For example, the sustainability issue of waste reduction in the supply chain is generated by resilience for SC design and recovery actions (Ivanov D., 2018). Agarwal et al., (2022) focused on the capability of waste reduction and its transformation into resource as the first enabler for environmental sustainability, which are related to resilient SC practices. The resilience through the initiation of backup supplier selection, extra reserved capacity, and preventive strategy has a positive role in achieving environmental sustainability in the post-

COVID crisis (Taleizadeh et al., 2022). Chen & Chen, (2019) focused on the positive effect of supplier collaboration through compliance and commitment on environmental sustainability. They inferred that supplier collaboration reduces air pollution and water/solid waste and decreases the consumption of natural resources and hazardous materials.

Besides, Costa et al., (2022) showed that flexibility in market forecasting and collaboration also contributes to waste reduction and ensure environmental sustainability. They demonstrated the beneficial impact of integrated logistics systems and redundancy via effective inventory policies on food waste, which subsequently affects environmental sustainability. Eggert & Hartmann (2023) postulated that resilience is reinforced by transparency and collaboration, which stem from organizations' environmental sustainability, through the sourcing of environmental materials, partnerships, and SC monitoring. They also showed the relationship between sustainability and resilience constructs by combining dynamic capabilities and relational capabilities in the supply chain. Esfahbodi et al., (2023) focused on the positive effect of cooperation achieving effluent waste and solid waste management. They inferred that cooperation with customers and integrated green logistics increase the environmental performance through reducing waste and emission. Govindan et al., (2014) showed that resilient supply chain practices have a positive effect on environmental sustainability. Resilience ensures environmental sustainability (e.g., environmental collaboration and waste elimination) through managing flexible sources, reverse logistics, and flexible transportation in the supply chain. Koh et al., (2017) also focused on the positive role of collaborative resilience practices on environmental sustainability, achieving efficient environmental resource management, and reducing pollution/emission. López & Ruiz-Benítez, (2020) highlighted that flexible sources of supply, visibility in information sharing, and resilient disaster recovery plans also have a positive effect on reducing emission and water and air pollution. Finally, Sodhi & Tang, (2021) explained the relationship between agile practices and environmental sustainability to ensure the use of natural resource optimization. The reviewed literature is broadly related to waste management and pollution/emission of environmental sustainability. Therefore, the following hypotheses have been developed for this theory-testing study of resilience and environmental sustainability.

H5a–H5d: Resilience practices, (a) Visibility, (b) Agility, (c) Flexibility and (d) Collaboration are positively associated with the waste management of environmental sustainability in the fashion supply chain.

H6a–H6d: Resilience practices, (a) Visibility, (b) Agility, (c) Flexibility and (d) Collaboration are positively associated with the reduction of pollution/emission of environmental sustainability in the fashion supply chain.

3.5 The Moderating Role of Digital Tools in Enhancing Resilience and Environmental Sustainability

In most existing literature, the focus is on the direct impact of digital tools on sustainability and resilience, rather than their moderating or mediating effects. However, A.S & Ramanathan, (2021) demonstrated that competence in digital supply chain tools moderates the relationship between supply chain resilience (SCR) and supply chain sustainability objectives. Specifically, their study suggests that the effect of resilience is stronger when digital competency is higher, particularly in the context of environmental sustainability during disruptions and pandemics. Aldrighetti et al., (2023) retrieved that data-driven Industry 4.0 tools have a stronger positive moderating effect on the relationship between closed-loop supply chain (CLSC) practices and environmental sustainability performance. They inferred that the application of digital tools (e.g., blockchain, BDPA, IOT) moderates the effect of SC recovery and resilience on pollution/emission of environmental sustainability. Moreover, Del Giudice et al., (2020) observed that a big-data-driven supply chain positively moderates the relationship between circular economy HRM practices and firm environmental performance. Esfahbodi et al., (2023) explored the moderating effect of green information systems (GIS) on the relationship between green logistics through collaboration and environmental sustainability.

Furthermore, digital transformation was found to positively moderate the relationship between joint problem-solving (JPS) strategies, environmental sustainability through trust mechanisms, SC agility, flexibility, and collaboration (Faruquee et al., 2021). Digital tools positively moderate the relationship between value co-creation (VCC) and resilience practices

(Ju et al., 2021). However, Ye et al., (2020) highlighted the impact of the technology gap on carbon intensity and positioning within the global value chain (GVC). They suggested the importance of continuous technological innovation and reconfiguration of existing GVCs for sustainable decarbonization (Chen et al., 2021). Moreover, there remains a significant gap in the adoption of low-carbon technology, innovation, and resilience practices within the fashion supply chain. While the impact of decarbonization outcomes remains inconclusive across industries, this study aims to test the following hypotheses regarding resilience, the moderating effect of digital tools, and environmental sustainability based on the aforementioned literature.

H7a–H7d: The relationship between resilience practices, (a) Visibility, (b) Agility, (c) Flexibility, and (d) Collaboration and waste management of environmental sustainability are stronger when actors of the supply chain adopt the application of digital tools.
H8a–H8d: The relationship between resilience practices, (a) Visibility, (b) Agility, (c) Flexibility and (d) Collaboration and pollution/emission of environmental sustainability are stronger when actors of the supply chain adopt the application of digital tools.

3.6 Theoretical Grounding and the Research Framework

According to Dynamic Capability Theory, organizations succeed in dynamic and uncertain environments by developing the ability to integrate, build, and reconfigure internal and external competences to address rapid changes (Teece et al., 1997; Bag et al., 2021; Belhadi et al., 2022). In the context of sustainable fashion supply chain management, this thesis conceptualizes four resilience constructs—visibility, agility, flexibility and collaboration—as dynamic constructs (capabilities) that enable firms to pursue social and environmental sustainability objectives while maintaining resilience practices. First, visibility enables to sense and monitor upstream and downstream conditions (e.g., environmental sustainability constructs of waste management, emission and pollution, social issues and working conditions), thereby supporting sustainable decision-making and supply chain resource reconfiguration. Second, agility allows immediate responses and adaptation of operations (seizing opportunities or allaying SC threats) which in turn supports sustainable supply chain under uncertainty. Third, flexibility provides structural and operational actions and logistics (such as multi-sourcing and backup sourcing, flexible operational design, workforce variability) that enable efficient reconfiguration of supply chain resources, aligning with sustainability goals such as managerial efficiency, sustainable customer-supplier relationship and overall social stability. Finally, collaboration helps firms to combine and align resources, knowledge and capabilities across the supply network, enhancing collective sensing, seizing and transformation of resources in ways that promote social and environmental sustainability. By treating visibility, agility, flexibility and collaboration as dynamic capabilities (constructs), FSC actors can strategically reconfigure their supply-chain resources and routines in the pursuit of sustainability and resilience.

The research framework presented in Figure 12 outlines the comprehensive model. It explores the relationship between resilience constructs, the application of digital tools, and social and environmental sustainability within the FSC. Specifically, the framework proposes that four key resilience constructs- visibility, agility, flexibility, and collaboration- have a direct effect on both internal and external social sustainability and waste management and pollution/emission of environmental sustainability, supported by prior research. These constructs are crucial for strengthening social and environmental sustainability, particularly in response to disruptions. Additionally, the model highlights the moderating role of digital tools, such as blockchain, big data analytics, and the Internet of Things, which enhances the effectiveness of resilience practices in promoting social and environmental sustainability. The implementation of digital tools is anticipated to enhance the positive relation between resilience and social and environmental sustainability by promoting efficient information exchange, improving response times, and boosting collaboration among SC actors.

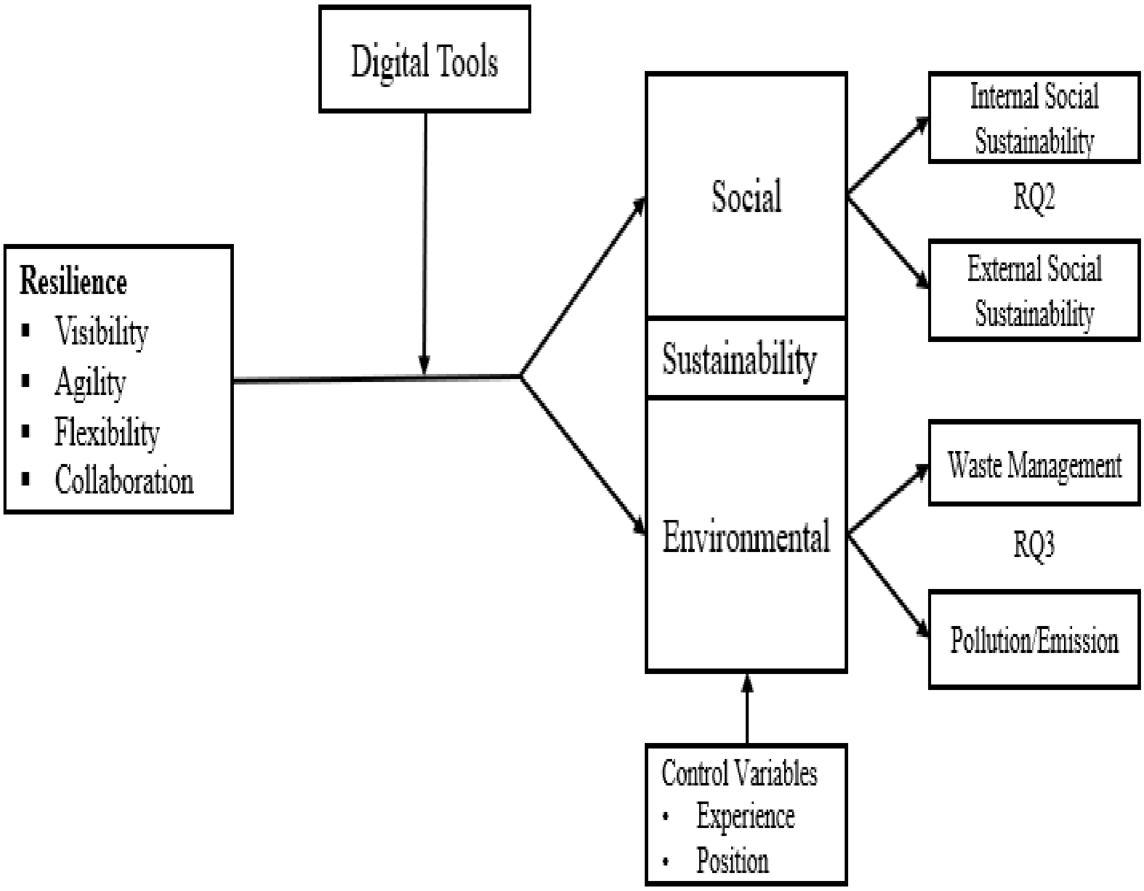

FIGURE 12: RESEARCH FRAMEWORK AND DIRECTIONAL RELATIONSHIP OF THIS STUDY

The framework considers two controlled variables—experience and position within the supply chain—that may influence the dynamics of these relationships, acknowledging that the perspective and expertise of SC actors may shape the impact of resilience practices on social and environmental sustainability. This model not only emphasizes the direct relationships between resilience and sustainability but also accounts for how digital tools can strengthen these connections, offering a holistic view of the interaction between resilience, digital tools, and social and environmental sustainability in the Bangladeshi fashion supply chain.

Chapter 4: Methodology

The methodology of this study follows a structured and chronological process encompassing the development of a questionnaire grounded in theoretical concepts. It followed several steps comprising data collection, data organization, statistical analysis, and concluding with a discussion of the results. The methodology is guided by the framework of Hair et al., (2010), Karlsson, (2023), and Forza & Sandrin, (2024) ensuring methodological precision and consistency across the research process through Figure 13 and subsequent steps.

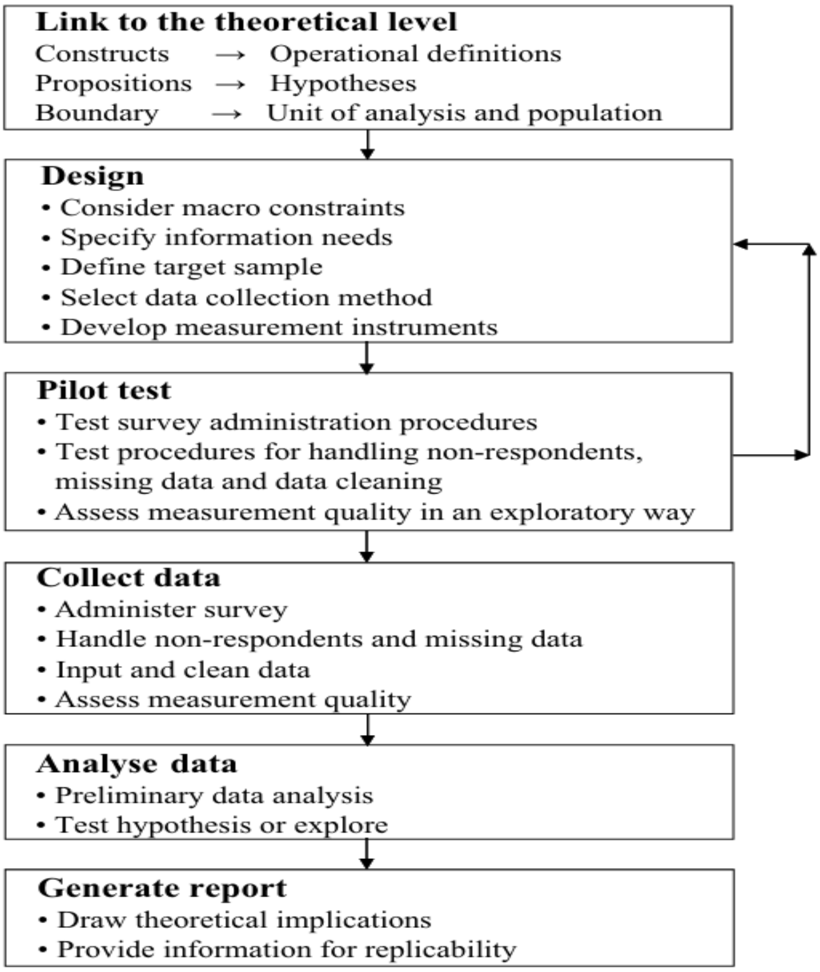

FIGURE 13: FRAMEWORK OF RESEARCH METHODOLOGY ADOPTED FROM FORZA & SANDRIN, (2024)

4.1 Link to Theoretical Level

After the schematic diagram of the research framework, this section transforms the theoretical construct into generating reports considering three aspects*:*

a) Construct -refers to the operational definition of the concept, the transformation to the observable or measurable element, and subsequent decomposition to refine measurement elements. This study evaluates the operational definitions for content validity and face validity (section 4.4.1) by examining how well the theoretical concept is translated and how appropriately each concept's domain is selected. The definition of a construct has been designed based on the eight rules of the conceptual definition suggested by Wacker (1998: 638). These eight rules are

- Formal conceptual definition using primitive and derived terms
- Each concept has been defined uniquely.
- Each concept includes only unambiguous and clear terms.
- Consider the parsimony virtue of a 'good' theory
- Consistency in defining concepts and constructs based on previous literature
- Conceptual definition does not have any broader terms
- Avoid the qualitative bias of the construct and hypothesis
- Proper validity checks for each construct and concept

b) Propositions -The development of hypotheses is based on general propositions and relevant literature. It presents the constructs and their relational role of the complex framework (independent, dependent, and moderating). Broadly, it shows the linkages between constructs and directional relationships based on the literature review that has been elaborately stated in the sections 3.2-3.5

c) Boundary Condition -it covers the unit of analysis and population of the study. The unit of analysis refers to the level of data aggregation during subsequent analysis (Forza C., 2002). Generally, the unit of analysis could be individual, group, plant, or companies (Flynn et al., 1990). The unit of analysis in this study is the fashion supply chain companies of Bangladesh. However, the level of reference is the C-level executives of the companies. As the unit of analysis and reference unit are not the same, this study is careful in all the phases for the cross-level inference problem and ecological fallacy problem (Robinson, 1950; Babbie, 1990). Moreover, the unit of analysis is a single respondent for both dependent and independent variables. Besides, the population of this study is all the actors of Bangladeshi Fashion supply chain.

