Name of Publisher: BRIGHT EDUCATION RESEARCH SOLUTIONS

Area of Publication: Business, Management and Accounting (miscellaneous)

Let's Start!

Journal of Management & Social Science

ISSN Online: 3006-4848
ISSN Print: 3006-483X

RECOGNIZED IN "Y" CATEGORY BY

[IMPACT OF SUPPLY CHAIN DIGITALIZATION ON PERFORMANCE: MODERATING ROLE OF TOP MANAGEMENT COMMITMENT IN PAKISTAN'S MANUFACTURING SECTOR]

Mr. Owais Ali
Research Scholar, Bahria University Karachi. Email: owaisali93@yahoo.com
Mr. Muhammad Jazib
Research Scholar, Bahria University Karachi. Email: Jazib-17@outlook.com

Review Type: Double Blind Peer Review

ABSTRACT

Purpose: This research explores how Supply Chain Digitalization (SCD) affects Supply Chain Performance (SCP), considering the moderating influence of Top Management Commitment (TMC) in Pakistan's manufacturing industry. **Methodology & Design:** The study employs an explanatory research design through a quantitative approach. The survey method has been applied using a structured questionnaire administered to Supply Chain Managers of 202 manufacturing firms across Pakistan, selected through a Simple Random Sampling method of Probabilistic Sampling. The analysis employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to evaluate the proposed hypotheses and examine the connections among SCD, SCP, and TMC. **Findings:** The research indicates that SCD enhances SCP by optimizing important metrics such as lead time and market responsiveness. However, the moderating effect of TMC shows a slightly negative impact on the SCD-SCP relationship. This indicates that while SCD enhances SCP, its success depends largely on how well top management aligns SCD with its strategic goals and supports its implementation. **Limitations:** This study is constrained by its focus on manufacturing firms in Pakistan and its reliance on a cross-sectional research design, which may overlook long-term effects. Additionally, the sample size might not adequately reflect the diversity present in Pakistan's manufacturing sector. **Implications:** To enhance SCP through digitalization, top management in Pakistani manufacturing firms should align their strategic objectives with digitalization goals, provide sufficient resources and training for employees, and ensure consistency. Future research should consider conducting longitudinal studies and investigating the distinctions between large-scale enterprises and small-to-medium enterprises to gain more comprehensive insights.

Keywords: Supply Chain Digitalization, Supply Chain Performance, Top Management Commitment, Manufacturing Secto

Introduction

Digitalization has been identified as a leading trend in the development of next-generation supply chains (Khan et al., 2024). It is enhancing product distribution, improving organizational flexibility in response to fluctuations in demand or supply, and increasing overall supply chain efficiency (McKinsey, 2016). The supply chain (SC) can be described as "A life cycle process that involves physical, informational, financial, and knowledge flows aimed at meeting end-user needs through products and services from various interconnected suppliers" (Felea & Albăstroiu, 2013). Supply Chain Management (SCM) has been defined by (Stein and Voehl 1998) as "A coordinated approach to managing the Supply Value Chain effectively addresses customer needs and expectations, starting from raw material suppliers, through manufacturing, all the way to the end customer". In today's business landscape, supply chains have become a transformative force, reshaping the operations of manufacturing firms globally through digitalization.

Supply chain digitalization has been explained as the un-physicalization of SCM, which may include information sharing, cost negotiations, and the recording of the goods' movements in a virtual supply chain environment, where all supply chain functions are carried out online. The process of digitalization can include several steps wherein some phases are considered necessary to have used with physical assets and in some other phases, the use of digital assets is considered essential. Thus, this entire process involves the use of both physical and digital assets (Chatterjee et al., 2023). This digitalization is characterized by the integration of contemporary technologies such as net-enabled devices, Artificial Intelligence (AI), and the Internet of Things (IoT). These advanced technologies can significantly enhance SC performance (Kache & Seuring, 2017). The ever-increasing advent of digital technologies has inevitably transformed the landscape of supply chain management. The role of immediacy, together with accuracy, is regarded as much much-expected outcomes in the present era, as manufacturing firms are seeking avenues to augment their technologies under the digital umbrella. These are redefining the traditional supply chain operations resulting in greater efficiency leading to reduced lead times and total product costs, hence, impacting substantially in performance metrics. Another important aspect is that these digital technologies may not be considered as a substitution to the real business processes but are an addition to them (Lewis et al., 2007).

The historical trajectory of SCM indicates a significant evolution from manual and labor-intensive processes to automated systems and, currently, to more advanced methodologies and digitalization. The advent of net-enabled devices has expedited information dissemination, whereas Artificial Intelligence (AI) has facilitated unprecedented levels of predictive accuracy and decision-making efficiency (H. Wang et al., 2016) . IoT has connected a number of assets across the SC, providing immediate tracking and improved visibility (Ben-Daya et al., 2019) . Literature indicates that the implementation of digital tools significantly impacts the supply chain's effectiveness, particularly the lead time of order processing through the upward supply chain, inventory turnover, and total cost of the product (Hosseini et al., 2019) . Research indicates that the impact of digitalization differs based on firm characteristics, such as firm size and the commitment of top management, which can influence the link between supply chain digitalization and performance (Wamba et al., 2020). Furthermore, a lack of consensus has been noted regarding the extent to which the commitment level of top management influences the relationship between the provision of essential support necessary for SCD and the enhancement of a firm's SCP in the pursuit of achieving and sustaining a competitive advantage (Siagian et al., 2022). The manufacturing firms have greater effects on their SCP, considering the scope of modalities involved in acquiring raw materials and converting them to finished goods for the downstream supply chain.

Many human activities within the manufacturing sector can be digitally transformed to enhance efficiency. The connection between SCD and SCP for manufacturing firms in Asia has been extensively studied and analyzed across various regions and scales. The Chinese Delta region was covered in a study carried out by Zhou et al. (2023) . A similar study has been conducted by (Chatterjee et al., 2023). There is limited literature covering the Indian region manufacturers analyzing SCD's effects on

SCP, considering the moderating role of Top Management Commitment (TMC). This research aims to address the highlighted gap in Pakistan's geographical context.
Despite the obvious benefits, the digitalization process is still at the initiation stage in Pakistani manufacturing sector (Rehman Khan et al., 2022a) further, a considerable gap has been observed in the literature regarding SCD impacts on SCP of manufacturing firms in Pakistan. Additionally, the moderating role of TMC in the link between SCD and SCP in manufacturing firms appears insufficient in the Pakistani context, identifying a theoretical gap. There is a lack of comprehensive understanding of how digitalization directly impacts supply chain performance, particularly in the context of manufacturing in Pakistan firms. This gap necessitates an in-depth study of the relationship between supply chain digitalization and its performance outcomes. this research seeks to fill the contextual and theoretical gaps identified in the supply chain of Pakistani manufacturing firms concerning SCD and SCP, considering the moderating effects of TMC. In light of this, the study presents the first and second research questions as follows.
RQ.1 What is the level of SCD in terms of Supply Chain Visibility (SCV) and Supply Chain Responsiveness (SCR)?
RQ.2 How does SCD influence lead time and a firm’s ability to respond to changes in customers’ requirements?
RQ.3 What is the relationship between SCD and SCP?
RQ.4 How does the firm’s top management’s commitment moderate the relationship between SCD and SCP?
The literature sufficiently covers the influence of SCD on SCP in manufacturing firms. Digital transformation impacts SCP, lead time, and overall cost reduction. Studying the moderating impacts of this sector’s higher management in the relationship between SCD and SCP is considered vital to broaden the understanding. The adoption of analytical research recommendations may have lasting impacts on the current management practices. The research is conducted in the geographical limits of Pakistan, covering the manufacturing sector. It explains how the emerging digital technologies enhance a firm’s SCP. Attention has been directed toward various emerging digital technologies, including the Internet of Things (IoT), Big Data Analytics, AI, and advanced tracking devices, all of which can be applied throughout the Pakistani manufacturing sector.

The remainder of the article is organized as follows: Firstly, the definitions of pertinent constructs are presented. Subsequently, the theoretical framework and the research hypotheses are articulated. Following that, the research methodology is described, including an explanation of how the data were analyzed to derive the results. Next, the findings, along with their theoretical and managerial implications, are delineated. Lastly, the limitations of this paper are acknowledged, and recommendations for future research are provided.

Literature Review

Supply Chain Digitalization

SCD incorporates digital technologies like cloud computing, IoT, and AI into supply chain operations, facilitating data-driven decision-making (Theodoraki et al., 2022). This approach has gained traction for its potential to boost company performance (Barreto et al., 2017; Wamba et al., 2020). SCD involves applying these technologies to plan, transact, connect, and carry out supply chain tasks (Sanders & Swink, 2020). It is distinct from digitization, which refers to converting analog processes into digital forms and automating them via IT (Hess et al., 2016; Horváth & Szabó, 2019).

Digitalization surpasses digitization by transforming business processes, fostering new communication pathways, and driving business growth through data utilization (Schwarzmüller et al., 2018). Technological advances like mobile phones, distributed computing, and digital networks exemplify this shift (Evans & Price, 2020). By leveraging digital technologies and advanced data analysis, digitalization enhances the efficiency and value of supply chain activities, benefiting businesses significantly (Barreto et al., 2017; Loske & Klumpp, 2022).

Supply Chain Visibility (SCV)

SCV indicates how much information is shared among supply chain participants for their collective advantage (Barratt & Oke, 2007). Limited visibility, Suppliers (upstream) and customers (downstream) play a crucial role in the challenge, especially highlighted during global events like the pandemic of 2019 (Sharma et al., 2020; Carter et al., 2015). Digital technologies, including Big Data Analytics (BDA), AI, IoT, and enhanced tracking systems, are critical to improving SCV and eliminating inefficiencies. Enhanced visibility enables better responses to market changes and reduces uncertainties, positively impacting the supply chain performance of a manufacturing company (Goh & Eldridge, 2019).

Supply Chain Responsiveness (SCR)

SCR refers to a firm's ability to respond promptly and effectively to customer demands or market changes to sustain a competitive edge. (Holweg, 2005). This involves ensuring smooth information flow and timely delivery of goods. Digital tools like real-time data analytics and automated decision systems significantly enhance responsiveness, enabling firms to adapt to market trends and manage risks effectively (Gaur & Bhattacharya, 2011). SCR is vital in fast-paced environments where response speed is influenced by product type, industry, and supply-demand dynamics. Digitalization accelerates supply chain processes, improving long-term performance.

Supply Chain Performance

SCP measures operational and logistical efficiency, focusing on a firm's adaptability to dynamic market demands, timely product delivery, and responsiveness to customer needs (Mofokeng & Chinomona, 2019). Integrating digital technologies improves SCP by reducing lead times, enhancing response to market demand dynamics (RMD), increasing production efficiency, and minimizing breakdowns (Mukhopadhyay & Kekre, 2002; Björkdahl, 2020). Digitalization also positively impacts logistics and operational performance by improving flexibility and responsiveness (Hosseini et al., 2019).

Various frameworks for SCP measurement exist, emphasizing flexibility, cost, efficiency, and responsiveness. For example, Beamon (1999) proposed flexibility, resources, and outputs as SCP measures, while Jeong & Hong (2007) emphasized the dependability and promptness of delivery Similarly, Lee et al. (2007) highlighted cost containment and reliability, and Vanichchinchai & Igel (2009) emphasized cost, flexibility, relationship, and responsiveness.

Aligned with literature, this study includes two key SCP indicators: Response to Market Demand Dynamics (RMD), the ability to modify products to meet evolving market needs, and Lead Time (LT), the time taken to deliver products, both critical for enhancing consumer satisfaction (Whitten et al., 2012).

Top Management Commitment

The responsibilities of top management, as outlined by (Siagian et al., 2022; Naeem et al., 2025a) is that it are how a company's leaders get involved and support their plans to perform day-to-day work. In this role, these leaders create and share the company's vision and objectives, take part in its management, provide the necessary resources and time, motivate and give power to the employees, and keep an eye on how the company is doing to make sure it meets its targets. Top management is defined as individuals or groups with the authority to oversee and control management, establish vision and goals, develop rules and policies, allocate resources, and implement initiatives. (Lewis et al., 2007). The mediating role of TMC is studied as it can impact the digitalization process in a positive and negative way for the business.

Theory Underpinning

Dynamic capability theory is derived from the Resource-Based View (RBV) (Teece et al., 1997; Ali et al., 2022; Farooq et al., 2023; Farooq & Ahmad, 2023). RBV suggests that companies can achieve a lasting competitive advantage by using valuable, irreplaceable, rare, and difficult-to-imitate resources (Barney, 1991; Anser et al., 2024; Anser et al., 2025). These resources can encompass both tangible and intangible assets, including human, financial, knowledge-based, and intellectual resources (Barney, 1991). The RBV concept is built on a static perspective, primarily emphasizing the analysis of a firm's competitive advantage derived from its unique internal resources. Certain researchers contend that within a dynamic environment, the foundational competitive dynamics may undergo alterations, and the inherent static nature of resources does not ensure the persistent maintenance of competitive advantage (Fainshmidt et al., 2016; Warner & Wäger, 2019). To explain the intense competition in dynamic markets, scholars have introduced DCT, which is rooted in the RBV Theory (Teece, 1997). Dynamic capabilities refer to a firm's capacity to integrate, organize, and adjust internal and external resources and abilities to effectively respond to a fast-changing external environment. (Wilden et al., 2013) . Dynamic capabilities improve a firm's adaptability and are harder to replicate than operational capabilities (D. J. Teece, 2014).

Based on the DCT, firms must utilize scarce resources effectively and manage them to remain competitive in dynamic environments (Karimi-Alaghehband & Rivard, 2020). Firms need flexibility to adapt their dynamic capabilities, which include sensing opportunities and threats, seizing opportunities, and sustaining competitiveness (Teece, 2007; Naeem et al., 2025b,c). Dynamic capability comprises adaptive, absorptive, and ability to innovate (Wang & Ahmed, 2007), along with prompt awareness, adaptability in learning, and skills for resource adjustment (Wilhelm et al., 2015). Within the realm of supply chain management, this encompasses dimensions such as knowledge acquisition, market-oriented perception, internal restructuring, and social network capabilities (Hong et al., 2018).

The increasing environmental dynamism driven by digital technology innovation and global disruptions like epidemics intensifies competition, demanding that companies utilize dynamic capabilities to effectively integrate and adjust resources for a competitive edge and enhanced performance (Fainshmidt et al., 2019).

Strengthens digitalization supply chain dynamic capabilities:

a. Enhancing supply chain visibility to analyze market information (Rogerson & Parry, 2020).
b. Improving agility and flexibility in business processes and collaboration among supply chain nodes to manage lead times efficiently.

Dynamic Capability Theory forms the foundation for exploring the relationship between SCD and SCP, moderated by TMC to the digitalization process.

Connection between SCD and SCP

SCD enhances supply chain operations and efficiency by improving integration and information transparency. This leads to enhanced coordination among procurement, production, inventory, and retail management processes, consequently improving overall performance (Bai et al., 2020; Fatorachian & Kazemi, 2021). SCD also improves product quality, productivity, and cost efficiency, enhancing supply chain functionality (Saryatmo & Sukhotu, 2021).

SCD employs digital techniques across procurement, production, sales, and logistics, improving product life cycles and promoting continuous performance enhancements. (Holmström & Partanen, 2014). It utilizes data integration and analysis to accelerate innovation, enabling businesses to develop new products, expand market share, and sustain competitive advantages (Hallikas et al., 2021).