4.2 Research Design

The research design encompasses all activities that preceded and supported the pilot survey and data collection phases. It addresses potential challenges, key issues, and essential requirements to ensure a rigorous and feasible analysis. Primarily, the research design serves as a blueprint, aligning the study with its objectives and guiding the planning process before data collection begins. Following the procedures outlined by Alreck & Settle (1985), and Forza C. (2002) the research design has been structured into the following chronological sub-sections.

4.2.1 Information Needs and Macro Constraints

Prior to examining the relationship between resilience, sustainability, and digital tools in the fashion supply chain, this study critically assesses the overall feasibility of the research project. As a step of research design, it assesses the suitability of the survey method and constraints related to time and cost. Moreover, an essential consideration of this study is the accessibility to the target population and the feasibility of engaging appropriate informants. The study systematically addresses these macro-level challenges, placing strong emphasis on effective time and cost management from the outset. Furthermore, it proactively implements strategies to minimize four key types of research design errors from the beginning.

- Sampling errors (e.g., random sampling, adequate sample size, and representative sample)
- Measurement error (e.g., validation, pilot testing, clear and unambiguous statement)
- Statistical calculation error (e.g., check and cross-check through SPSS and Smart PLS)
- Internal validity error (e.g., control variables, pre-test and post-test, consistent measurement tool)

4.2.2 Target Sample and Population

Generally, population means the entire group of people, companies, or plants that researchers wish to investigate. The population for this study consists of actors within the FSC in Bangladesh. Each individual actor, regardless of their position within the supply chain, is considered an element of the population. Each population element represents one individual within the overall population. Besides, a population frame is "a listing of all the elements in the population from which the sample is to be drawn" (Forza & Sandrin, 2024). The population frame of this study is the member directory of the BGMEA. BGMEA is the most widely available, acceptable, and representative source for fashion supply chain in Bangladesh. This population frame could be used for replication of the Bangladeshi fashion supply chain study and true representation of the international area (Schoenherr & Swink, 2012).

Moreover, this study chooses the Bangladeshi fashion supply chain due to their global outreach in FSC and direct connection to the downstream fashion buyers of developed countries. In fact, Bangladeshi fashion supply chain covers a wide range of the global fashion supply chain. Complex supply chain dynamics due to local and imported inputs for the supply chain is another reason for selecting Bangladesh. Moreover, the critical assessment of 4 million workers' involvement, including the concern of child labor practices, human rights issues, ethical sources, and the issue of sustainability practices are also the important reasons for selecting the Bangladeshi fashion supply chain. Furthermore, major brands like PRADA, H&M, ZARA, Uniqlo, Mango, Pull and Bear, and Walmart mostly source from Bangladesh. As such, it is considered an ideal context for this study.

A sample is the subset of a population that consists of some elements that have been drawn from the population. There are several sample designs under the probabilistic and non-probabilistic sampling. This study uses random sampling, considering two important concerns of sampling design: *randomness and sample size.* While randomness is related to the ability of the sample to truly represent the population's interest. Sample size considers the statistical significance level and power of the hypothesis testing. For the main data collection, this study surveyed a sample of 1,200 Bangladeshi SC actors within the fashion industry, sourced from the BGMEA database. The survey invitation was sent via email in June 2024 using the "Lime Survey" online survey platform due to-

- Cost savings of in-person data collection
- Most outreach to respondents
- Gave an authoritative impression to respondents for anonymity
- Reduce interviewer bias

This survey process was followed by two email reminders and phone call follow-ups in July and August of 2024, as the guideline suggested by Dillman, (1978). Despite the initial outreach, 40 questionnaires (respondents) were undeliverable, and 39 responses were excluded from the final dataset due to incomplete answers, missing data, or inconsistencies in responding to double-barreled questions. Ultimately, 190 usable responses were obtained, resulting in an acceptable response rate of 16.37%, which meets the minimum standard outlined by Kotrlik et al. (2001) and Frohlich (2002). This 16.37% response rate in the domain of operations and supply chain management (OSCM) is adequate for statistical analysis.

Furthermore, 190 sample sizes for SEM have been used based on the established rules supporting their validity for purposes of analysis. Using Cohen's (1992) rule, the sample size is 90 (power 80%, significance level of 5%, with five predictors; 50+8*5 rules). Additionally, using the G∗Power test with power = 0.80, effect size = small-medium, and significance level 5%. Besides, the method employed for data analysis, i.e. PLS-SEM does not suffer from small sample size and non-normality of data (Hair et al., 2010; Memon et al., 2021). Furthermore, the number of respondents in this research approximates the number of respondents in others' well-established works in the field of green and environmental supply chain within local areas; for example, 52 respondents in the United Kingdom have been considered by Rao (2002). Holt & Ghobadian, (2009) studied SEM with 60 observations in Southeast Asia. Finally, Godinho et al., (2016) also studied SEM with 52 respondents in Brazilian SMEs.

4.3 Data Collection Method

This study employs a survey-based research design to investigate the fashion supply chain. The choice of survey method is justified by the fact that, while the knowledge base surrounding the Bangladeshi fashion supply chain is emerging, it is not entirely underdeveloped. Moreover, deriving insights applicable to the global fashion supply chain context requires generalizability. The theoretical foundation of this study supports the necessity for empirical testing of the relationship between resilience, sustainability, and digital tools. The data collection instrument consists of a self-developed, structured questionnaire based on previous literature and adequate research validation. This study has well-thought-out the following key considerations when designing the survey and questionnaire.

4.3.1 Wording and Scaling

“Wording” in survey research refers to the formulation of words that have clear meaning and understanding to respondents. The word used in the questionnaire would not have any ambiguity or double meaning to the respondents. This study was very careful in wording from the questionnaire design, and formulation till final execution. It tried to avoid social desirability bias in terms of wording, balancing positive and negative items, thus reducing acquiescence and disacquiscence and response style (Podsakoff et al., 2003). Furthermore, this study avoided the use of leading questions. It ensured clarity by eliminating too many double-barreled questions, thereby enhancing the validity and reliability of the responses. No statement of the questionnaire exceeds 20 words to retain the single purpose and concentration of the respondents (Oppenheim A, 1992). Lengthy items or sentences were deliberately avoided to reduce complexity and enhance clarity. However, the intrinsic meaning and authenticity of each statement were carefully preserved to ensure the brevity of conceptual accuracy.

Besides, this study always upholds the due ethical consideration and cultural values in terms of wording, such that proposed items are not offensive or discriminatory towards any individual, respondent, FSC industry, or social and religious entity of Bangladesh. The scale used in this study was selected based on its ease of use for respondents and its suitability for facilitating subsequent data analysis. Among the four common types of measurement scales—nominal, ordinal, interval, and ratio—this study employed an interval scale for collecting metric data analysis. Specifically, respondents were asked to rate each item using a five-point Likert scale, ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). The Likert scale was chosen because-

- It is effective in capturing various degrees of agreement.
- It ensures a symmetrical response and is very useful for comparison.
- It reduces the cognitive load.
- It improves response rate by allowing the measurement of relative intensity in respondents’ perceptions.

4.3.2 Respondent Identification

The targeted respondents are senior-level executives, such as CEOs, COOs, sustainability managers, supply chain managers, procurement managers and company owners. These individuals have been selected due to their comprehensive understanding of the key topics, including sustainability, resilience, and the application of digital tools within their supply chain operations. Table 17 provides further insight into the sample composition. It outlines the demographic breakdown of the respondents.

TABLE 17: DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Demographic Characteristics	Quantity
A) Position of the Respondents	
CEO	45
COO	25
Owner	26
Supply chain Manager	13
Sustainability Manager	32
Procurement Manager	21
Others (e.g., Director, General Manager, Executive Officer)	28
B) Working Experience	
1-5 years	27
6-10 years	64

	11-15 years	42
	16 years and more	57
C)	**Firm Size (Based on employees)**	
	<250 Employees	18
	> 250 Employees	172
D)	**Annual Turnover**	
	Less than $ 50K	9
	$50K - $100K	12
	$100K - $0.5 Million	35
	$0.5Million - $1 Million	61
	Above $1 Million	73
E)	**Types of Business**	
	Brand Owner	15
	Supplier of Raw Materials	20
	Supplier of Components	29
	Supplier of Manufacturing Activities	110
	Distributor	10
	Others	6

Here it is worth noting that this study collected data for three constructs of environmental sustainability, including resource efficiency management based on the final constructs from the systematic literature review. After collecting data, it proceeds to test correlation among the constructs. It is seen that the correlation coefficient of waste management and resource efficiency management is higher than .70. The result indicates the higher positive correlation between these two constructs of environmental sustainability. After critical assessment and literature support, this study proceeds to assess environmental sustainability with two constructs (waste management and reducing pollution/emission). While Table 18 and Table 19 provide the descriptive statistics for the constructs and their correlations with respect to social and environmental sustainability.

TABLE 18: MEAN, STANDARD DEVIATION AND CORRELATION OF THE VARIABLES FOR RQ2

	Mean	STD.	ROLE	EXP	VIS	AGL	FLE	COL	DIG	INT	EXT
ROLE	3.78	2.01	1								
EXP	2.68	1.04	-.078	1							
VIS	4.05	.620	.009	-.009	1						
AGL	3.88	.678	-.278	.004	.293	1					
FLE	3.93	.747	-.107	.072	.312	.369	1				
COL	3.89	.795	-.226	-.248	.333	.218	.339	1			
DIG	3.93	.643	-.186	.024	.387	.637	.248	.243	1		
INT	3.93	.633	-.181	.213	.411	.688	.375	.410	.635	1	
EXT	3.89	.672	-.181	.201	.396	.221	.310	.374	.195	.404	1

Listwise N=190$_c$

TABLE 19: MEAN, STANDARD DEVIATION AND CORRELATION OF THE VARIABLES FOR RQ3

	Mean	STD	ROLE	EXP	VIS	AGL	FLE	COL	DIG	WST	P/E
ROLE	3.78	2.01	1								
EXP	2.68	1.04	-.078	1							
VIS	4.05	.621	.009	-.009	1						
AGL	3.88	.678	-.278	.004	.293	1					
FLE	3.93	.747	-.107	.072	.312	.369	1				
COL	3.89	.795	-.226	-.248	.333	.218	.339	1			
DIG	3.84	.611	.065	-.061	.136	.315	.173	.193	1		
WST	3.93	.623	-.294	-.079	.402	.644	.351	.437	.266	1	
P/E	3.96	.562	-.122	-.062	.347	.533	.287	.329	.228	.679	1

Listwise N=190$_c$

4.3.3 Measurement Item Development

Measurement item development refers to the process of creating the questions or statements used in a questionnaire to capture specific constructs. This can be approached either deductively—drawing directly from existing literature and validated scales—or inductively—developing items based on qualitative insights or expert input. In this study, a *hybrid* approach is adopted, combining both deductive and inductive strategies. This approach acknowledges that no single source of literature can encompass the full breadth of knowledge required to address all research questions comprehensively. An item pool has been created with careful attention, ensuring homogeneity within constructs at the beginning of the research design. In addition, the study is mindful of the distinction between unidimensional and multidimensional constructs to ensure accurate representation and measurement. The final measurement items (*Chapter 5*) for each construct, presented in the following sections, were primarily derived from peer-reviewed literature, ensuring content validity and theoretical grounding. The list, scale, and role of variables and their respective references have been stated in Table 20.

TABLE 20: LIST OF VARIABLES, ROLE IN THE MODEL AND THEIR RESPECTIVE REFERENCES

Variables	Role	Adapted from
Visibility	Independent Variable	(Faruquee et al., 2021; A.S & Ramanathan, 2021; Münch & Hartmann, 2022; Bag et al., 2022)
Agility	Independent Variable	(Abdelilah et al., 2018; Faruquee et al., 2021; Mubarik et al., 2021; Kazancoglu et al., 2022)
Flexibility	Independent Variable	(Faruquee et al., 2021; Ivanov D., 2021; Enrique et al., 2022; Silva et al., 2022)
Collaboration	Independent Variable	(Frederico et al., 2021; Mastos et al., 2021; Silva et al., 2022)
Digital Tools Social Sustainability	Moderating Variable	(Faruquee et al., 2021; Han & Trimi, 2022; Bag et al., 2022)
Digital Tools Environmental Sustainability	Moderating Variable	(Faruquee et al., 2021, Han & Trimi, 2022; Bag et al., 2022)
Internal Social Sustainability	Dependent Variable	(Luthra et al., 2017; Mani & Gunasekaran, 2018; Croom et al., 2018; Mastos et al., 2020; Rai et al., 2021; Agarwal et al., 2022)
External Social Sustainability	Dependent Variable	(Croom et al., 2018; Sarker et al., 2021; Sauer et al., 2022 Aldrighetti et al., 2022; Eggert & Hartmann, 2023)
Waste management of Environmental Sustainability	Dependent Variable	(Zhu et al., 2008; Del Giudice et al., 2020; Bag et al., 2022; Esfahbodi et al., 2023).

Pollution/Emission of Environmental Sustainability	Dependent Variable	(Dubey et al., 2019; López & Ruiz-Benítez, 2020; Mastos et al., 2020; Raut et al., 2021)

4.4 Validity and Reliability as Measurement Quality

This section evaluates the goodness of measures with a focus on validity and reliability. As noted by Forza C. (2002), "Validity is concerned with measuring the right concept, while reliability is concerned with stability and consistency in measurement." Accordingly, this study places a strong emphasis on ensuring validity to minimize systematic errors and conducts appropriate reliability tests to mitigate random errors, as recommended by Carmines & Zeller (1990). To ensure robust measurement quality, this study systematically conducts two primary types of validity assessments, which are elaborated upon in the following sub-sections. These steps help to establish both the accuracy and consistency of the measurement instruments used in the empirical investigation.

4.4.1 Content Validity

Content validity is the precondition to other forms of validity. It refers to the extent to which the selected items truly reflect the designated domain and adequate operational definition of the constructs (Teeluckdharry et al., 2021). Content validity involves a two-stage process of instrument development (questionnaire development) and judgement based on the consensus of the items, domain, and sample (Carr et al., 1985). To test content validity, this study fulfills the five conditions suggested by Guion (1977)

- Focus on the consensus of the behavioral content
- Reduction of unambiguity in the construct definition
- Ensure the construct-relevant the content
- Acceptance and consensus of experts on content, domain selection, and sample
- Response content must be reliably observed and re-evaluated.