Additionally, blockchain technology enhances product information transparency, increasing consumer trust and purchasing inclination. This boosts consumer surplus and contributes to improved SCP (Choi et al., 2020). In light of these arguments, we propose the following hypothesis.

H1: SCD positively impacts supply chain performance.

Relationship of TMC with SCD and SCP

Technological innovation drives turbulence in the marketplace and scientific communities, prompting firms to integrate technological and market knowledge to motivate the digitalization of their SCM systems (Bhattacharyya & Kumar, 2023). TMC is critical in sustaining and successfully digitalizing SCM by ensuring employee competencies, knowledge-sharing, training, and motivation throughout the process (Bhattacharyya & Kumar, 2023).

TMC involves allocating adequate budgets for emerging technologies such as IoT, AI, and Big Data Analytics throughout SCM stages, including warehousing, procurement, and inventory management logistics (Flöthmann et al., 2018; Aamer et al., 2023). Leadership must also invest in training to enhance employee skills. TMC fosters trust in digitalization's success, reduces financial costs, and improves operational efficiency (Bhattacharyya & Kumar, 2023). Digitalizing SCM processes ultimately optimizes costs and improves firms' competitiveness and profitability. Based on these arguments, the following hypothesis is suggested.

H2: TMC moderates SCP's influence via SCD

Conceptual Framework

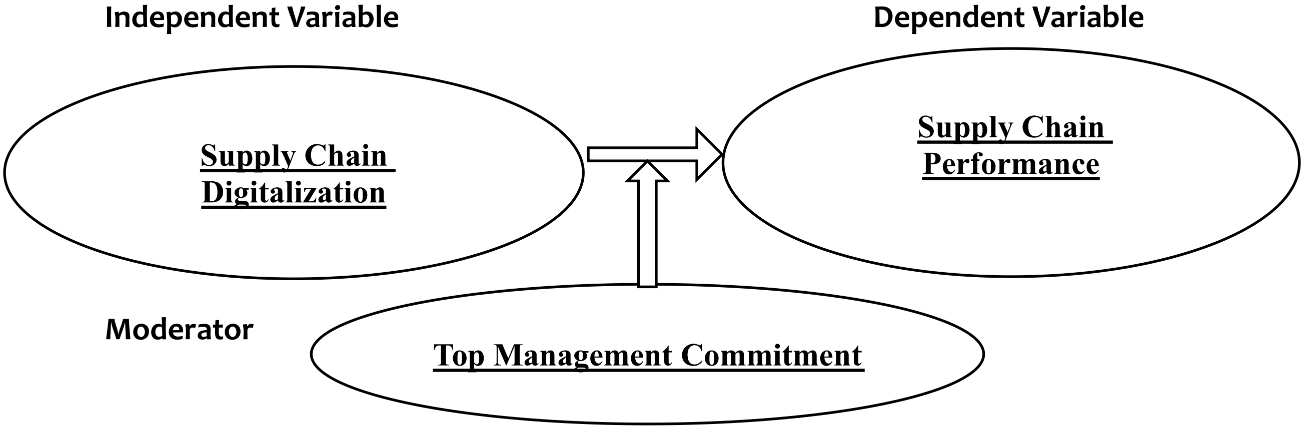

Figure 1 Conceptual Framework

Research Methodology

Research Approach

Mayring (2007) distinguishes between inductive and deductive approaches to analysis. The inductive approach is strictly qualitative, focusing on qualitative content analysis. In contrast, the deductive approach begins with a theory and allows for both qualitative and quantitative analysis, either simultaneously or independently. Deductive approaches are particularly suited for quantitative studies (Mayring, 2007; Fischer et al., 2023).

Research Design

The study uses an explanatory research design to explore the impact of digital technologies on organizational performance in Pakistan's manufacturing sector. It focuses on understanding cause-and-effect relationships and testing hypotheses with empirical quantitative data, advanced statistical methods, and theoretical frameworks to establish causal links. This design organizes data collection and analysis to ensure relevance to the study's objectives, following the realistic approach proposed by. Fischer et al. (2023).

Research Population

According to Koech & Ronoh (2015), the typical supply chain model for manufacturing involves acquiring raw materials, manufacturing or assembling parts, and delivering products through retailers to end consumers. The impact of SCD on SCP has been widely studied in the manufacturing sectors across China, India, and Europe.

This research evaluates the impact of SCD on SCP in Pakistan's manufacturing sector, including the influence of top management's commitment. The study targets manufacturing firms located in key hubs like Karachi, Lahore, and Faisalabad. Each firm's Supply Chain Manager will act as the respondent, and one questionnaire will be administered per firm.

Sample Size & Sampling Technique

A sampling technique provides guidelines for selecting a sample from a population (Altmann, 2014). The ideal sample size must be large enough to represent the population and generalize findings. This study uses the Simple Random Sampling method, a probabilistic approach ensuring every population member has a known, non-zero chance of selection, as employed by Rehman Khan et al. (2022b). More respondents than the calculated sample size were approached to secure sufficient valid responses.

From a population of 424 manufacturing firms, shortlisted from 567 companies listed in the State Bank of Pakistan's database of annual report submissions, a sample size of 202 was determined using the following Cochran's (1977) Sample Size Formula for Proportions with Finite Population Correction (FPC):

$$S = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)}$$

$$S = \frac{(1.96)^2(424)(0.5)(1-0.5))}{(0.05)^2(424-1)+(1.96)^2(0.5)(1-0.5)} \quad => \quad \boldsymbol{S = 202}$$

Where,
N = Total population size
P = Population proportion (Maximum sample size i.e., 50% of the population)
d = Degree of accuracy (5% margin of error)
X = Constant value of 1.96 at 95% Confidence level

Moreover, the above sample size calculation has also been cross-checked and verified through an online platform, Sample Size Calculator by Raosoft, Inc. The sample size calculated by the aforementioned online calculator using the above values is the same: 202. Therefore, a sample size of 202 is considered appropriate for a survey in order to attain results with a 5% Margin of Error.

Research Instrument

The survey method will test hypotheses derived from existing theories to explore the impact paths of SCD and SCP. This method relies on factual information and emphasizes empirical data gathering and normative analysis for statistical and quantitative insights (Flynn et al., 1990). Email will be the main method for distributing questionnaires, providing a cost-effective and time-efficient strategy for empirical research (Scudder & Hill, 1998).

The questionnaire consists of two sections:

1. Demographic Details of Participants.
2. Research questions measuring SCD, SCP, and TMC, where 1 signifies "strongly disagree," 3 represents "neutral," and 5 denotes "strongly agree."

The questionnaire, which measures three different variables, was adopted from the studies tabulated below:

Table 1: Summary of Research Instrument

Variable	Authors/ Source	No. of Items	Scale
Supply Chain Digitalization	(Chatterjee et al., 2024)	6	1-5
Supply Chain Performance	(Liu et al., 2022)	6	1-5
Top Management Commitment	(Wei et al., 2020)	5	1-5

A survey through a questionnaire has been chosen for data collection. The questionnaire includes demographic questions to gather general information, such as professional experience and qualifications. It also incorporates Likert Scale questions to gauge the "intensity" of attitudes concerning elements of the latent variable. Respondents rate their agreement on a scale from Strongly Agree to Disagree Strongly. The Likert Scale's primary advantage is effectively differentiating attitudes and aspects (Dundas, 2004).

Data Collection

According to Brannen (2017) , to carry out the research, it is important to gather the required data from authentic sources that can be analyzed and interpreted in further study. There are two main data sources of collection, including primary and secondary sources of data. The primary source used in the research is a self-administrated questionnaire. This research also adopts the questionnaire with a five-point Likert scale with five common options.

Data Analysis Method

Considering the small sample size and relatively complex framework using moderating variables, PLS-SEM has been used, and it works efficiently with small sample sizes where models are complex (Willaby et al., 2015) . Given its nonparametric characteristics, significant statistical power, and capacity to manage intricate models comprising numerous constructs and indicators, PLS-SEM is regarded as a valuable methodological approach (Sarstedt et al., 2017). The demographic data of the participants have been descriptively analyzed using IBM SPSS (Statistical Package for the Social Sciences) Statistics.

Results

Demographic Result

The survey data was gathered through questionnaire from people working in different Manufacturing firms across the manufacturing sector of Pakistan. Prior start of study questions, demographic data was collected, comprising the following information: Academic qualification, Work experience, Designation (Managerial level), Business type, approximate number of employees at the company, City of the manufacturing setup/ plant.

A total of 300 questionnaire forms (Google survey forms) were distributed through Emails and other online platforms. A total of 202 valid responses (67.33%) were received on a voluntary basis from different manufacturing firms based in different parts of Pakistan within the given timeline of the survey. This number (202) is also equal to the minimum sample size calculated for this study. SPSS has been used for the analysis of demographics and respondent profiles. All the demographic data have been reported using SPSS software 29.0.2.0 Version. Respondents' profile charts extracted from the SPSS software are appended below:

Table 3: Respondent's Demographics

Characteristics of Respondents (N=202)	Frequency	Percent	Characteristics of Respondents (N=202)	Frequency	Percent
Academic Qualification			**Business Type**		
Bachelors	74	36.4	Food & Beverages	11	5.2
Masters	115	57.1	Packaging	16	7.9
Pharm-D	13	6.5	Garments Industry	8	3.9

Work Experience			Paint Manufacturing	18	9.1
Less than 2 Years	13	6.5	Automobiles & Parts Manufacturing	24	11.9
2 - 5 Years	74	36.4	FMCG	42	20.8
6 - 10 Years	66	32.5	Aviation Parts	11	5.2
More than 10 Years	50	24.7	Spice Manufacturing	15	7.4
Designation (Managerial Level)			Sportswear Manufacturing	12	6
Medium Level	89	44.2	Pharmaceuticals	13	6.5
Upper Medium Level	84	41.6	Steel Manufacturing	5	2.6
Higher Level	29	14.3	Chemicals Manufacturing	15	7.4
Number of Employees			OMC	8	3.9
10 or Less	5	2.6	Sports Goods Manufacturing	5	2.6
11 to 25	8	3.9	Aviation Parts	11	5.2
26 to 50	13	6.5			
51 to 100	26	13			
101 or more	149	74			

Estimated Model

The technique used for evaluating the reliability and validity of the research is the PLS algorithm for estimating the path coefficients and other estimates. Bootstrapping tests the significance of latent variables and their relationships.

Before the PLS-SEM analysis, common method bias was examined as a single survey that was conducted for the data collection (Craighead et al., 2011). The common method bias was examined by evaluating Variance Inflation Factors (VIFs) in the collinearity test. According to Kock (2017), to ensure clarity and reliability, the VIF values must remain below the threshold of 3.3. In this research, all the VIF values for the constructs are indeed below this point, confirming that common method bias is not a concern here.

For data analysis, the PLS-SEM model using Smart PLS 4.0 (Ringle, C. M., Wende, S., and Becker, J.-M. 2024) was used. PLS-SEM was performed in two stages to evaluate the measurement model, which includes internal consistency, discriminant validity, reliability, convergent validity, and collinearity statistics, as well as the structural model for hypothesis testing. (Hair & Alamer, 2022).

PLS-Algorithm was run on the path model to initiate the process of reliability and validity measurement. Below is the structural model picture taken from the SmartPLS after running PLS-Algorithm on the collected data.

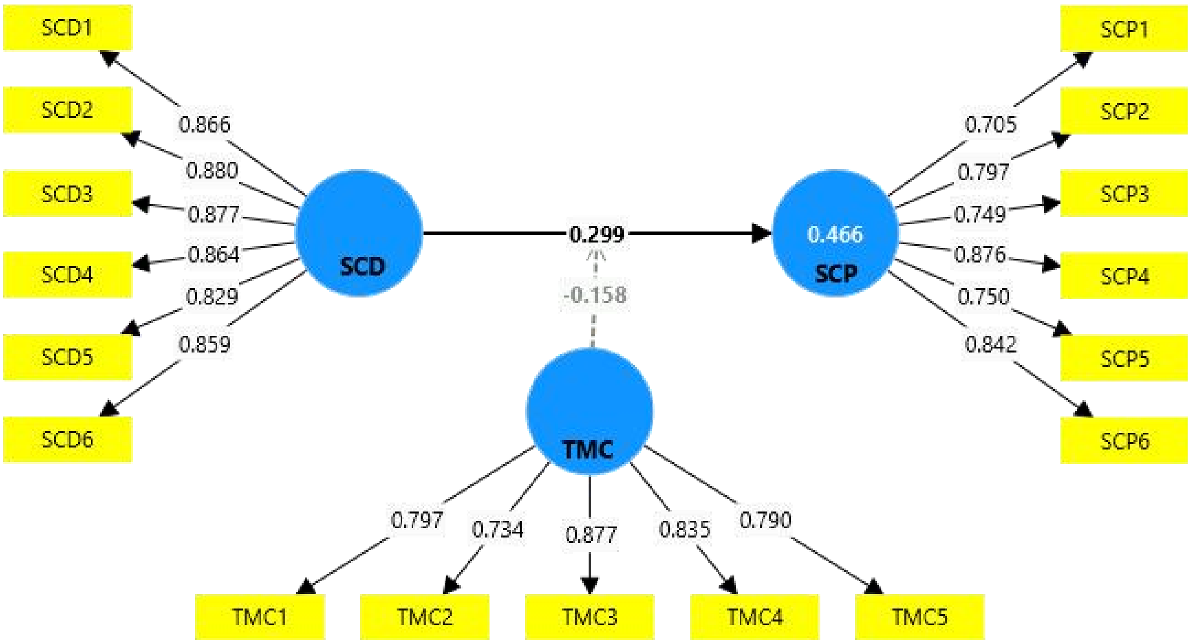

Figure 2: PLS Algorithm

The figures in the yellow boxes are the indicators of the variables. The numerical figures on the arrows arising from the independent, moderator and dependent variables to the indicators represent the outer loadings. The value inside the blue circle represents the value of R square (coefficient of determination).

Constructs Reliability & Validity

To evaluate the reliability and validity of the constructs, we calculated Composite Reliability (CR) and Average Variance Extracted (AVE). The calculated values for CR and AVE are above 0.80 and 0.50, respectively. (Hair et al., 2017).

Furthermore, assessing the consistency of the constructs requires estimating Cronbach's Alpha (α). The estimate of Cronbach's Alpha was found to exceed the conservative threshold value of 0.7, indicating that the measurement instrument used demonstrates good consistent reliability. (Kock, 2014, 2015; Talke et al., 2011).

The convergent validity of all construct items has been evaluated. To determine convergent validity, the loading factors for each construct were analyzed, with all values exceeding the minimum threshold of 0.708 (Chin, 2010).

Table 4 Constructs Reliability and Validity Data

Construct	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)	Indicator	Outer Loading	VIF
SCD	0.932	0.939	0.946	0.744	SCD1	0.866	2.876
					SCD2	0.880	3.21
					SCD3	0.877	3.038
					SCD$	0.864	3.208

					SCD5	0.829	2.514
					SCD6	0.859	3.249
SCP	0.877	0.885	0.908	0.622	SCP1	0.705	1.552
					SCp2	0.797	1.983
					SCP3	0.749	1.98
					SCP4	0.876	3.206
					SCP5	0.750	2.854
					SCP6	0.842	2.596
TMC	0.867	0.881	0.904	0.653	TMC1	0.797	1.971
					TMC2	0.734	1.678
					TMC3	0.877	2.698
					TMC4	0.835	2.47
					TMC5	0.790	1.816

Discriminant Validity

It is defined as the uniqueness of construct and distinction between the constructs. The construct should be distinctive in that it does not capture the phenomena of other constructs. Discriminant validity has been estimated for all the constructs in terms of the following two methods:

Fornell and Larcker Criterion

The findings show that the square roots of all AVEs exceed the bifactor correlation coefficients, thereby establishing the discriminant validity of all constructs. (Fornell & Larcker, 1981).