To ensure content validity and enhance the suitability of the measurement items, this study consulted with experts in the field of SC sustainability, as expert opinion was recommended by DeVellis (2021). This study conducted in-depth interviews with three academicians specialized in questionnaire design, who evaluated the content validity of the scales used to measure the constructs (Forza C., 2002). Their valuable feedback had been incorporated into the final version of the questionnaire. Furthermore, the study evaluated face validity, which pertains to the degree to which the items apparently represent the intended constructs, as perceived by laypersons or respondents. Feedback collected from a small group of potential respondents was analyzed, and appropriate modifications were made to improve clarity, readability, and perceived relevance.

4.4.2 Construct Validity

After the successful outcome of content validity, this study proceeds to construct validity. *Construct validity* refers to the degree to which a measure represents and acts as the concept being measured (Forza & Sandrin, 2024). It identifies whether the items are tapping into the underlying theory or model behavior (Boateng et al., 2018). Construct validity is the most complex and critical to a substantive theory testing study concerning a measure (Bagozzi et al., 1991). It consists of *convergent validity and discriminant validity.* While convergent validity indicates the proportion of variance explained by a specific latent variable. It tests whether having the same or similar constructs should be highly correlated. Generally, it is determined by examining the average variance extracted (AVE) value of the model. An AVE of 0.50 or higher indicates that convergent validity has been achieved (Hair et al., 2010). Besides, another method is the multitrait-multimethod matrix (MTMM) approach. The value of AVE and the discriminant validity value of this study have been stated in Table 21.

TABLE 21: LIST OF AVERAGE VARIANCES EXTRACTED (AVE) AND DISCRIMINANT VALIDITY (DV)

SL. No.	Constructs	AVE	**DV (√AVE> R)**
1	Visibility	.618	.786
2	Agility	.633	.795
3	Flexibility	.780	.883
4	Collaboration	.751	.866
5	Internal Social Sustainability	.676	.822
6	External Social Sustainability	.753	.867
7	Wast Management	.719	.847

8	Pollution/Emission	.575	.758
9	Digital Tools Social Sustainability	.634	.796
10	Digital Tools Environmental Sustainability	.564	.750

On the other hand, discriminant validity ensures that a construct measure is empirically unique and represents phenomena in a way that does not merely reflect some other construct (Hair et al., 2010; Raykov T., 2011; Teeluckdharry et al., 2021). It means that a test does not correlate too highly with measures from others and is supposed to differ. There are several techniques to test discriminant validity. For example, Fornell & Larcker (1981) criterion and the cross-loadings test (Chin, 1998). In addition, the Heterotrait-Monotrait Ratio (HTMT) test has been performed to examine discriminant validity and supporting uni-dimentionality. All the values of the respective constructs are less than the cutoff value 1 (Van Riel et al., 2017). The output of the HTMT ratio of this study for the RQ2 and the RQ3 has been stated in Table 22 and Table 23.

TABLE 22: LIST OF HETEROTRAIT-MONOTRAIT (HTMT) RATIO OF ALL CONSTRUCTS FOR RQ2

	VIS	AGL	FLE	COL	DIG	INT	EXT
VIS							
AGL	0.346						
FLE	0.352	0.416					
COL	0.378	0.246	0.367				
DIG	0.143	0.269	0.143	0.080			
INT	0.476	0.794	0.415	0.456	0.266		
EXT	0.470	0.280	0.344	0.430	0.106	0.478	

TABLE 23: LIST OF HETEROTRAIT-MONOTRAIT (HTMT) RATIO OF ALL CONSTRUCTS FOR RQ3

	VIS	AGL	FLE	COL	DIG	WST	P/E
VIS							
AGL	0.346						
FLE	0.352	0.416					
COL	0.378	0.246	0.367				
DIG	0.173	0.378	0.199	0.128			
WST	0.461	0.734	0.383	0.481	0.314		
P/E	0.419	0.642	0.331	0.383	0.284	0.795	

4.4.3 Reliability as Measurement Quality

Reliability is concerned with stability and internal consistency in the measurement. Broadly, reliability covers dependability, predictability, accuracy, and the extent to which a measuring procedure yields the same results on repeated trials (Kerlinger, 1986; Carmines & Zeller, 1990). It has been assessed after data collection. To test the reliability of the measurement quality, this study starts testing through the test-retest method for correlation based on different times of response. Moreover, it also assessed reliability through splitting the collected data into two separate analyses. There was also not a significant difference in the different time frames. This assessment has been done of the equivalency, homogeneity, and inter-correlation of the items used in a construct. It reflects the capability of independently measuring the same construct. The most popular test within the internal consistency method is the Cronbach coefficient alpha (Cronbach, 1951). Accordingly, Cronbach's Alpha (α) and composite reliability (CR) values exceeded .70 in this study. These results suggest the internal consistency of the data. The outcomes of internal consistency have been stated in Table 24.

TABLE 24: VALUE OF CRONBACH'S ALPHA AND COMPOSITE RELIABILITY OF THE CONSTRUCTS

SL. No.	Constructs	Cronbach's Alpha (α)	Composite Reliability (CR)
1	Visibility	.846	.851
2	Agility	.855	.862
3	Flexibility	.929	.931
4	Collaboration	.917	.921
5	Internal Social Sustainability	.880	.881
6	External Social Sustainability	.934	.939
7	Wast Management	.902	.904
8	Reducing Pollution/Emission	.815	.834
9	Digital Tools Social Sustainability	.867	.874
10	Digital Tools Environmental Sustainability	.809	.833

4.5 Pilot Testing

Once the questionnaire was developed, this study adhered to a systematic protocol for its administration. The sampling units were clearly identified, and the measurement properties of the survey instrument were rigorously examined. Aligning with the recommendations of Dillman (1978), the pre-testing phase involved three distinct respondent groups (academicians, industry experts, and target respondents). These groups had been selected to ensure-

(i) Alignment with the objectives of the study

(ii) Avoid the inclusion of redundant or irrelevant questions specific to the fashion supply chain.

(iii) Obtain practical feedback from potential respondents

The questionnaire was distributed to a small pretest sample through both email and face-to-face interaction. Participants were asked to evaluate the clarity of the instructions and questions and to highlight any challenges related to understanding the questions or providing responses. This phase ensured face validity and usability of the instrument.

In the second phase, a pilot test was conducted involving 12 respondents, following the recommended contact-administration protocol. The aim was to perform an exploratory assessment of measurement quality and refine the sampling frame as needed. Feedback from this pilot study confirms the clarity, applicability, and reliability of the questionnaire items. The pilot results demonstrated that the instrument possessed sufficient internal consistency, validating its readiness for the final survey implementation. The final survey questionnaire has been attached as Appendix 1.

4.6 Data Assessment

4.6.1 Respondent and Non-respondent Bias

After testing necessary statistical assumptions, first as a preliminary analysis, the t-test was conducted to compare respondents and non-respondents based on their roles and experience (e.g., CEO, COO, supply chain manager, sustainability manager, owner, procurement manager, and others). The results indicated no significant difference, as the p-value exceeded .05. Subsequently, non-response bias was evaluated by comparing early respondents (42%) and late respondents (58%), following the approach of Lambert & Harrington (1990). The analysis showed a p-value greater than .05, confirming that non-response bias is not a concern for further study.

4.6.2 Common Method Bias

As the respondents for independent and dependent variables are the same person in this study, the researcher was very careful about the common method bias from the beginning of the research design. Accordingly, common method bias has been assessed before, during, and after data collection through the two controlling guidelines suggested by Kock et al., (2021).

- **Procedural control***:* As a procedural control for the design part, this study avoided using ambiguous words in the questionnaire, reduced social desirability bias, and was aware of the acquiescence and dis-acquiescence of any statement in the questionnaire. Finally, it balanced the questionnaire design with positive and negative items and methodological and psychological separation.

- **Statistical control:** For statistical control, this study used statistical control measures, Harman's single-factor test, where all variables were subjected to unrotated exploratory factor analysis. The results revealed no single factor explaining more than 50% of the variance (Esfahbodi et al., 2023; Podsakoff et al., 2003), with the highest variance being 24.8%. As such, common method bias does not pose a significant issue for the analysis. Additionally, this study performed the marker-variable analysis using the lowest bivariate correlation between variables and "year of working in the fashion industry" as it is unrelated to at least one of the variables (Craighead et al., 2011). The comparison after adjustment of the marker variables, the correlations remained significant for all independent variables that could be used as additional support against the common method bias for the dataset.

The item of each construct has required correlation to meet the validity and reliability standard; Bartlett's test and the Kaiser-Meyer-Olkin (KMO) measure were assessed. Thus, the dataset was deemed suitable to proceed with factor analysis, and the optimal number of factors to retain, the Kaiser-Guttman criterion eigenvalue approach, was adopted with the respective cumulative variance explained value. The outcome of the test is stated in the Table 25.

TABLE 25: OUTCOME OF THE BARTLETT'S TEST AND KAISER-MEYER-OLKIN (KMO) TEST

Test	Result
Research Question 2	
KMO	.838
$\chi 2$	8688
DF	630
P-value	<0.05
Research Question 3	
KMO	.881
$\chi 2$	5018.69
DF	780
P-value	<0.05

4.7 Measurement of the Model

To measure the measurement validity of the model, this study performed exploratory factor analysis (EFA) using principal component analysis and Varimax rotation to extract factors with Eigenvalue >1. The factor loading of each of the items was greater than .50, and the Average Variance Extracted (AVE) value was higher than the standard benchmark of .50 (Hair et al., 2010). This result confirms the convergent validity of the model. The detailed statistics of Cronbach's Alpha (α), CR and factor loading, and AVE have been stated in the respective sections. Afterward, the discriminant validity of the model was assessed by extracting the value of the square root of AVE. This study compares the square root of AVE with the respective correlation coefficient between each pair of constructs. In all cases, this value is greater than the correlation value suggesting the appropriate discriminant validity in the model (Fornell & Larcker, 1981). Finally, variance inflation factors (VIF) were calculated to verify multicollinearity. All items across the model had VIF less than <5, confirming that multicollinearity was not a concern (Hair et al., 2010). The overall output of VIF for all items has been stated in Appendix *2.*

Chapter 5: Analysis and Result

This chapter explains the detailed analyses and results, including the specific output of all hypotheses under RQ2 and RQ3. This chapter illustrates the impact of resilience practices on both social and environmental sustainability, as well as the moderating role of digital tools, which are discussed in sections 5.1 and 5.2.

5.1 The Effect of Resilience on Social Sustainability and Moderating Role of Digital Tools

To test the hypotheses related to resilience practices, digital tools, and social sustainability in the Bangladeshi FSC, the Partial Least Square-Structural Equation Model (PLS-SEM) was performed. This study performed PLS-SEM through the Smart-PLS 4.0 software. Smart-PLS 4.0 is widely accepted in published research due to its wide uses and necessary analysis (Aldrighetti et al., 2023; Delic & Eyers, 2020). The PLS-SEM has been used instead of CB-SEM for this study because PLS-SEM is more appropriate for a small sample size and overcomes the non-normality issues of the data set (Hair et al., 2010; Memon et al., 2021). PLS-SEM also benefits underexplored associations. In Table 26, the standard factor loading items under the respective construct has been stated. Several items of the questionnaire have been excluded for not having adequate factor loading in respect to the designated construct and retaining the items having factor loading more than 0.50 (Hair et al., 2010). The analysis started with testing the effect of the control variables (i.e., year of experience and position in the supply chain) on internal and external social sustainability. The effect of the control variables is $\beta\_{EXP} = -0.028$ and $\beta\_{POS} = -0.027$, $P > 0.05$ for internal social sustainability, and $\beta\_{EXP} = -0.04$, and $\beta\_{POS} = -0.02$, $P > 0.05$ for external social sustainability. The control variables demonstrated no significant impact on internal or external social sustainability.

Subsequently, the hypotheses (H1a–H1d) and (H2a–H2d) were tested to evaluate the direct effect of four independent variables—visibility, agility, flexibility, and collaboration—on internal and external social sustainability through the structured equation model. Afterward, hypotheses H3a–H3d and H4a–H4d were analyzed to assess the moderating effect of digital tools on both internal and external social sustainability.

TABLE 26: MEASUREMENT ITEMS AND RESPECTIVE STANDARD FACTOR LOADING

Measurement Constructs and Items		Std. Loading
Visibility (VIS)		
VIS_1	Tracking, tracing, and localization system	0.803
VIS_2	Use of Physical transportation for tracking and innovative analytical tools	0.766
VIS_3	Real-time information sharing and disclosure	0.749
VIS_4	Reduce intermediaries in the supply chain	0.829
VIS_5	Trustworthy information governance system	0.781
Agility (AGL)		
AGL_1	Large product varieties and rapid change of production line	0.804
AGL_2	Reorganize of the existing supply chain relationship at the strategic level	0.839
AGL_3	Respond to the strategic change in the market, people, technology, and society	0.791
AGL_4	Reconfigure the supply chain before competitors for competitive advantage	0.806
AGL_5	Supplier selection and segmentation decision in the supply chain during crisis	0.735
Flexibility (FLE)		
FLX_1	Re-organization of operational SC after disruption	0.891
FLX_2	Flexible capacity in logistics at demand uncertainty	0.910
FLX_3	Having flexible sources of suppliers in the supply chain	0.872
FLX_4	Apply a postponement strategy throughout the supply chain	0.885
FLX_5	Tactical flexibility in operations and accept minor and random changes	0.856
Collaboration (COL)		
COL_1	Ability to work with suppliers for products and information flows	0.841
COL_2	Having a company-customer collaborative approach in the supply chain	0.874

COL_3	Having a relationship with the competitors and stakeholders	0.853
COL_4	Facilitate human-machine collaboration	0.911
COL_5	Assurance of commitment and compliance among the supply chain actors	0.851
Application of Digital tools for Social Sustainability (DIG)		
DIG_1	Application of digital tools for customer management	0.837
DIG_2	The use of digital tools in supporting human resource management	0.797
DIG_3	The use of digital tools to improve social networks and communication	0.578
DIG_4	Application of digital tools for managing workers and employees	0.878
DIG_5	Digital tools application for trustworthy supplier relationship	0.855
Internal Social Sustainability (INT)		
INT_1	Integrated Human Resource Management Practices	0.838
INT_2	Structured resource governance and knowledge management system	0.812
INT_3	Health, safety of workers, and working conditions in the office and factory	0.840
INT_4	Evaluate and monitor workers' satisfaction in the supply chain	0.825
INT_5	Arrangement of training and learning facilities on sustainability practices	0.790
External Social Sustainability (EXT)		
EXT_1	Upholding human rights during supply chain operations	0.859
EXT_2	Disclose (to the customers) all the issues related to suppliers and actors	0.886
EXT_3	Child labor protection and upholding stakeholders' rights	0.891
EXT_4	Employment opportunities for society	0.853
EXT_5	Community governance and upholding cultural diversity	0.897
EXT_6	Protecting customer rights and promoting loyalty	0.814

In Figure 14, the conceptual direction of four resilience constructs on social sustainability and the moderating role of the application of digital tools has been outlined, and afterward the output of these directional relationships is also stated in Figure 15.