Table 5 Discriminant Validity through Fornell and Larcker Criterion

Discriminant Validity - Fornell-Larcker Criterion

	SCD	**SCP**	**TMC**
SCD	0.863		
SCP	0.549	0.789	
TMC	0.471	0.564	0.808

Cross Loading

The table below shows that the outer loadings of an indicator with its own construct are greater than loadings with the other constructs, confirming the discriminant validity of the constructs.

Table 6 Discriminant Validity through Cross Loadings

Discriminant Validity – Cross Loadings

	SCD	**SCP**	**TMC**	**TMC x SCD**
SCD1	0.866	0.46	0.373	-0.305
SCD2	0.88	0.373	0.353	-0.231
SCD3	0.877	0.56	0.486	-0.423

SCD4	0.864	0.409	0.313	-0.222
SCD5	0.829	0.526	0.434	-0.331
SCD6	0.859	0.457	0.435	-0.327
SCP1	0.414	0.705	0.368	-0.268
SCP2	0.485	0.797	0.466	-0.498
SCP3	0.411	0.749	0.508	-0.195
SCP4	0.419	0.876	0.499	-0.448
SCP5	0.355	0.75	0.326	-0.33
SCP6	0.493	0.842	0.466	-0.372
TMC1	0.287	0.4	0.797	-0.157
TMC2	0.198	0.369	0.734	-0.225
TMC3	0.426	0.538	0.877	-0.353
TMC4	0.437	0.422	0.835	-0.313
TMC5	0.499	0.513	0.79	-0.202
TMC x SCD	-0.366	-0.45	-0.314	1

Collinear Statistics

The collinearity statistics coefficient evaluates the multicollinearity across the entire model, incorporating the variations presented by other variables within the model. This coefficient facilitates examining whether the respondents perceive each variable as conceptually distinct from the others. All estimated values fall below the recommended threshold of 3.3. (Kock & Lynn, 2012) indicating that none of the latent variables are collinear with others in the model, establishing their conceptual uniqueness within the framework of this study. Therefore, collinearity issues are absent. Below are the tables from SmartPLS 4.0 presenting the Outer VIF and Inner VIF for indicators:

Outer Model List

Table 7: Collinear Statistics Outer Model List

Collinearity Statistics (VIF) - Outer Model	
	VIF
SCD1	2.876
SCD2	3.21
SCD3	3.038
SCD4	3.208
SCD5	2.514
SCD6	3.249
SCP1	1.552
SCP2	1.983
SCP3	1.98
SCP4	3.206
SCP5	2.854
SCP6	2.596
TMC1	1.971
TMC2	1.678

TMC3	2.698
TMC4	2.47
TMC5	1.816
TMC x SCD	1

Inner Model List & Matrix
Table 8 Collinear Statistics Inner Model List & Matrix

Collinearity Statistics (VIF) - Outer Model	
	VIF
SCD -> SCP	1.378
TMC -> SCP	1.325
TMC x SCD -> SCP	1.19

Hypothetical Testing
Coefficient of Determination
There are no definite criteria for R-squared in the PLS Algorithm. It is the correlation between the independent and dependent variables of the study. It shows the explanatory power of the variable within the framework. The following values have been calculated:
Table 9 R-Square Overview

R-Square Overview		
	R-Square	**R-Square Adjusted**
SCP	0.466	0.458

The results show that SCD (IV) can explain the SCP (DV) to the extent of 45.8% (R^2 Adjusted = 0.458) which can be considered as the predictive power of this model.
Bootstrapping
The bootstrapping method helps to estimate the P-value and T-Value which are utilized to check if the hypothesis is supported or not. The following criteria were laid out for the significance level of 5% to support the hypotheses:
Criteria: Significance Level 5%: $P<0.05$, $t>1.96$ (Support)

Two hypotheses were formulated in the study, one of which was concerned with the moderating effects of TMC on the linkage SCD→SCP. The SCD was subdivided into two dimensions, SCV (supply chain visibility) and SCR (supply chain responsiveness). We found that SCD could impact SCP significantly and positively, as the path coefficient concerned is 0.299 with the level of significance as $p < 0.05$ (H1).

The study has shown that the moderator TMC impacts H1 (SCD→SCP) significantly and negatively, with a path coefficient of -0.158, and a level of significance is $p < 0.05$ (H2).
Table 10 Path Coefficients - Mean, Std Deviation, T-Values, P-Values

Path Coefficients - Mean, Std Deviation, T-Values, P-Values					
	Original Sample (O)	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**
SCD -> SCP	0.299	0.301	0.083	3.616	0
TMC -> SCP	0.351	0.358	0.06	5.821	0
TMC x SCD	-0.158	-0.152	0.052	3.014	0.003

-> SCP

Moderator Analysis

To evaluate the impact of the moderator TMC on the relationship SCD→SCP (H1), a multigroup analysis (MGA) was performed using SmartPLS 4.0. The analysis utilized a bootstrapping procedure with 5000 resamples to determine the p-value difference for the two moderator categories related to linkage H1. If the p-value difference exceeds 0.95 or falls below 0.05, we conclude that the moderator significantly affects the linkage significant (J. F. Hair, 2016) The result provided implies that the moderator TMC's effect on the linkage of H1 (SCD→SCP) is significant.

Table 11 Moderator Analysis

Moderator Analysis (MGA)				
Linkage	**Moderator**	**Hypothesis**	**P-Value Differencs**	**Remarks**
SCD→SCP	TMC	H1	0.003	Significant

Discussion

This research explores the quantitative connection between SCD and SCP within manufacturing firms in Pakistan, utilizing data gathered from companies registered with the State Bank of Pakistan. The evaluation employed Structural Equation Modeling (Smart PLS 4.0) to determine SCD's effect on SCP while considering the moderating role of TMC.

SCD positively influences SCP by streamlining operational processes and enhancing supply chain efficiency (Frank et al., 2019; Zhao et al., 2023; Ivanov, 2020). Digitalization improves SCV and SCR, strengthening relationships with suppliers and customers. These effects are reflected in reduced lead times and better responsiveness to dynamic market demands, achieving key research objectives. TMC significantly affects SCP through SCD, as committed top management supports effective implementation of digitalization, improving performance (Wei et al., 2020). This dimension aligns with the research objective of evaluating TMC's role in enhancing SCP via SCD.

Hypothesis 1, which shows that the SCD significantly impacts the SCP of manufacturing firms and has been observed positively. This aligns with the findings of other scholars, such as (Frank et al., 2019; Ivanov & Dolgui, 2020). Zhou et al. (2023) explained that the SCD drives the SCP positively in Chinese region manufacturing firms. Hypothesis 2 for the moderating effects of TMC on the firm's SCP through digitalization has been observed to have a significant negative impact. This relationship shows Pakistani manufacturing firms' diverse and uncommon characteristics regarding the moderating effects of the top management's commitment to SCP and SCD. There could be many reasons for explaining this phenomenon some of which are mentioned below:

Non-alignment of top management with the goals of digitalization can lead to conflicts and inefficiencies. For instance, if top management promotes digitalization without considering the operational intricacies, it may lead to degraded performance (Bose & I., 2016) . Over-emphasis on adoption of digitalization without sufficient preparation may lead to inefficiencies. As explained by (Davenport & Westerman, 2018), implementation of advance digital tools without proper training may lead to errors which will negatively impact the performance. It may happen that the top management commit to digitalization in principle but fails to allocate sufficient resources such as time, money or talent to it. This may also lead to poorly implemented digital solutions which hampers the intended benefits negatively impacting the firm's performance (Kotter, 1996).

Theoretical Implications

This study has utilized 202 manufacturing companies as the research objects and built the mechanism of "SCD→SCP" based on the moderating effects of TMC. The study analyzes specific digitalization processes to improve the SCP and the moderating role of TMC through PLS-SEM. This result also addresses the question Stank et al. (2019) mentioned about how a firm interfaces with other entities in the digital age's upward and downward supply chains. Thus, the results of this study enhance the empirical understanding of the relationship between supply chain digitalization and performance, influenced by TMC within the current SCD literature.

Compared with other studies conducted in the fields of SCD and SCM, this study comprehensively covers the impacts of SCD and explores the improvement process of SCP in the context of TMC, which can be considered an instrument to narrow the existing theoretical gap, especially concerning the Pakistani manufacturing industry.

Practical Implications

Alongside theoretical contributions, the results of this research emphasize valuable practical insights into the Pakistani manufacturing sector, providing a firsthand perspective of the latest practices and prevailing issues in the manufacturing sector. Results show that SCD enables the improvement of operations and business processes pertaining to the supply chain to improve SCP. This research underscores the need for digitalization through careful deliberation and consideration of the TMC to avoid the negative impacts observed in the findings.

Pakistani manufacturing firms should develop executable strategies for implementing SCD. It is imperative that organizations concentrate on the enhancement of a digital supply chain by cultivating employees' competencies to maximize the advantages offered by a digitalized supply chain system. To achieve this objective, employees require targeted training aimed at skill development. With such effective training, employees will be equipped to proficiently manage the contemporary technologies employed in SCM.

The article has provided a rare insight into the manufacturing sector of Pakistan regarding the potentially negative role of TMC in smooth transition of supply chain activities towards digitalization. This viewpoint may help the top management to endeavor for the most rationalized process for implementation of the SCD using a cooperative and conducive environment.

Recommendations and Conclusion

Recommendations

Keeping in view the findings of this study, the following major recommendations are being made:

Pakistani manufacturing firms have adopted the digitalization of respective supply chains deliberately, considering the factors involved, as emphasized in this study. The digitalization of supply chains is linked with supply chain performance; therefore, appropriate steps are to be taken to ensure a smooth transition towards supply chain digitalization, ensuring a positive outcome in terms of performance. It is recommended that the organization's top-level management ensure that their strategic objectives are aligned with the initiatives for supply chain digitalization goals. This involves clear communication of digitalization benefits and alignment with organizational goals to avoid any potential inefficiencies developed through the negative relationship highlighted in this study's findings. A focused training program should be developed to enhance employees' digital competencies on the available and proposed digitalization software and hardware equipment. This will help them smoothly adopt new digital tools and technologies, comprehensively reducing errors and improving overall efficiency.

Limitations

This study focuses on manufacturing firms in Pakistan, particularly in Karachi, where most respondents are based. Therefore, the findings may not apply to other regions. The sample size of 202 manufacturing firms may not capture the full diversity of Pakistan's large manufacturing sector. Although the sample size has been calculated to be adequate for this study, a larger sample size could have resulted in more generalizable and realistic findings. The scope of this study includes the complete manufacturing sector of Pakistan. The collection of responses from organizations belonging to multiple sectors leads to difficulties with respect to accessibility, specifically considering the limited time scale of the study. This study establishes a theoretical framework that explores the connections among SCD, SCP, and TMC. An empirical test was conducted and analyzed through structural equation modeling. Due to time constraints, this research takes a cross-sectional approach, which may restrict its capacity to draw conclusions about the long-term effects of supply chain digitalization on supply chain performance.

Future Research

The limitations of the study highlighted above can be utilized as a possible avenue for future researchers. A few are mentioned:

Conducting longitudinal studies might have helped in understanding the long-term effects of digitalization activities, providing an in-depth understanding of their effects. Future research may employ a case study methodology to further investigate and substantiate this relationship through the lens of longitudinal enterprise practices. Single IV and DV have been studied in this research. SCD and SCP are broad terminologies. Future researchers may subdivide the IV and DV into other variables for a more diverse and deepened information collection. This study does not distinguish between large firms and SMEs (Small and Medium Enterprises). The size of a firm can significantly influence the implementation of supply chain digitalization technologies. Consequently, control variables like firm size or years since establishment should be factored into future research.

Conclusion

This study encompasses the impact of SCD on SCP in Pakistan's manufacturing sector, elaborating on the moderating role of Top Management Commitment (TMC). A quantitative approach was utilized to analyze the data collected from 202 manufacturing firms using a structured questionnaire comprised of 17 questions (excluding demographics). The findings of this research reveal the following critical points: Research indicates that SCD considerably boosts SCP, enhancing crucial performance metrics like order fulfillment lead time and adaptability to customers' changing needs throughout the supply chain. This finding supports earlier studies highlighting how digitalization improves supply chain visibility, responsiveness, and efficiency. The research reveals that TMC plays a significant yet intricate moderating role in the relationship between SCD and SCP. A negative relationship in TMC×SCD→SCP shows that just by having top management commitment and digitalization initiatives may not ensure efficacy. The effectiveness of these elements depends on how they are executed and integrated into the strategic vision and strategy of the organization and its culture. This research emphasizes the potential transformative digitalization in enhancing SCP. However, the success of such initiatives largely depends on the strategic commitment and support of top management. By resolving the identified limitations and implementing the highlighted recommendations, Pakistani manufacturing firms can effectively pursue the challenges of digitalization and achieve continuous improvements in supply chain performance.

References

Aamer, A., Sahara, C. R., & Al-Awlaqi, M. A. (2023). Digitalization of the supply chain: transformation factors. *Journal of Science and Technology Policy Management*, *14*(4), 713–733. https://doi.org/10.1108/JSTPM-01-2021-0001

Ali, S., Murtaza, G., Hedvicakova, M., Jiang, J., & Naeem, M. (2022). Intellectual capital and financial performance: A comparative study. *Frontiers in Psychology*, *13*, 967820.

Anser, M. K., Naeem, M., Ali, S., Ali, S., & Javid, R. (2025). The relationship between artificial intelligence and environmental performance: the mediating role of external environmental factors. Humanities and Social Sciences Communications, 12(1), 1-7.

Anser, M. K., Naeem, M., Ali, S., Huizhen, W., & Farooq, S. (2024). From knowledge to profit: business reputation as a mediator in the impact of green intellectual capital on business performance. Journal of Intellectual Capital, 25(5/6), 1133-1153.

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics*, *229*, 107776. https://doi.org/10.1016/j.ijpe.2020.107776

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Barratt, M., & Oke, A. (2007). Antecedents of supply chain visibility in retail supply chains: A resource-based theory perspective. *Journal of Operations Management*, *25*(6), 1217–1233. https://doi.org/10.1016/j.jom.2007.01.003

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing*, *13*, 1245–1252.