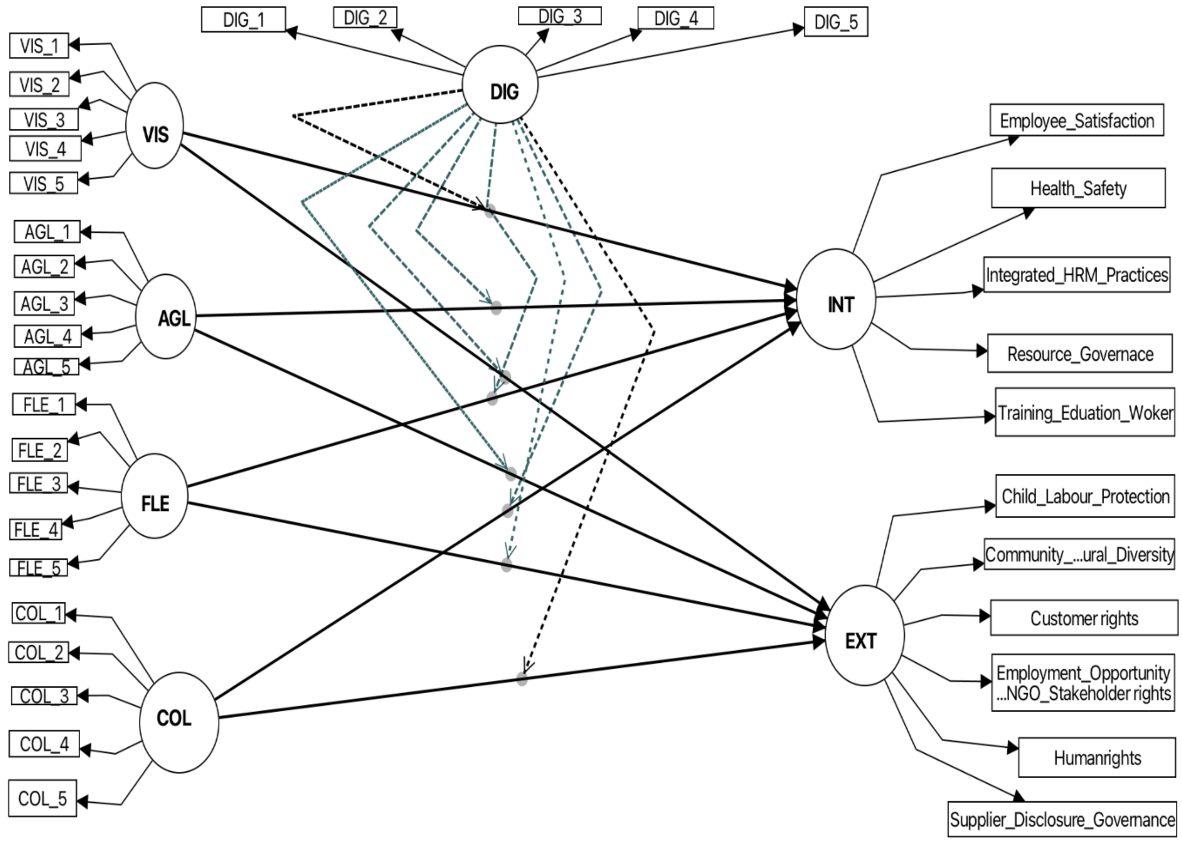

FIGURE 14: CONCEPTUAL PATH DIRECTION OF RESILIENCE, DIGITAL TOOLS AND SOCIAL SUSTAINABILITY

The result reveals a positive correlation between resilience constructs and both internal and external social sustainability. Specifically, visibility, agility, and collaboration within the FSC are positively associated with social sustainability. Consequently, hypotheses H1a, H1b, and H1d are supported ($β\_{VIS}$ = 0.137, $β\_{AGL}$ = 0.464, $β\_{COL}$ = 0.288, $P < 0.05$) for internal social sustainability, while H1c is not supported (P-value > 0.05). This trend for visibility, agility, and collaboration also extends to external social sustainability, as shown by the results ($β\_{VIS}$ = 0.247, $β\_{AGL}$ = 0.202, $β\_{COL}$ = 0.260, $P < 0.05$). Visibility has a comparatively higher positive impact on external social sustainability ($β\_{VIS}$ = 0.247) than on internal social sustainability ($β\_{VIS}$ = 0.137). While agility has a stronger impact on internal social sustainability ($β\_{AGL}$ = 0.464 for INT > $β\_{AGL}$ = 0.202 for EXT). Collaboration, like agility, has a more positive effect on internal social sustainability ($β\_{COL}$ = 0.288 for INT > $β\_{COL}$ = 0.260 for EXT).

The findings from moderation demonstrate that visibility is positively moderated by digital tools, enhancing the relationship with internal and external social sustainability ($β\_{VIS * DIG}$ = 0.203 for INT, and $β\_{VIS * DIG}$ = 0.173 for EXT, $P < 0.05$). This finding suggests that digital tools significantly strengthen the impact of visibility on internal and external social sustainability. However, this study finds mixed results for agility. The application of digital tools negatively moderates the relationship between agility and internal social sustainability ($\beta_{AGL * DIG}$ = -0.260, P < 0.05). Digital tools negatively moderate the effect of collaboration on external social sustainability in the SC ($\beta_{COL * DIG}$ = -0.301, P < 0.05). Moreover, the application of digital tools does not moderate the relationship between flexibility practice and both internal and external social sustainability in the fashion supply chain. A detailed summary of hypothesis testing outcomes is presented in Table 27.

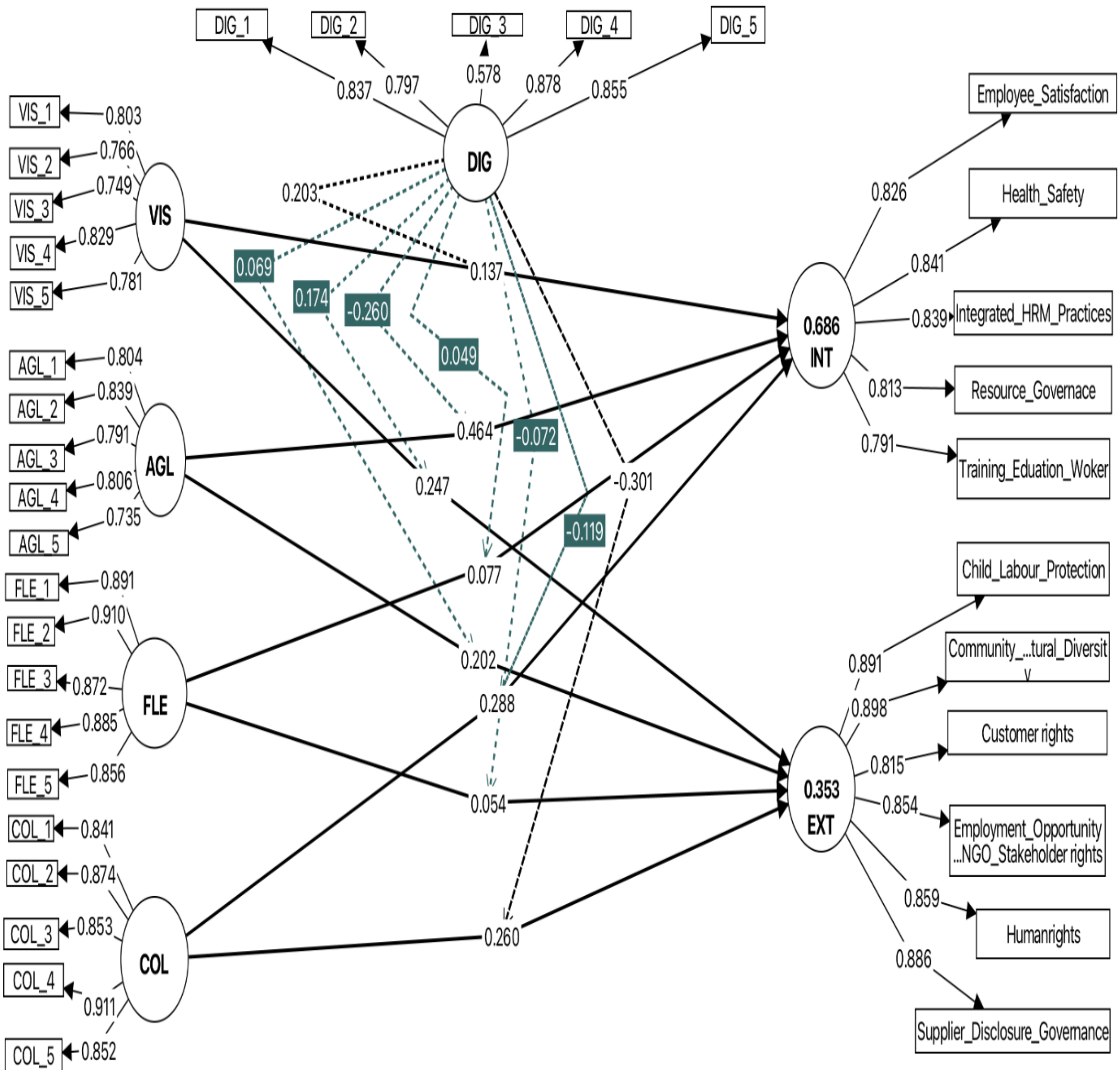

FIGURE 15: RESULT OF PATH DIRECTION OF RESILIENCE, DIGITAL TOOLS AND SOCIAL SUSTAINABILITY

TABLE 27: HYPOTHESIS TESTING RESULTS FOR RESEARCH QUESTION 2

Hyp.	Path direction	Path-Coff.	T-Stat.	P-value	Explanation
H1a	VIS -> INT	0.137	1.88	0.059	Supported
H1b	AGL -> INT	0.463	8.236	0.000	Supported
H1c	FLE -> INT	0.076	1.409	0.159	Not Supported
H1d	COL -> INT	0.287	5.056	0.000	Supported
H2a	VIS -> EXT	0.247	3.045	0.002	Supported
H2b	AGL -> EXT	0.201	2.787	0.005	Supported
H2c	FLE -> EXT	0.054	0.774	0.438	Not Supported
H2d	COL -> EXT	0.259	3.427	0.001	Supported
H3a	DIG * VIS -> INT	0.202	2.291	0.002	Supported
H3b	DIG * AGL -> INT	-0.260	4.864	0.001	Not Supported
H3c	DIG * FLE -> INT	0.049	0.933	0.350	Not Supported
H3d	DIG * COL -> INT	-0.118	1.385	0.165	Not Supported
H4a	DIG * VIS -> EXT	0.173	1.912	0.056	Supported
H4b	DIG * AGL -> EXT	0.069	1.388	0.165	Not Supported
H4c	DIG * FLE -> EXT	-0.072	0.920	0.357	Not Supported
H4d	DIG * COL -> EXT	-0.301	3.053	0.002	Not Supported

Finally, this study reports the $r^2_{\_INT}$ = .686 with the adjusted $r^2_{\_INT}$ = .670 and the $r^2_{\_EXT}$ = .353 with the adjusted $r^2_{\_EXT}$ = .321. The output of CFA shows that chi-square (x^2) is 1085.05 (p-value < 0.05), and the degree of freedom (DF) is 630 and the subsequent relative chi-square (x^2/DF) is 1.73. This relative chi-square (1.73 < 3) is smaller than the recommended threshold (Kline, 2016). The Root Mean Square Error of Approximation (RMSEA) is .062, which is less than the 0.08 benchmark (Hair et al., 2010) and the Standardized Root Mean Residual (SRMR) is 0.052. Moreover, the comparative fit index (.91) and the Tucker-Lewis Index (TLI) is 0.90, and the incremental fit index (.91) are at acceptable level.

5.2 The Effect of Resilience on Environmental Sustainability and Moderating Role of Digital Tools

Like social sustainability, the relationship between resilience, digital tools, and two constructs of environmental sustainability (i.e., waste management and reducing pollution/emission) has been examined in the FSC. The PLS-SEM was also performed through Smart-PLS 4.0. The analysis again started with testing the effect of the control variables (i.e., year of experience and position of the supply chain) on waste management and reducing pollution/emission of environmental sustainability. The results of the control variables are $\beta\_{EXP} = -0.028$ and $\beta\_{POS} = -0.027$, $P > 0.05$ on waste management, and $\beta\_{EXP} = -0.019$ and $\beta\_{POS} = -0.012$, $P > 0.05$ on pollution/emission of the environmental sustainability model. The control variables demonstrated no significant impact on any constructs of environmental sustainability. Then, the hypotheses H5a–H5d and H6a–H6d were tested to evaluate the direct effect of four independent variables—visibility, agility, flexibility, and collaboration—on waste management and reducing pollution/emission of environmental sustainability through SEM. The hypotheses H7a–H7d and H8a–H8d were analyzed to assess the moderating effect of digital tools on environmental sustainability and resilience practices. However, before testing hypotheses, several preliminary statistical analyses have been done to check the suitability of the data. The detailed preliminary methodological analysis has been discussed in chapter 4. Accordingly, the measurement items for RQ3 and the respective factor loadings of the constructs have been listed in Table 28.

TABLE 28: MEASUREMENT ITEMS AND RESPECTIVE STANDARD FACTOR LOADING

Measurement Constructs and Items		Std. Loading
Visibility (VIS)		
VIS_1	Tracking, tracing, and localization system	0.794
VIS_2	Use of Physical transportation for tracking and innovative analytical tools	0.780
VIS_3	Real-time information sharing and disclosure	0.743
VIS_4	Reduce intermediaries in the supply chain	0.821

VIS_5	Trustworthy information governance system	0.793
Agility (AGL)		
AGL_1	Large product varieties and rapid change of production line	0.792
AGL_2	Reorganize of the existing supply chain relationship at the strategic level	0.838
AGL_3	Respond to the strategic change in the market, people, technology, and society	0.799
AGL_4	Reconfigure the supply chain before competitors for competitive advantage	0.810
AGL_5	Supplier selection and segmentation decision in the supply chain during crisis	0.738
Flexibility (FLE)		
FLX_1	Re-organization of operational SC after disruption	0.888
FLX_2	Flexible capacity in logistics at demand uncertainty	0.913
FLX_3	Having flexible sources of suppliers in the supply chain	0.877
FLX_4	Apply a postponement strategy throughout the supply chain	0.885
FLX_5	Tactical flexibility in operations and accept minor and random changes	0.851
Collaboration (COL)		
COL_1	Ability to work with suppliers for products and information flows	0.848
COL_2	Having a company-customer collaborative approach in the supply chain	0.877
COL_3	Having a relationship with the competitors and stakeholders	0.858
COL_4	Facilitate human-machine collaboration	0.909
COL_5	Assurance of commitment and compliance among the supply chain actors	0.840
Digital Tools Environmental Sustainability (DIG)		
DIG_1	Uses circular purchase and design through digital tools (blockchain/BDPA)	0.748
DIG_2	Uses blockchain for resource sharing and knowledge management practices	0.777

DIG_3	Uses digital tools (AI) support to ensure strategic environmental planning and recovery management in supply chain disruption	0.787
DIG_4	Uses the cloud-based platform for the analytics and warning capability of the supply chain	0.581
DIG_5	Uses digital tools to ensure transparency in the supply chain actors	0.835
Waste Management (WST)		
WST_1	Waste produced and distributed in the manufacturing process or from customers is recycled	0.837
WST_2	Recycled waste and garbage are reprocessed as a new product	0.888
WST_3	Having a green research, design and development for waste and garbage management	0.879
WST_4	The firm designs/optimizes ways to recycle waste materials and spare parts	0.857
WST_5	Reduction of solid waste in the supply chain process	0.775
Reducing Pollution/Emission (P/E)		
P/E_1	Reduction in air pollution	0.737
P/E_2	Reduction of wastewater	0.735
P/E_3	Having greenhouse gas reduction strategies	0.780
P/E_4	Decrease in consumption of hazardous/harmful materials	0.838
P/E_5	Reporting and disclosure of environmental emission	0.691

It is worth mentioning that the item DIG_3 of digital tools for social sustainability model (factor loading .57) and DIG_4 of digital tools (factor loading .581) for environmental sustainability model fall into the moderate/marginally acceptable range. However, this study decided to keep these two items having a good construct-level reliability. The Cronbach's $\alpha \geq .70$, Composite Reliability (CR) $\geq .70$, and Average Variance Extracted (AVE) $\geq .50$, having these items in the construct of digital tools. Moreover, the items are theoretically important (Abdul-Hamid et al., 2022). If this study drops these items, it will reduce content validity. The important digital tool (i.e., cloud-based platform) is no longer covered under the digital tools. Therefore, this study proceeds with DTG_3 for socials sustainability and DTG_4 for environmental sustainability. Furthermore, the model fit is also acceptable, and after keeping this item, the overall CFA/SEM model has good fit indices (CFI ≥ .90, and RMSEA ≤ .08). Finally, the other items load strongly, and most of the items of the digital tools are ≥ .70; a single .57 and .581 won't invalidate the construct.