https://doi.org/10.1016/j.promfg.2017.09.045
Beamon, B. M. (1999). Measuring supply chain performance. In *International Journal of Operations and Production Management* (Vol. 19, Issue 3, pp. 275–292). https://doi.org/10.1108/01443579910249714
Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: a literature review. *International Journal of Production Research*, *57*(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140
Bhattacharyya, S. S., & Kumar, S. (2023). Study of deployment of "low code no code" applications toward improving digitization of supply chain management. *Journal of Science and Technology Policy Management*, *14*(2), 271–287. https://doi.org/10.1108/JSTPM-06-2021-0084
Björkdahl, J. (2020). Strategies for Digitalization in Manufacturing Firms. *California Management Review*, 62(4), 17–36. https://doi.org/10.1177/0008125620920349
Bose, & I. (2016). *Innovation, adoption, and implementation of BI: A case analysis from the Indian insurance industry. Information & Management,. 53(4)*, 516–528.
Brannen, J. (Ed.). (2017). *Mixing Methods: qualitative and quantitative research*. Routledge. https://doi.org/10.4324/9781315248813
Chatterjee, S., Mariani, M., & Ferraris, A. (2023). Digitalization of Supply Chain and Its Impact on Cost, Firm Performance, and Resilience: Technology Turbulence and Top Management Commitment as Moderator. *IEEE Transactions on Engineering Management*. https://doi.org/10.1109/TEM.2023.3297251
Chatterjee, S., Mariani, M., & Ferraris, A. (2024). Digitalization of Supply Chain and Its Impact on Cost, Firm Performance, and Resilience: Technology Turbulence and Top Management Commitment as Moderator. *IEEE Transactions on Engineering Management*, 1–16. https://doi.org/10.1109/TEM.2023.3297251
Chin, W. W. (2010). How to Write Up and Report PLS Analyses. In *Handbook of Partial Least Squares* (pp. 655–690). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-32827-8_29
Choi, B., Choudhary, M. C., Regan, J., Sparks, J. A., Padera, R. F., Qiu, X., Solomon, I. H., Kuo, H.-H., Boucau, J., Bowman, K., Adhikari, U. Das, Winkler, M. L., Mueller, A. A., Hsu, T. Y.-T., Desjardins, M., Baden, L. R., Chan, B. T., Walker, B. D., Lichterfeld, M., … Li, J. Z. (2020). Persistence and Evolution of SARS-CoV-2 in an Immunocompromised Host. *New England Journal of Medicine*, *383*(23), 2291–2293. https://doi.org/10.1056/NEJMc2031364
Davenport, T. H., & Westerman, G. (2018). *Why So Many High-Profile Digital Transformations Fail. Harvard Business Review. Retrieved from Harvard Business Review*.
Elwan Ibrahim, S., & Ogunyemi, O. (2012). The effect of linkages and information sharing on supply chain and export performance. *Journal of Manufacturing Technology Management*, *23*(4), 441–463. https://doi.org/10.1108/17410381211230394
Evans, N., & Price, J. (2020). Development of a holistic model for the management of an enterprise's information assets. *International Journal of Information Management*, *54*. https://doi.org/10.1016/j.ijinfomgt.2020.102193

Fainshmidt, S., Pezeshkan, A., Lance Frazier, M., Nair, A., & Markowski, E. (2016). Dynamic Capabilities and Organizational Performance: A Meta-Analytic Evaluation and Extension. *Journal of Management Studies*, *53*(8), 1348–1380. https://doi.org/10.1111/joms.12213

Fainshmidt, S., Wenger, L., Pezeshkan, A., & Mallon, M. R. (2019). When do Dynamic Capabilities Lead to Competitive Advantage? The Importance of Strategic Fit. *Journal of Management Studies*, *56*(4), 758–787. https://doi.org/10.1111/joms.12415

Farooq, M., & Ahmad, N. (2023). Nexus between board characteristics, firm performance and intellectual capital: an emerging market evidence. *Corporate Governance: The International Journal of Business in Society*, *23*(6), 1269-1297.

Farooq, M., Noor, A., & Naeem, M. (2023). Does family ownership moderate the relationship between board characteristics and corporate social responsibility? Evidence from an emerging market. Asian Journal of Business Ethics, 12(1), 71-99.

Fatorachian, H., & Kazemi, H. (2021). Impact of Industry 4.0 on supply chain performance. *Production Planning & Control*, *32*(1), 63–81. https://doi.org/10.1080/09537287.2020.1712487

Felea, M., & Albăstroiu, I. (n.d.). *DEFINING THE CONCEPT OF SUPPLY CHAIN MANAGEMENT AND ITS RELEVANCE TO ROMANIAN ACADEMICS AND PRACTITIONERS*.

Fischer, H. E., Boone, W. J., & Neumann, K. (2023). Quantitative Research Designs and Approaches. In *Handbook of Research on Science Education* (pp. 28–59). Routledge. https://doi.org/10.4324/9780367855758-3

Flöthmann, C., Hoberg, K., & Wieland, A. (2018). Competency requirements of supply chain planners & analysts and personal preferences of hiring managers. *Supply Chain Management: An International Journal*, *23*(6), 480–499. https://doi.org/10.1108/SCM-03-2018-0101

Flynn, B. B. , S. S. , S. R. G. , B. K. A. & F. A. J. (1990). Empirical Research Methods in Operations Management. *Journal of Operations Management*, 250–284.

Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of Operations Management*, *28*(1), 58–71. https://doi.org/10.1016/j.jom.2009.06.001

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39. https://doi.org/10.2307/3151312

Frank, A. G., Mendes, G. H. S., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, *141*, 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Gaur, J., & Bhattacharya, S. (2011). The relationship of Financial and Inventory performance of manufacturing firms in Indian Context. In *California Journal of Operations Management* (Vol. 9, Issue 2).

Goh, S. H., & Eldridge, S. (2019). Sales and Operations Planning: The effect of coordination mechanisms on supply chain performance. *International Journal of Production Economics*, *214*, 80–94. https://doi.org/10.1016/j.ijpe.2019.03.027

Hair, J., & Alamer, A. (2022). Partial Least Squares Structural Equation Modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. *Research Methods in Applied Linguistics*, *1*(3), 100027. https://doi.org/10.1016/j.rmal.2022.100027

Hair, J., Hollingsworth, C. L., Randolph, A. B., & Chong, A. Y. L. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial Management & Data Systems*, *117*(3), 442–458. https://doi.org/10.1108/IMDS-04-2016-0130

Hallikas, J., Immonen, M., & Brax, S. (2021). Digitalizing procurement: the impact of data analytics on supply chain performance. *Supply Chain Management: An International Journal*, *26*(5), 629–646. https://doi.org/10.1108/SCM-05-2020-0201

Heavin, C., & Power, D. J. (2018). Challenges for digital transformation – towards a conceptual decision support guide for managers. *Journal of Decision Systems*, *27*(sup1), 38–45. https://doi.org/10.1080/12460125.2018.1468697

Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (n.d.). *Options for Formulating a Digital Transformation Strategy*. https://www.researchgate.net/publication/291349362

Holmström, J., & Partanen, J. (2014). Digital manufacturing-driven transformations of service supply chains for complex products. *Supply Chain Management: An International Journal*, *19*(4), 421–430. https://doi.org/10.1108/SCM-10-2013-0387

Hong, J., Zhang, Y., & Ding, M. (2018). Sustainable supply chain management practices, supply chain dynamic capabilities, and enterprise performance. *Journal of Cleaner Production*, *172*, 3508–3519. https://doi.org/10.1016/j.jclepro.2017.06.093

Horváth, D., & Szabó, R. Zs. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, *146*, 119–132. https://doi.org/10.1016/j.techfore.2019.05.021

Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. *Transportation Research Part E: Logistics and Transportation Review*, *125*, 285–307. https://doi.org/10.1016/j.tre.2019.03.001

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review*, *136*, 101922. https://doi.org/10.1016/j.tre.2020.101922

Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International Journal of Production Research*, *58*(10), 2904–2915. https://doi.org/10.1080/00207543.2020.1750727

J. F. Hair, F. H. T. M. R. and M. S. (2016). *A Primer on Partial Least SquaresStructuralEquationModeling(PLS-SEM)*.

Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. *International Journal of Operations and Production Management*, *37*(1), 10–36. https://doi.org/10.1108/IJOPM-02-2015-0078

Karimi-Alaghehband, F., & Rivard, S. (2020). IT outsourcing success: A dynamic capability-based model. *The Journal of Strategic Information Systems*, *29*(1), 101599. https://doi.org/10.1016/j.jsis.2020.101599

Khan, N., Naeem, M., & Siraj, M. (2024). Evaluating Green Supply Chain Performance Using Multi-Criteria Decision-Making (MCDM) Models. RADS Journal of Business Management, 6(2), 113-123.