For the testing hypotheses (H5-H8), the following structural framework has been designed through Smart PLS. This path directional graph shows the direct effect of resilience on waste management and reducing pollution/emission of environmental sustainability. It also illustrates how the application of digital tools moderates the relationship between resilience and environmental sustainability within the fashion supply chain.

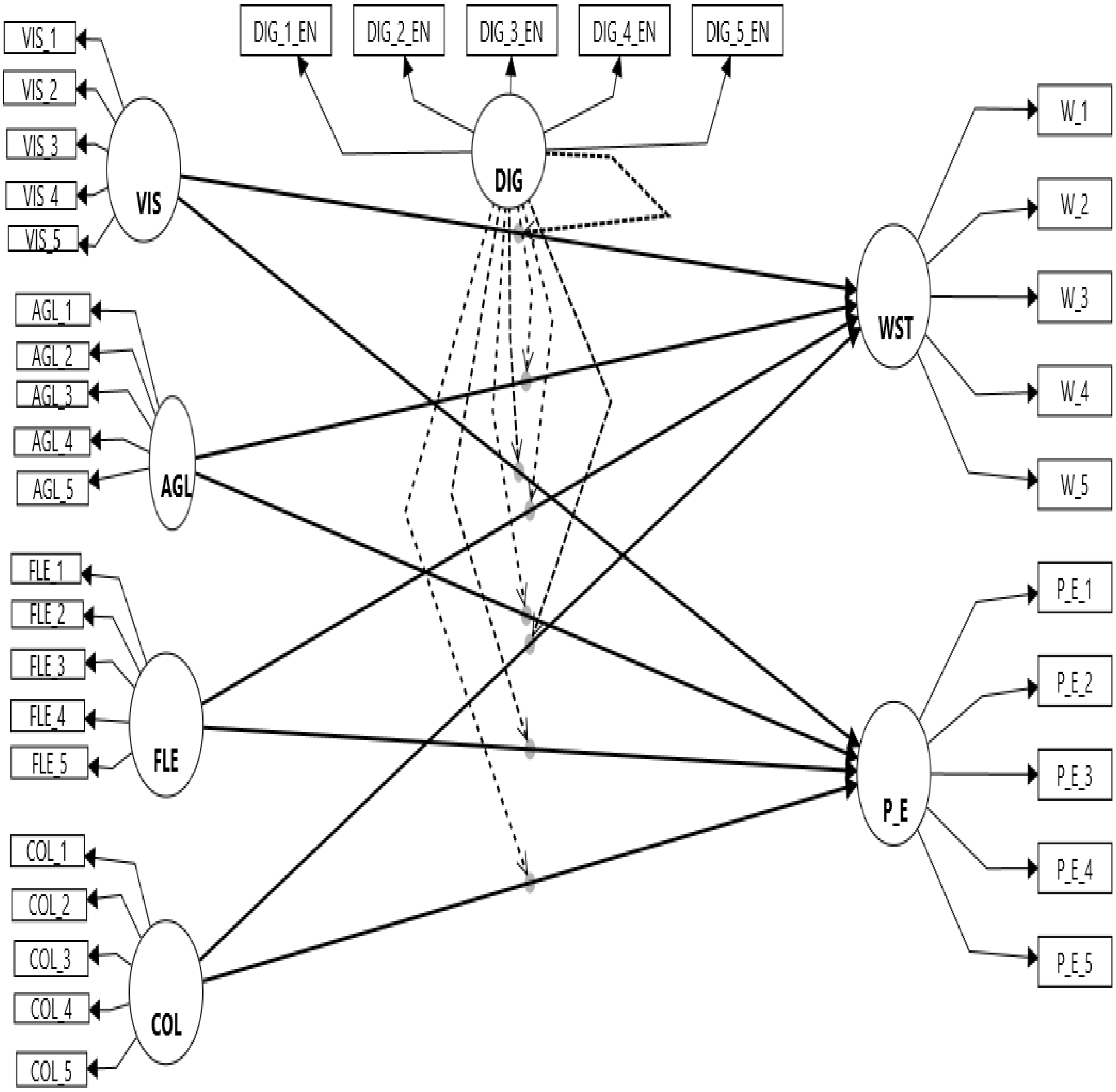

FIGURE 16: CONCEPTUAL PATH DIRECTION OF RESILIENCE, DIGITAL TOOLS AND ENVIRONMENTAL SUSTAINABILITY

After testing the preliminary statistical analysis, this study finds the following results that have been stated in Figure 17.

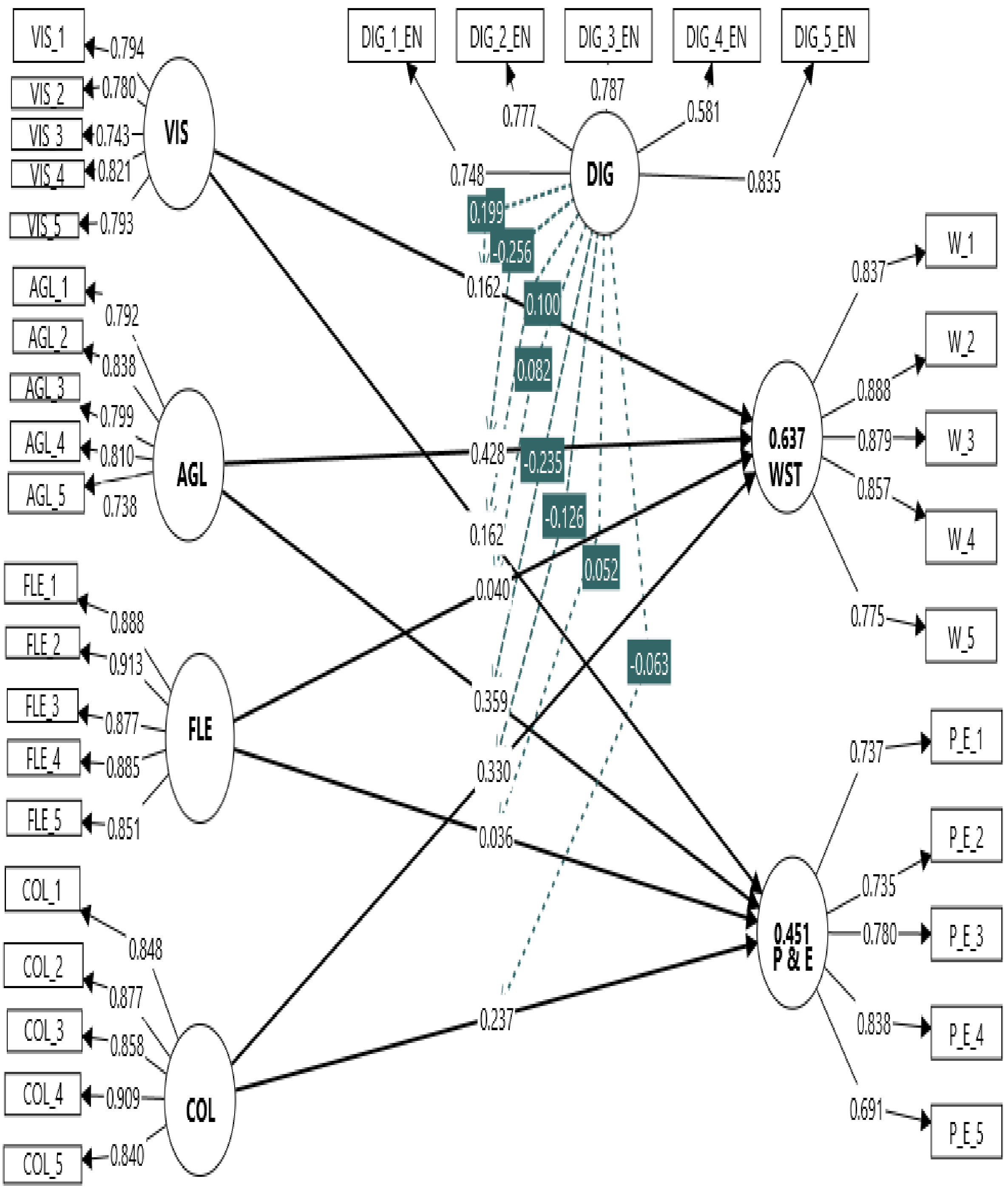

FIGURE 17: RESULT OF PATH DIRECTION OF RESILIENCE, DIGITAL TOOLS AND ENVIRONMENTAL SUSTAINABILITY

The result reveals that visibility, agility, and collaboration within the FSC are positively associated with environmental sustainability. Consequently, hypotheses H5a, H5b, and H5d are supported ($\beta_{VIS} = 0.162$, $\beta_{AGL} = 0.428$, $\beta_{COL} = 0.330$, $P < 0.05$) for waste management of environmental sustainability, while H5c is not supported. This trend also extends to reduce pollution/emission of environmental sustainability as shown by the result ($\beta_{\_VIS} = 0.162$, $\beta_{\_AGL} = 0.355$, $\beta_{\_COL} = 0.237$, $P < 0.05$). Agility has comparatively a higher positive impact on waste management than reducing pollution/emission ($\beta_{\_AGL} = 0.428 > \beta_{\_AGL} = 0.355$), while collaboration also has more (0.10) positive impact ($\beta_{\_COL} = 0.330 > \beta_{\_COL} = 0.237$) on waste management than reducing pollution/emission.

The other way around, visibility has an almost similar positive impact on both the waste management and reducing pollution/emission construct of environmental sustainability ($\beta_{\_VIS} = 0.163$ for WST, and $\beta_{\_VIS} = 0.162$ for P/E). However, this study could not find any positive or negative effect of flexibility as a construct of resilience on waste management and reducing pollution/emission of environmental sustainability in the fashion supply chain. The respective P-value for flexibility towards waste management and pollution/emission of environmental sustainability is > 0.05, which is not statistically significant.

The findings derived from the moderation of digital tools demonstrate that visibility is positively moderated by digital tools, enhancing the relationship with waste management ($\beta_{\_VIS * DIG} = 0.196$, $P < 0.05$). This suggests that digital tools significantly strengthen the impact of visibility on environmental sustainability through managing waste, remanufacturing waste, reproducing and distribution. However, this study could not find a similar moderating effect of digital tools for reducing pollution/emission from environmental sustainability. Agility exhibits a negatively moderated effect through digital tools in both waste management and reducing pollution/emission for environmental sustainability ($\beta_{\_AGL*DIG} = -0.256$ for WST, $\beta_{\_AGL*DIG} = -0.235$ for P/E, $P < 0.05$). This finding is completely opposite to proposed hypotheses of H_{7b} and H_{8b}. The application of digital tools does not moderate even the relationship between flexibility and environmental sustainability in the fashion supply chain. Similarly, this is also true for collaboration, digital tools, and environmental sustainability.

Finally, this study reports the $r^2_{\_WST} = 0.637$ with the adjusted $r^2_{\_WST} = 0.619$ and the $r^2_{\_P/E} = 0.451$ with the adjusted $r^2_{\_P/E} = 0.423$. The confirmatory factor analysis (CFA) was performed to estimate the model measurement and to check the unidimensionality and robustness of the model. The output shows that the Standardized Root Mean Residual (SRMR) is 0.062 <

0.08, the benchmark (Hair et al. 2010). Moreover, the normed fit index (0.78) and Fornell-Larcker (FL) criteria for all constructs are higher than 0.70. A detailed summary of hypothesis testing with their respective t-statistic outcomes is presented in Table 29.

TABLE 29: RESULT OF HYPOTHESIS TESTING FOR RESEARCH QUESTION 3

Hypothesis		**Path-Coefficient**	**T statistic**	**P-value**	**Explanation**
H5a	VIS -> WST	0.162	2.056	***	Supported
H5b	AGL -> WST	0.428	7.820	***	Supported
H5c	FLE -> WST	0.040	0.687	NS	Not Supported
H5d	COL -> WST	0.330	4.616	***	Supported
H6a	VIS -> P/ E	0.162	2.086	***	Supported
H6b	AGL -> P/ E	0.359	4.69	***	Supported
H6c	FLE -> P/ E	0.036	0.563	NS	Not Supported
H6d	COL -> P/E	0.237	3.535	***	Supported
H7a	DIG * VIS -> WST	0.199	2.119	***	Supported
H7b	DIG * AGL -> WST	-0.256	5.490	***	Not Supported
H7c	DIG * FLE -> WST	0.082	1.502	NS	Not Supported
H7d	DIG * COL -> WST	-0.126	1.243	NS	Not Supported
H8a	DIG * VIS -> P/E	0.100	1.017	NS	Not Supported
H8b	DIG * AGL -> P/E	-0.235	2.911	***	Not Supported
H8c	DIG * FLE -> P/E	0.052	0.730	NS	Not Supported
H8d	DIG * COL -> P/E	-0.063	0.595	NS	Not Supported

DIG = Application of Digital Tools, WST = Waste Management of Environmental Sustainability, P/E = Pollution/ emission of Environmental Sustainability

Chapter 6: Discussion

6.1 Discussion based on Research Question 2

This section empirically discusses the effect of practicing resilience constructs on social sustainability and the moderating effect of digital tools on the fashion supply chain.

6.1.1 Main Effects of Resilience Constructs on Social Sustainability

The findings of the first empirical model reveal a mixed outcome between resilience constructs and social sustainability. In general, it aligns with the literature suggesting that resilience practices boost socially sustainable supply chains. Graphically, Figure 18 could be the basis for the discussion of resilience, social sustainability, and digital tools with respect to Hypotheses H1-H4.

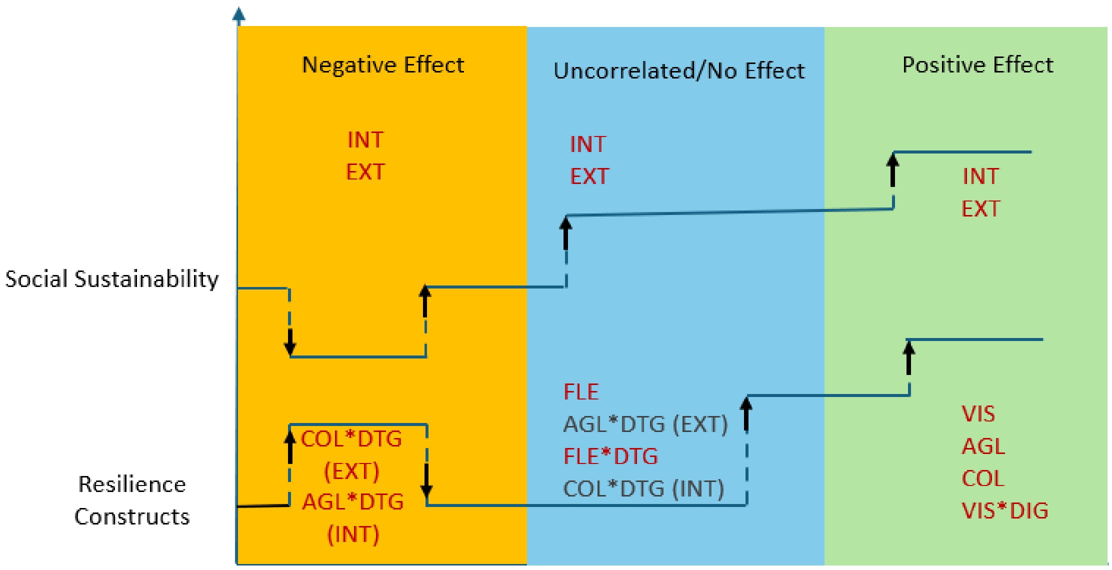

FIGURE 18: GRAPHICAL EXPLANATION OF THE RESULT OF RQ2

This graph shows which resilience constructs have positive effects, negative effects, and no effect on social sustainability along with the moderating role of digital tools. The top directional line represents social sustainability, and the bottom directional line represents resilience constructs. First, the yellow rectangle shows the negative effect of resilience constructs on social sustainability. Because the directional lines of social sustainability and resilience are in opposite direction. It illustrates the negative moderating effect of collaboration and digital tools on external social sustainability. It also shows the negative moderating effect of agility and digital tools on internal social sustainability. Similarly, the second blue colored rectangle shows that there is no directional relationship between resilience constructs and social sustainability, and the p-value of these constructs are not significant in either positive or negative. Finally, the light green colored rectangle illustrates a positive relationship between resilience constructs and social sustainability, highlighting the moderating role of digital tools, as indicated by a significant p-value. Most of the findings of the light green rectangle are aligned with previous findings. For example, Münch & Hartmann, (2023) demonstrated that visibility in the supply chain increases human resources skills, education and training, following health and safety regulations as an internal social sustainability outcome. Consistently, this study confirms that visibility practices—such as continuous tracking and tracing, analytical innovation, information sharing, and the disclosure of information among supply chain actors—significantly improve internal social sustainability. It also confirms that visibility practices have a positive effect on customer satisfaction, customer loyalty, human rights, job opportunities, and preventing child labor in the fashion supply chain. This external social sustainability could be achieved by ensuring a trustworthy information system, reducing intermediaries, and sharing information in real-time between actors. These findings align with Mol A., (2015), who highlighted the critical role of transparency in achieving value chain sustainability. This research substantiates transparency through effective information sharing, and the use of innovative analytical tools protects stakeholder rights, NGO rights, and respectfully promotes local cultural diversity. Thus, visibility enhances external social sustainability in the fashion supply chain. Ahmad et al., (2022) further emphasized the significance of real-time visibility for sustainability, ensuring accurate information flows and processes throughout the supply chain. Visibility through a trustworthy information governance system promotes sustainability reporting and disclosure of suppliers' issues and shares these issues with the customers and society.

Moreover, visibility through reducing intermediaries has also been used as a resilience indicator of customer satisfaction and loyalty. The findings related to visibility and social sustainability suggest that transparency not only enhances the accountability of suppliers but also fosters trust and relationships with customers and society. These insights align with previous research that emphasize the importance of data integrity and traceability in a sustainable supply chain. The evidence indicates that the visibility mechanism contributes to greater resilience, acting as a key determinant of customer satisfaction and loyalty. However, the positive effect of visibility on social sustainability is clear; further research is needed to explore the potential risks, such as overexposure to data sharing or the effect of increased pressure on suppliers or other actors for sustainability. Few studies explicitly examine how cultural or regulatory disagreements influence the implementation of visibility-driven governance and social sustainability across global supply chains. Future research work should focus on these issues. The extent to which the feeling of a micromanaged culture, a constant tracking and tracing system leads to pressure and restraint to innovation could be considered as another psychological aspect of visibility. Future research could also concentrate on the effect of this behavioral aspect related to resilience and social sustainability in the supply chain. This study ignores the “always on” feeling of supply chain actors, and how it grossly affects social sustainability in FSC could be another way of analyzing the relationship between visibility and social sustainability.

The empirical findings reinforce that agility serves as a key enabler of resilience. Agility has a positive effect on social sustainability in the fashion supply chain, particularly through its role in fostering adaptability and trust between stakeholders. This finding is aligned with the finding of Kazancoglu et al., (2022). It confirms the importance of strategic planning, as well as agile practices to foster trust among stakeholders. Agility through strategic adaptation to market dynamics, technological advancements, and social changes demonstrates a significant positive impact on the sustainable supply chain. These insights support the positive link between agility and external social sustainability. This empirical evidence highlights the importance of strategic planning in leveraging agility to sustain relationships with suppliers and social engagement. These agile capabilities allow rapid adaptation against demand fluctuation and market uncertainty in the fashion industry.

In addition, agile practices such as strategic supplier segmentation and the pursuit of competitive advantages demonstrate how organizations can optimize their responsiveness. In fact, agility not only mitigates the effects of disruption but also contributes to an inclusive and equitable supply chain, which is an essential pillar of social sustainability (Jena & Ghadge, 2021). The link between agility and social sustainability outcomes suggests that agility should be seen not just as an operational efficiency tool but as a strategic asset for sustainability-driven value chains. The empirical data supports this positive relationship. However, the degree to which agility contributes to social sustainability depends on organizational maturity, sector-specific factors, and regional contexts. Future empirical studies could further explore how cultural, regulatory, and technological differences influence the agility-social sustainability link across diverse global supply chains.

Collaboration is a key driver of social sustainability, facilitating improvements through the customer-supplier relationship and human-machine collaboration (Koh et al., 2017). Strong interaction among internal actors, suppliers, and customers is vital to achieve long-term sustainability (Wang et al., 2022; Münch & Hartmann, 2023). Consistent with the literature, this study confirms that collaboration as a resilience construct positively influences both internal and external social sustainability by maintaining compliance and commitment between actors. Furthermore, collaborative practices, when embedded in resilience strategies, have a positive impact on both internal (e.g., employee well-being, workplace engagement) and external (e.g., supplier responsibility, customer satisfaction) constructs of social sustainability. The research also highlights that human-machine collaboration and multi-directional (vertical and horizontal) coordination mechanisms enhance governance structures and improve social sustainability across the fashion supply chain. Such collaboration enables FSC actors to manage complexity and ethical standards, and foster trust throughout the supply chain. It also strengthens customer-supplier governance, ensuring a mutual understanding of expectations about labor rights, fair wages, and social stakeholder engagement. These results reinforce the notion that collaboration is not merely a support function but a strategic enabler of social sustainability.

The majority of earlier studies concentrate on the connection between internal social sustainability and collaboration. The interplay of supplier governance, relational capital, information disclosure concerning sustainability, and the practices of agility and flexibility remain an unexplored area in literature, warranting further research. The visibility, agility, and collaboration results reinforce the existing literature by extending its applicability to

Bangladeshi fashion supply chain actors, alongside other industries such as mining and energy. Contrary to expectation, the result of flexibility is diverse from previous literature. For example, the outcome of flexibility is not in line with the literature of Kazancoglu et al., (2022) and Sarker et al., (2021). The possible reason for this contradictory result of flexibility could be many. Such as, Bangladeshi FSC companies perceive flexibility as part of internal operational logistics with a limited need to align with SC actors' sustainability. Flexibility through operational adjustment may improve short-term efficiency but does not necessarily improve working conditions, stakeholder equity, or customer and social engagement, which are core to social sustainability. This could be another reason why flexibility does not have a positive effect on social sustainability. Furthermore, flexibility through quick changes in the supply chain operations may lead to social dumping, which hurts supply chain social actors, internal management, and regular labor forces. Subsequently, this may have short-term benefit but not long-term social sustainability.

6.1.2 Moderating Effect of Digital Tools between Resilience and Social Sustainability

The moderating effect of digital tools presents an interesting and somewhat counterintuitive finding compared to previous literature. This study confirms that the application of digital tools moderates the positive relationship between internal and external social sustainability, and resilience practices. This finding is aligned with the outcome of the study of A.S & Ramanathan, (2021) and Bag et al., (2022). It particularly confirms that digital tools through the application of blockchain and BDPA strengthen the impact of visibility on governance, training, education, and customer and suppliers' satisfaction. The greater adoption of digital tools (i.e., blockchain, BDPA, IOT, AI, and CBP) for transparency among fashion supply chain actors enhances integrated human resource management, health and safety, and knowledge management. Data-driven Industry 4.0 accelerates the positive effect of visibility through information sharing, tracking and tracing, localization, and reducing intermediaries on social sustainability in FSC. This study empirically showed the positive moderating role of digital tools in the relationship between visibility and human resource management. However, the success of the moderating role of digital tools also depends on the level of digital competency and digital maturity of the supply chain actors. Therefore, the positive moderating effect indicates that digital maturity is a critical success factor that maximizes social sustainability and visibility. FSC actors with advanced digital capabilities are more likely to turn visibility into social well-being, such as upholding human rights, protecting child labor, increasing diversity, and maintaining trust among actors. Future research could explore which specific digital tools (e.g., AI or blockchain) offer the greatest leverage for different types of visibility-driven social sustainability outcomes.

Although the application of digital tools is often considered as an enabler of collaboration, this study finds a negative moderating effect, indicating that when digital tools are heavily relied upon, the positive effect of collaboration on social sustainability is reduced. The hypothesis H4d shows the negative outcome and is not aligned with the finding of Del Giudice et al., (2020). The finding related to digital tools and collaboration also contradicts the outcome of Luthra et al., (2020), McGrath et al., (2021), and Sharma et al., (2022). This counterintuitive result could be discussed by several possible factors. Companies in developing countries such as Bangladesh could maintain strict corporate privacy instead of digital tools-driven collaboration. The actors in the Bangladeshi fashion supply chain prioritize human-based collaboration over technology-based collaboration due to their fear of technological advancement. They probably rely on personal, trust-based, face-to-face interactions among the fashion supply chain actors. Moreover, human relationships and attachment matter in socially connected collaborations. Specifically, in the fully digitalized cultures or sectors may erode emotional connection, empathy, and informal coordination, which might be essential for building social sustainability and local stakeholder engagement.

Interestingly, agility is also negatively moderated by digital tools in the context of internal social sustainability. A plausible explanation for these inconsistencies is the reliance on diverse and specific digital applications by actors. The application of these diversified digital tools hinders seamless agile practice within the managerial operations and division in the fashion supply chain, disrupting the quick strategic change. Furthermore, the levels of managerial efficiency of various FSC actors in agile practices that achieve social sustainability might influence the moderating role of digital tools.

On the other hand, this study suggests that the flexibility construct of resilience does not exert any influence on social sustainability within Bangladesh's fashion supply chain. Several reasons may explain this outcome, including job insecurity and weakened labor rights. Workers may experience anxiety about potential job loss when flexible practices fail to align with company objectives or are not implemented effectively. Another responsible factor could be the rise of a secondary labor market within the Bangladeshi fashion industry. Many companies outsource portions of their workload to subcontracted factories that adopt similar operational strategies without a strategic orientation toward flexibility for social sustainability. Furthermore, flexibility may be perceived as a limit to opportunities for stable, long-term employment relationships and hinder collective bargaining, trade union participation, and the development of strong social ties among actors and therefore compromising social sustainability.

These findings underline the importance of better collaboration of technological tools with human to overcome social sustainability challenges. These findings further contribute to the necessity of technology-based real-time information sharing for social sustainability and its synergic benefits in the FSC. This study also brings forward to the argument that technology-driven transparency improves internal and external social sustainability. It develops high levels of supply chain traceability, monitoring, and information-sharing capabilities. Companies can create further internal and external social advantages by implementing resilience practices, capturing sustainability.

6.2 Discussion based on Research Question 3

This section explains the empirical effect of resilience constructs on environmental sustainability, particularly on waste management and reducing pollution/emission of environmental sustainability. Figure 19 is the graphical basis for the explanation of resilience constructs, digital tools, and environmental sustainability.

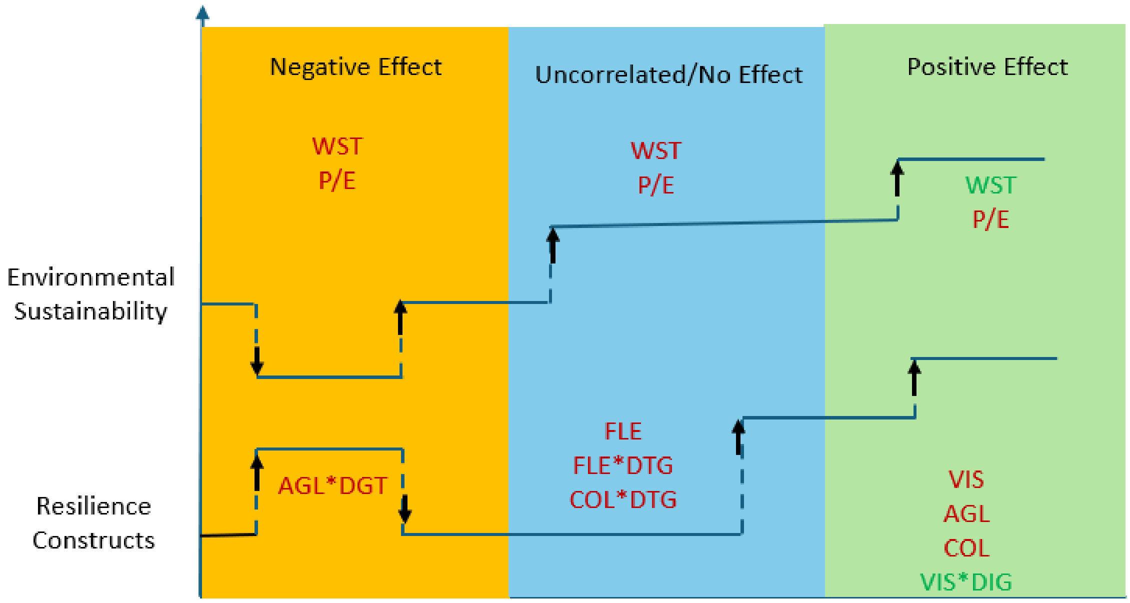

FIGURE 19: GRAPHICAL EXPLANATION OF THE RESULTS OF RQ3

This graph shows which constructs of resilience have positive, negative, and no effects on environmental sustainability along with the moderating role of digital tools. The top directional line represents environmental sustainability, and the bottom directional line represents resilience constructs. First, yellow-colored rectangle shows the negative effect of resilience on environmental sustainability. The top directional line represents environmental sustainability, and the bottom directional line represents resilience constructs. Specifically, it illustrates the negative moderating effect of agility combined with digital tools on waste management in relation to environmental sustainability. Similarly, the second blue colored rectangle shows that there is no directional relationship between resilience and environmental sustainability, and the p-value of these constructs is not significant in either positive or negative. Finally, the light green colored rectangle shows the positive relationship between resilience constructs and environmental sustainability with the moderating role of digital tools and a significant p-value.

6.2.1 Main Effects of Resilience Constructs on Environmental Sustainability

The findings of this section reveal a mixed outcome between resilience constructs and environmental sustainability. Most of the findings are aligned with the broader literature suggesting that resilience practices boost environmentally sustainable supply chains. For example, it demonstrates that transparency in the supply chain increases the disclosure of environmental information and the disclosure of carbon emission by visibility in management, regulation, and supply chain policy. Consistently, the answer of the RQ3 confirms that visibility practices, such as continuous tracking and tracing, analytical innovation, information sharing, and information disclosure among SC actors, significantly contribute to waste reduction, green design, recycling, conservation, and new product development for environmental sustainability. Besides, visibility practices have a positive effect on reducing pollution/emission in the fashion supply chain. Visibility has a positive effect on reducing air pollution, water pollution, CO_2 emission, and greenhouse gas reduction, as is the case with the findings of Apeji & Sunmola, (2022) and Belhadi et al., (2022). This research corroborates transparency through effective information safeguards and eco-friendly factory design enhance environmental sustainability, proper waste treatment plants and low carbon emission in the FSC. Ahmad et al., (2022) further emphasizes the significance of real-time visibility for environmental sustainability, ensuring accurate information flows across the supply chain.

Furthermore, agility measures how companies adapt their supply chain to manage waste through product manufacturing and adequate environmental capability (Sarkis, 2021). The redundant capacity through agility is considered a safeguard for the wasted resources and energy. This study also focused on the ability for contingency plans, as agile practices have a positive effect on waste management and reducing pollution/emission in the fashion supply chain. This positive effect could be done through strategic change and quick recovery for decarbonization. Agility through strategic change create a circular supply chain which, also aligns with the finding of Chari et al., (2022). This study confirms that agility is associated with strategic responses for reducing carbon emission, and disclosing environmental reporting. These insights reinforced a positive relationship between agility and both constructs (i.e., waste management and reducing pollution/emission) of environmental sustainability.

Stakeholder collaboration is a key driver of environmental sustainability, facilitating green management and green supply chains and reducing waste and energy consumption (Ahmed et al., 2020). Strong interaction among internal actors, suppliers, and customers is vital to achieve long-term sustainability (Münch & Hartmann, 2023; Wang et al., 2024). Consistent with the previous literature, the findings of this section confirm that collaboration positively influences both waste management and reducing pollution/emission of environmental sustainability by reducing water usage, air and solid waste, and decreasing hazardous materials. The visibility, agility, and collaboration results reinforce the existing literature by extending its applicability to FSC actors in Bangladesh, alongside other industries such as mining and energy. Most earlier studies concentrate on the wider connection between collaboration and environmental sustainability. There is limited literature in which researchers show the direct effect of collaboration, specifically on waste management or reducing pollution/emission for environmental sustainability. However, the interplay of environmental resource efficiency management and the practice of resilience remain unexplored areas in literature. Environmental reporting and carbon accounting for information disclosure related to resilience also remains an unexplored area in the literature, warranting further research. Contrary to expectation, the data from the respondents do not support the literature for flexibility. The result of flexibility differs from the studies of Govindan et al., (2014) and López & Ruiz-Benítez, (2020). The contradictory result may be due to Bangladeshi companies viewing flexibility primarily as an aspect of internal operational logistics, which they consider having limited importance for aligning with supply chain actors. Moreover, very short-term flexibility may not always bring long-term environmental sustainability.

6.2.2 Moderating Effect of Digital Tools between Resilience and Environmental Sustainability

The moderating effect of digital tools presents an interesting and somewhat counterintuitive finding compared to previous literature in case of resilience and environmental sustainability relationship. Digital tools moderate the positive relationship between environmental sustainability and resilience practices (A.S & Ramanathan, 2021; Bag et al., 2022). In line with the literature, this study particularly confirms that digital tools strengthen the impact of visibility in waste management. That means the greater adoption of digital tools for transparency or visibility among SC actors enhanced efficient waste management, remanufacturing, green supply chains, circular economies and natural conservation in operations. Visibility through information sharing has been moderated by blockchain based circular economy, AI-based waste management, and digital tools centric green SC design to enhance environmental sustainability. Furthermore, digital tools were found to positively moderate the relationship between joint problem-solving strategies, trust mechanisms, and supply chain agility, flexibility, and collaboration (Faruquee et al., 2021) but this study did not find any moderating effect of digital tools with collaboration for environmental sustainability. The probable reasons could be the preference of the Bangladeshi FSC actor for human-centric collaboration instead of technology-based collaboration for environmental sustainability. Esfahbodi et al., (2023) explored the moderating effect of green information systems (GIS) on the relationship between green logistics through collaboration and environmental sustainability.

On the other hand, hypothesis H7b shows the reverse outcome from the findings of Del Giudice et al., (2020) and Sharma et al., (2022). This study infers that digital tools negatively moderate the relationships between agility and waste management and reduce pollution/emission in the FSC. The negative moderating effect means higher agility and the higher use of digital tools weakens the positive effect on waste management instead of strengthening environmental sustainability. The agility/digital tools may create unintended consequences. First, the plausible explanation for this outcome could be resource misalignment and lack of transformative action in the FSC of Bangladesh (Uddin et al., 2023). Organizational agility and digital tool adoption often focus on cost reduction, speed, and short-term competitiveness. This might divert resources away from long-term sustainability, making environmental sustainability less of a priority. For instance, many fast-moving garment factories employ digital tracking systems to accelerate exports; this increases supply chain pressure, leading to higher water and energy consumption and chemical discharge. Second, the use of digital tools entails costs such as energy-intensive data centers, e-waste, and ICT hardware. In Bangladesh, the integrated recycling system, e-waste management, and renewable energy infrastructure are still underdeveloped; the expanded use of digital tools may inadvertently affect environmental outcomes. Third, agility practice through quick adaptation is weakly regulated in Bangladesh. Due to weak regulatory oversight, firms may respond quickly to buyer demand at the expense of eco-friendly processes. This reactive approach prioritizes economic value but undermines agility and sustainability. Fourth, institutional and policy gaps further exacerbate the problem. Environmental regulations in Bangladesh are weakly enforced at the field level of FSC. Consequently, firms adopt agility and digital tools mainly to meet international buyers' requirements for efficiency and cost-effectiveness, rather than to comply with environmental sustainability standards. In fact, it transforms the role of these capabilities toward competitiveness rather than environmental responsibility, producing a negative moderating effect. Finally, limited digital literacy leads to underutilization or misuse of tools, which in turn creates inefficiencies, higher resource consumption, and added complexity without yielding environmental benefits. Besides, the companies in developing countries like Bangladesh maintain different corporate resilience policies instead of digital tool-driven agility. Actors of Bangladeshi FSC may give more focus to human-based agile management practices rather than technology-based agility. A plausible explanation for these inconsistencies also lies in the unequal access to digital tools and technological infrastructure among companies in Bangladesh supporting agile practices for environmental sustainability.

Furthermore, the use of different digital tools within sustainable supply chains can serve diverse objectives. For instance, the Internet of Things (IoT) is primarily employed to enable real-time monitoring and early detection of disruptions, while blockchain technology enhances transparency, trust, and collaboration among supply chain actors. Similarly, cloud-based platforms facilitate agility by enabling rapid and seamless information sharing. However, the simultaneous use of multiple digital tools can generate synergistic benefits, yet it may also lead to challenges such as data overload and unequal distribution of advantages among stakeholders. Consequently, the impacts of these technologies tend to vary across social and environmental sustainability.

These findings demonstrate the need for better agile practices in conjunction with technological tools to overcome environmental sustainability challenges. These findings further contribute to the need for real-time technology-based information sharing and its synergic benefits in the FSC. This study also brings forward the argument that technology-driven transparency improves waste management. It develops high levels of traceability, monitoring, and information-sharing capabilities. Companies can create further environmental advantages by implementing resilience practices and capturing sustainability.

Chapter 7: Conclusion

7.1 Summary of Key Findings

This study aims to explore how resilience constructs influence sustainability, and what is the role of digital tools in this relationship. The first part of research work is to identify the best supply chains practices that combine sustainability, resilience and digital tools concepts (RQ1). It categorizes the concepts to explore the constructs and issues through a systematic literature review. Moreover, it demonstrates a literature mapping based on four interactions: a) sustainability and resilience, b) sustainability and digital tools, c) resilience and digital tools, and d) sustainability, resilience and digital tools. This categorization represents an advancement in existing literature from different inter-relational perspectives. Afterward, it identifies more focused and less focused topics in SC literature. For example, topics such as the interactive study on sustainability governance, agility, and flexibility are less studied. Furthermore, digital tools governance and sustainability disclosure in SC are also less studied area. Following this mapping, this study identifies the research gaps and designs a relational framework to test different hypotheses.

The second part of the work is an empirical study on how various resilience constructs affect internal and external social sustainability, and the moderating role of digital tools in the fashion supply chain (RQ2). Based on a survey and SEM output, the results show that visibility, agility, and collaboration have a positive impact on internal and external social sustainability. SC actors emphasize transparency in information flow, agile strategic planning, and collaboration that are more likely to achieve better social sustainability. Digital tools have been found to moderate the relationship with the positive effects of visibility for social sustainability. However, digital tools have amplified the negative effects of collaboration for social sustainability. The third part of this work is related to how various resilience constructs affect waste management and pollution/emission of environmental sustainability and the moderating role of digital tools in the fashion supply chain (RQ3). The results indicate that visibility, agility, and collaboration have a significant positive impact on environmental sustainability (i.e. waste management and reducing pollution/emission). SC actors emphasize tracking and tracing in information flow, strategic reconfiguration of SC, and human-machine collaboration that are contributing factors to manage waste and reduce pollution/emission in FSC. While certain findings correspond with established research and others deviate. Furthermore, digital tools have amplified the positively moderating effects of visibility but the negatively moderating effects of agility in the environmental sustainability model. The varied results underscore the necessity for future study that integrate other constructs across diverse industries or global supply chains.

7.2 Theoretical Contributions and Managerial Implications

This study makes a theoretical contribution by proposing a SLR and two separate empirical models. It focuses on the synergistic nexus of resilience, digital tools, social sustainability, and environmental sustainability from developing countries' perspective. It identifies several unraveling research works on specific issues of internal social sustainability, external social sustainability, waste management, and reducing pollution/emission of environmental sustainability through SLR. This study examines widely recognized resilience constructs and empirically evaluates their relevance within the Bangladeshi FSC. Theoretically, it prioritizes resilience constructs associated with social and environmental sustainability. Moreover, it significantly reinforces limited empirical results from previous case studies and conceptual analyses.

Therefore, empirical evidence portrays the important building blocks in developing a new extended theory for resilience, sustainability, and digital tools ties. This study is empirically the first evidence for Bangladeshi FSC actors, considering the moderating role of digital tools and the effect of resilience practices on social and environmental sustainability. Aligning with recent insights from literature, it confirms the positive link between resilience, sustainability, and digital tools. However, it differs in the case of the flexibility construct of resilience. The contradicting result of flexibility and others could be attributed to variability in model specification, construct definition, and measurement differences or the diverse setting of the model. These contradicting findings could be a new input for theory-building study of supply chains that challenges the general notion of resilience, sustainability, and digital tools connection. Finally, this study advocates for the uniform adoption of digital tools to maintain consistency and foster collaboration among all actors in the fashion supply chain. It also claims that an isolated focus on agility or flexibility may not always yield socially and environmentally sustainable supply chain. It emphasized the necessity of a more integrated and collaborative approach in the FSC.

From the managerial perspective, these findings offer actionable insights into fashion supply chain actors. The results serve as inputs to take SC decisions, including prioritizing resilience constructs and the digital tools to achieve sustainability. The findings have been discussed with actors and stakeholders involved in the fashion industry and academia. The explored issues of different constructs can benefit decision-makers in choosing appropriate sustainable supply chain decisions. Furthermore, the clustering of literature organizes, synthesizes, and coheres research in a structured way that could also be input for decision makers in the FSC. It strategically supports SC actors to identify what sustainability and resilience constructs, and digital tools should be proposed to maintain long term supply chain performance. Previous qualitative studies focused on the importance of digital tools for sustainability and this study strengthens this proposition with empirical evidence from Bangladeshi FSC. This is a guideline for managers and practitioners to promote resilience practices and the adoption of digital tools for social and environmental sustainability. The results further assist managers who face a constant trade-off between resilience, sustainability, and digital tools.

7.3 Future Research Directions

Subsequent research may broaden these findings by investigating several resilience constructs. However, a list of potential future research gaps has been outlined in section 2.4. The future research could include adaptive, proactive, reactive, and dynamic skills, which were excluded from this study as resilience constructs. For example, empirical research on the effect of adaptive strategies to achieve social and environmental sustainability in the fashion supply chain could be another research study. Moreover, the effect of dynamic capabilities (sensing, seizing, and transformation strategies) on the sustainability performance of the fashion supply chain could also be another research topic. There is also a key avenue to advance the theoretical model examining the moderating role of specific digital tools—such as blockchain-rather than considering digital tools as a collective entity for resilience and sustainability relationships. Furthermore, as the cross-sectional research design some extent limit the ability to infer causality or capture dynamic change over time, the future longitudinal or case-based approaches could provide deeper insights into the evolution of resilience and sustainability practices in the Bangladeshi fashion supply chain. Future research could also be done considering digital tools as a mediator variable in relation to resilience and sustainability.

Furthermore, digitalized disclosure and governance of supplier issues for developing countries could be new research for the sustainability of the fashion industry. This thesis infers that digital tools negatively moderate the relationship between agility/collaboration and sustainability which is intriguing but underexplored. Therefore, more qualitative or mixed-methods research could unpack these counterintuitive results. From the geographical perspective, a comparative study could focus on the challenges of resilience and sustainability in developed and developing economies for FSC. Another way around, how resilience practices of customers from developed countries affect sustainability practices for focal companies could be another research study. Another possibility of further research could extend these findings by examining the effect of resilience using similar or alternative constructs on environmental resource efficiency management that has been removed from analysis due to its high collinearity. The literature indicates that sustainability practices also positively influence resilient performance within the supply chain. That was out of consideration in this study and in completely the opposite direction of the stated hypotheses. Therefore, the effect of social and environmental sustainability practices on the resilience of FSC could be another study for further research. Because there is a simultaneous effect between resilience and sustainability.

7.4 Limitation of the Study

Likewise other studies, this study is not without limitations. From the theoretical perspective, this study has several limitations: a) It considered only peer-reviewed articles in the 'Scopus' database for systematic literature review, although ‘Scopus’ has a wide range of academic acceptance and a large data set. However, the additional research could exhibit broader scenarios by considering the Web of Science (WOS) database. b) The article selection process for this study is limited to a subject area 'Business and Management' and confined to Q_1 and

Q_2 of the SJR standard. It was done to identify the unique sustainability challenges of this area. In this regard, the important articles related to the study could be excluded from this study. It considers several digital tools to be a collaborative entity. However, they could have different utilities and capacities in the fashion supply chain. This study considers only four resilience constructs (visibility, agility, flexibility, and collaboration) but other important resilience constructs (e.g., proactive, reactive, and seizing capabilities) could come up with different results. From the methodological point of view, this study does not assess the simultaneity or reverse effect of social and environmental sustainability on resilience.

From a specific industry point of view, it focuses solely on the fashion supply chain sector. Using a sample of 190 respondents from Bangladesh may not fully represent the diversity of global FSC actors. Therefore, the global generability of this study is limited to Bangladesh and fashion industry. Although this thesis follows the procedural and statistical controls to manage the common method bias, may still pose the risks of common method variance. This study focuses on only internal and external social sustainability without exploring economic sustainability. From environmental sustainability analysis, it considers waste management and reducing pollution/emission without exploring the effect on environmental resource efficiency management.

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Appendix 1: Questionnaire

RESEARCH TITLE: The Effect of Resilience on Social and Environmental Sustainability and the Role of Digital Technologies: Evidence from Bangladeshi Fashion Supply Chain

This survey aims to investigate the ramifications of the interplay between sustainability, resilience, and digitalization, while addressing three aforementioned research inquiries along with their moderating and mediating effects. The questionnaire survey is part of research held in the European project Reschape (grant n.101061729 - https://reschape.eu/).

In light of our academic pursuit for diverse perspectives, it is imperative to underscore that there exist no definitively right or wrong responses. Consequently, we kindly request you participate by providing insights based on your knowledge, wisdom, experience, and observations.
Importantly, all information disclosed shall remain strictly confidential, and any data collected will be utilized anonymously for scholarly purposes. Your cooperation in this endeavor is greatly appreciated.

The survey is divided into two sections. In the first section (SECTION- A), there are descriptive questions. In the second part (SECTION- B), you are asked to rate some statements regarding sustainability, resilience and digitalization practices in supply chain. It will take approximately 15 minutes to fill out this questionnaire.

We thank you in advance for your cooperation.
For the respondents
I hereby give my consent to participate in the above-mentioned survey. I know that my participation is voluntary and that I can withdraw from the survey at any time without giving any reason. I am aware that the collected data will be used for research purposes only and will be treated confidentially.
The answer should be a single choice:

☐ I agree

Code of the questionnaire

SECTION A: GENERAL INFORMATION

What is the main business specialisation of your company?	a. Garments and textile b. Footwear and leather goods c. Decoration and interiors d. Jewellery e. Other
Does your company have environmental sustainability certification or a sustainability report?	a. Yes b. No
If your company has environmental sustainability certification, could you please write the name of the certification	
Does your company have a social sustainability certification or a sustainability report?	a. Yes b. No
If your company has social sustainability certification, could you please write the name of the certification	
Does your company have any commercial relationship with EU countries	a. Yes b. No
Country where your company has production facilities	a. Asia b. Europe c. North America d. South America e. Others
Types of business	a. Brand owner b. Supplier of raw materials c. Supplier of components d. Supplier of manufacturing activities e. Distributor f. Others
Range of your company's annual turnover	a. Less than $ 50000

	b. $50000 - $10000 c. $100000 - $500000 d. $500000 - $1000000 e. $1000000 – Higher
Number of employees in your company	a. Less than 10 b. Less than 50 c. Less than 250 d. 250 and more people
When was your company established?	___(Year)
What is your position in the company?	a. CEO b. COO c. Supply chain manager d. Owner e. Procurement manager f. Sustainability manager g. Others
How many years of working experience do you have?	a. 1-5 years b. 6-10 years c. 11-15 years d. 16 year and more
What is your educational typology?	a. High school diploma b. Bachelor’s degree c. Master’s degree d. PhD e. Other
Name	
Company name	
Email address	

SECTION B:

1. Sustainability Practices in the Supply Chain

Considering the last year, to what extent do you think you have adopted the following sustainability practices for your supply chain? Please circle your answer on a scale of **1 (not yet practised in my supply chain) to 5 (very commonly practiced in my supply chain).**

1.1 Social sustainability practices

Social Sustainability practices in management construct	
My company has a good communication flow and shares necessary information among departments of the company for a sustainable supply chain	1 - 2 - 3 - 4 - 5
My company has adequate managerial assistance and guidance to promote sustainability in supply chain as a core organizational value	1 - 2 - 3 - 4 - 5
My company has an appropriate integrated human resource management system that encourages supply chain actors to participate in sustainability practices	1 - 2 - 3 - 4 - 5
My company has a structured resource governance that goes beyond the current knowledge-based management for sustainability practices in the supply chain	1 - 2 - 3 - 4 - 5
Social sustainability practices in workers construct	
My company is concerned about the health, safety of workers, and the appropriate working conditions in the office and factory during supply chain activities	1 - 2 - 3 - 4 - 5
My company continuously evaluates and monitors the satisfaction of the workers in the supply chain	1 - 2 - 3 - 4 - 5
My company has a suitable internal and external training facility on sustainability practices in the supply chain	1 - 2 - 3 - 4 - 5
My company has collaborative facilities on higher education and research of workers with universities and professional institutes	1 - 2 - 3 - 4 - 5
Social sustainability practices in customer construct	

My company has easy access to measure customer satisfaction	1 - 2 - 3 - 4 - 5
My customer is satisfied with our sustainability practices	1 - 2 - 3 - 4 - 5
My customer is loyal to my product and retained for a long time thanks to our sustainability practices	1 - 2 - 3 - 4 - 5
My company always focusses on customer demand related to sustainability in supply chain	1 - 2 - 3 - 4 - 5
My company has a delivery tracking system for information sharing with customers	1 - 2 - 3 - 4 - 5
Social sustainability practices in suppliers construct	
My company offers benefits and incentives to suppliers for sustainability	1 - 2 - 3 - 4 - 5
My company offers improvement programs and training for suppliers' workers	1 - 2 - 3 - 4 - 5
My company discloses (to the customers) all the issues related to suppliers	1 - 2 - 3 - 4 - 5
My company adopts sustainability practices in selecting, and evaluating supplier relationships and is concerned about gender discrimination	1 - 2 - 3 - 4 - 5
My company is concerned about the child labour at suppliers 'sites	1 - 2 - 3 - 4 - 5
Social sustainability practices in overall society construct	
My company has a good number of job opportunities for the community	1 - 2 - 3 - 4 - 5
My company upholds human rights in all the spheres of supply chain practices without any compromise	1 - 2 - 3 - 4 - 5
My company broadly offers assistance for educational programmes and a wellbeing programme for society	1 - 2 - 3 - 4 - 5

My company is committed to local community development, cultural diversity and compliance of social governance issues of the supply chain	1 - 2 - 3 - 4 - 5
My company collaborates with NGOs in terms of sustainability practices	1 - 2 - 3 - 4 - 5

1.2 Environmental Sustainability

Environmental sustainability in Waste management construct	
My company has a proper waste reduction protocol to ensure environmental sustainability shared with the supply chain	1 - 2 - 3 - 4 - 5
My company has a proper waste treatment plant to ensure environmental sustainability shared with supply chain	1 - 2 - 3 - 4 - 5
My company reuses the waste to ensure environmental sustainability	1 - 2 - 3 - 4 - 5
My company engages supply chain actors in circular economy practices	1 - 2 - 3 - 4 - 5
My company is committed to conserving nature during operations and supply chain	1 - 2 - 3 - 4 - 5
Environmental sustainability in pollution/emission construct	
My company has proper water treatment plant to reduce water pollution in supply chain operations	1 - 2 - 3 - 4 - 5
My company has a proper air system in the plant to reduce air pollution in supply chain operations	1 - 2 - 3 - 4 - 5
My company has green house gas reduction strategies	1 - 2 - 3 - 4 - 5
My company periodically evaluates the carbon emission rate and reports the carbon emission rate in its annual statement	1 - 2 - 3 - 4 - 5
My company is concerned with solid waste emission and global warming	1 - 2 - 3 - 4 - 5
Environmental sustainability in resource efficiency construct	

My company has an efficient resource management system and reduces natural resource consumption with the support of suppliers	1 - 2 - 3 - 4 - 5
My company has reverse logistics optimization and efficient energy management shared with suppliers	1 - 2 - 3 - 4 - 5
My company has a green design and innovation involving suppliers	1 - 2 - 3 - 4 - 5
My company maintains adequate environmental accounting and reporting disclosure involving suppliers	1 - 2 - 3 - 4 - 5
My company is environmentally aware in supply chain operations	1 - 2 - 3 - 4 - 5

2. Resilience constructs of your company

To deal with disruption in supply chain, it is important that your company is resilient. We distinguish four types of resilience constructs, namely visibility, agility, flexibility, and collaboration. To what extent do you agree or disagree with the following statements? Please circle your answer on a scale of 1 (strongly disagree) to 5 (strongly agree).

Resilience: Visibility construct	
My company ensures visibility through tracking and tracing system and localisation systems	1 - 2 - 3 - 4 - 5
My company ensures visibility in supply chain through physical vehicles and innovative analytical tools	1 - 2 - 3 - 4 - 5
My company ensures visibility in supply chain through real-time information sharing and disclosure all along the supply chain	1 - 2 - 3 - 4 - 5
My company ensures visibility by reducing intermediary in supply chain	1 - 2 - 3 - 4 - 5
My company has a trustworthy information sharing governance system for supply chain	1 - 2 - 3 - 4 - 5

Resilience: Agility construct

If necessary, my company can adopt new activities, product varieties, or technologies in response to challenging situations in the supply chain	1 - 2 - 3 - 4 - 5
My company can easily reorganise existing supply chain relationship from strategic point of view	1 - 2 - 3 - 4 - 5
My company can respond strategically to the market change, social factors and technologies of the existing supply chain	1 - 2 - 3 - 4 - 5
My company can reconfigure the supply chain before a competitor during disruption for competitive advantages	1 - 2 - 3 - 4 - 5
If needed, my company can easily make major changes along the supply chain in terms of material flows, selection of suppliers, and supplier segmentation	1 - 2 - 3 - 4 - 5

Resilience: Flexibility construct	
After facing a challenging period in the supply chain, my company still has the ability to radical re-organise supply chain at operational level and logistics	1 - 2 - 3 - 4 - 5
My company has Flexible capacity in logistics at demand uncertainty	1 - 2 - 3 - 4 - 5
My company has flexible sources of suppliers in the supply chain	1 - 2 - 3 - 4 - 5
My company applies a postponement strategy throughout the supply chain	1 - 2 - 3 - 4 - 5
My company can ensure tactical flexibility in operations and accept minor and random changes through localisation strategy	1 - 2 - 3 - 4 - 5

Resilience: Collaboration construct	
My company is able to work with suppliers for products and information flows	1 - 2 - 3 - 4 - 5
My company has a company-customer collaborative approach in the supply chain	1 - 2 - 3 - 4 - 5

My company has a relationship with the stakeholders and a compliance agreement in supply chain	1 - 2 - 3 - 4 - 5
My company facilitates in-company integration, human machine collaboration and empowerment in supply chain	1 - 2 - 3 - 4 - 5
My company has a healthy relationship with the competitors and stakeholders	1 - 2 - 3 - 4 - 5

3. Application of Digital Tools

To what extent do the following statements apply to you? Please circle your answer on a scale of 1 (does not apply in supply chain at all) to 5 (strongly apply to supply chain) in here (BDPA- Bigdata and predictive analytics, CBP- Cloud based platform, AI- Artificial Intelligence, IoT- Internet of Things)

Digital Tools for sustainability and resilience	
My company uses digital technologies (i.e. blockchain/BDPA/CBP/AI) for customer management in supply chain	1 - 2 - 3 - 4 - 5
My company uses circular purchase and design through blockchain/BDPA in supply chain	1 - 2 - 3 - 4 - 5
My company uses blockchain for resource sharing and knowledge management and structured human resource management practices in the supply chain	1 - 2 - 3 - 4 - 5
My company uses blockchain / cloud-based platform that help to ensure employee satisfaction in supply chain	1 - 2 - 3 - 4 - 5
My company uses blockchain to ensure trust mechanism and supplier relationship in the supply chain	1 - 2 - 3 - 4 - 5
BDPA supports for human resource development in supply chain	1 - 2 - 3 - 4 - 5
The cloud-based platform influences the development of social networks in supply chain	1 - 2 - 3 - 4 - 5
My company uses digital technologies to ensure transparency in supply chain actors	1 - 2 - 3 - 4 - 5

My company uses digital technology (BDPA) for flexible source and supplier orientation in supply chain	1 - 2 - 3 - 4 - 5
My company uses digital technology (IoT) to improve visibility in supply chain through information sharing, processing and collaborative planning	1 - 2 - 3 - 4 - 5
My company uses digital technology (AI) support to ensure strategic planning and recovery management in supply chain disruption	1 - 2 - 3 - 4 - 5
My company uses the cloud-based platform for the analytics and warning capability of the supply chain	1 - 2 - 3 - 4 - 5
My compnay uses digital technologies (IoT/AI) to ensure agility in supply chain through social network and agile SC design	1 - 2 - 3 - 4 - 5

This is the end of the questionnaire. Thank you very much for your participation! If you want to receive a summary of the questionnaire results, please leave your email address below.

Email Address:

Appendix 2: Multicollinearity Test result

Collinearity statistics (VIF)	
Items	VIF
VIS_1	1.901
VIS_2	1.793
VIS_3	1.528
VIS_4	2.033
VIS_5	1.880
AGL_1	1.885
AGL_2	2.249
AGL_3	1.831
AGL_4	1.965
AGL_5	1.696
FLE_1	3.128

FLE_2	3.787
FLE_3	2.888
FLE_4	3.186
FLE_5	2.539
COL_1	2.631
COL_2	2.879
COL_3	2.644
COL_4	3.850
COL_5	2.546
DIG_1_SO	2.305
DIG_2_SO	2.123
DIG_3_SO	1.551
DIG_4_SO	2.382
DIG_5_SO	2.376
DIG_1_EN	1.575
DIG_2_EN	1.746
DIG_3_EN	2.026
DIG_4_EN	1.354
DIG_5_EN	2.175
INT_Health and Safety	2.257
INT_Integrated HRM Practices	2.325
INT_Training and Education of Woker	1.841
INT_Resource Governance	2.008
INT_Employee satisfaction	2.049
EXT_Child Labor Protection	3.908
EXT_Community Governance and Cultural Diversity	3.992
EXT_Customer rights	2.664
EXT_Employment Opportunity, NGO and Stakeholder rights	2.986
EXT_Human rights	2.876

EXT_Supplier Disclosure and Governance	3.413
WST_1	2.456
WST_2	4.076
WST_3	3.690
WST_4	2.606
WST_5	1.874
P/E_1	1.593
P/E_2	1.677
P/E_3	1.565
P/E_4	2.052
P/E_5	1.564