Kock, N. (2014). Advanced Mediating Effects Tests, Multi-Group Analyses, and Measurement Model Assessments in PLS-Based SEM. *International Journal of E-Collaboration*, *10*(1), 1–13. https://doi.org/10.4018/ijec.2014010101

Kock, N. (2015). Common Method Bias in PLS-SEM. *International Journal of E-Collaboration*, *11*(4), 1–10. https://doi.org/10.4018/ijec.2015100101

Kock, N., & Lynn, G. (2012). Lateral Collinearity and Misleading Results in Variance-Based SEM: An Illustration and Recommendations. *Journal of the Association for Information Systems*, *13*(7), 546–580. https://doi.org/10.17705/1jais.00302

Koech, W. K., & Ronoh, R. K. (2015). Benefits of Supply Chain Management in the Manufacturing Sector. *International Journal of Science and Research (IJSR) ISSN*. https://doi.org/10.21275/ART20162219

Kotter, J. P. (1996). *Leading Changqe. Harvard Business Review Press.*

Lee, S. M., Baker, C. R., Cho, S. H., Heckathorn, D. E., Holland, M. W., Newgent, R. A., Ogle, N. T., Powell, M. L., Quinn, J. J., Wallace, S. L., & Yu, K. (2007). Development and Initial Psychometrics of the Counselor Burnout Inventory. *Measurement and Evaluation in Counseling and Development*, *40*(3), 142–154. https://doi.org/10.1080/07481756.2007.11909811

Lewis, S., Gambles, R., & Rapoport, R. (2007). The constraints of a 'work–life balance' approach: an international perspective. *The International Journal of Human Resource Management*, *18*(3), 360–373. https://doi.org/10.1080/09585190601165577

Liu, K. P., Chiu, W., Chu, J., & Zheng, L. J. (2022). The Impact of Digitalization on Supply Chain Integration and Performance. *Journal of Global Information Management*, *30*(1), 1–20. https://doi.org/10.4018/jgim.311450

Loske, D., & Klumpp, M. (2022). Verifying the effects of digitalisation in retail logistics: an efficiency-centred approach. *International Journal of Logistics Research and Applications*, *25*(2), 203–227. https://doi.org/10.1080/13675567.2020.1815681

Mayring, P. (2007). Introduction: Arguments for Mixed Methodology. In *Mixed Methodology in Psychological Research* (pp. 1–4). BRILL. https://doi.org/10.1163/9789087903503_002

McKinsey. (2016). Supply Chain 4.0: The next-generation digital supply chain. *McKinsey Insights*.

Mofokeng, T. M., & Chinomona, R. (2019). Supply chain partnership, supply chain collaboration and supply chain integration as the antecedents of supply chain performance. *South African Journal of Business Management*, *50*(1). https://doi.org/10.4102/sajbm.v50i1.193

Mukhopadhyay, T., & Kekre, S. (2002). Strategic and Operational Benefits of Electronic Integration in B2B Procurement Processes. *Management Science*, *48*(10), 1301–1313.

https://doi.org/10.1287/mnsc.48.10.1301.273
Naeem, M., Khan, A., Rehman, A., Farooq, S., Mehboob, A., Abdali, A. S., & Ahmad, B. (2025). Does Artificial Intelligence With Blockchain Reduce the Costs of the Financial Sector?. In Generative AI for Web Engineering Models (pp. 147-160). IGI Global.
Naeem, M., Memon, S., Salman, M., Mehboob, A., Fatima, A., & Rehman, A. (2025). Transformational Leadership and Operational Efficiency in Industry 4.0: The Mediating Role of Digitalization through the Lens of Dynamic Capabilities Theory. Asian Journal of Economics, Finance and Management, 7(1), 240-251.
Naeem, M., Siraj, M., Ali, S., Rehman, A., & Farooq, S. (2025). The Role of Artificial Intelligence in Risk Management: Practices of the Banking Sector. In Generative AI for Web Engineering Models (pp. 83-106). IGI Global.
Rehman Khan, S. A., Ahmad, Z., Sheikh, A. A., & Yu, Z. (2022a). Digital transformation, smart technologies, and eco-innovation are paving the way toward sustainable supply chain performance. *Science Progress*, *105*(4). https://doi.org/10.1177/00368504221145648
Rehman Khan, S. A., Ahmad, Z., Sheikh, A. A., & Yu, Z. (2022b). Digital transformation, smart technologies, and eco-innovation are paving the way toward sustainable supply chain performance. *Science Progress*, *105*(4). https://doi.org/10.1177/00368504221145648
Rogerson, M., & Parry, G. C. (2020). Blockchain: case studies in food supply chain visibility. *Supply Chain Management: An International Journal*, *25*(5), 601–614. https://doi.org/10.1108/SCM-08-2019-0300
Sanders, N. R., & Swink, M. (n.d.). *The Intelligent Supply Chain: A Maturity Model for Digitization and Visibility*.
Sarstedt, M., Ringle, C. M., & Hair, J. F. (2017). Partial Least Squares Structural Equation Modeling. In *Handbook of Market Research* (pp. 1–40). Springer International Publishing. https://doi.org/10.1007/978-3-319-05542-8_15-1
Saryatmo, M. A., & Sukhotu, V. (2021). The Influence of the Digital Supply Chain on Operational Performance: A Study of the Food and Beverage Industry in Indonesia. *Sustainability*, *13*(9), 5109. https://doi.org/10.3390/su13095109
Schwarzmüller, T., Brosi, P., Duman, D., & Welpe, I. M. (2018). Schwarzmüller, T., Brosi, P., Duman, D., & Welpe, How Does the Digital Transformation Affect Organizations? Key Themes of Change in Work Design and Leadership. Management Revue. *(2018). How Does the Digital Transformation Affect Organizations? Key Themes of Change in Work Design and Leadership. Management Revue, 29(2), 114–138*, *29*(2), 114–138.
Scudder, G. D., & Hill, C. A. (1998). A review and classification of empirical research in operations management. *Journal of Operations Management*, *16*(1), 91–101. https://doi.org/10.1016/S0272-6963(97)00008-9
Setzler, E. J., & Sezen, H. (2008). Model for the Lateral Behavior of Reinforced Concrete Columns Including Shear Deformations. *Earthquake Spectra*, *24*(2), 493–511. https://doi.org/10.1193/1.2932078
Sharma, O., Sultan, A. A., Ding, H., & Triggle, C. R. (2020). A Review of the Progress and Challenges of Developing a Vaccine for COVID-19. *Frontiers in Immunology*, *11*.

https://doi.org/10.3389/fimmu.2020.585354
Siagian, H., Tarigan, Z. J. H., & Basana, S. R. (2022). The role of top management commitment in enhancing competitive advantage: The mediating role of green innovation, supplier, and customer integration. *Uncertain Supply Chain Management*, *10*(2), 477–494. https://doi.org/10.5267/j.uscm.2021.12.003
Stank, T., Esper, T., Goldsby, T. J., Zinn, W., & Autry, C. (2019). Toward a Digitally Dominant Paradigm for twenty-first century supply chain scholarship. *International Journal of Physical Distribution & Logistics Management*, *49*(10), 956–971. https://doi.org/10.1108/IJPDLM-03-2019-0076
Stein, M. and V. F. (1998). *Macrologistics Management*.
Talke, K., Salomo, S., & Kock, A. (2011). Top Management Team Diversity and Strategic Innovation Orientation: The Relationship and Consequences for Innovativeness and Performance. *Journal of Product Innovation Management*, *28*(6), 819–832. https://doi.org/10.1111/j.1540-5885.2011.00851.x
Teece, D. J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, *28*(13), 1319–1350. https://doi.org/10.1002/smj.640
Teece, D. J. (2014). The Foundations of Enterprise Performance: Dynamic and Ordinary Capabilities in an (Economic) Theory of Firms. *Academy of Management Perspectives*, *28*(4), 328–352. https://doi.org/10.5465/amp.2013.0116
Teece, D. J. , P. G. ; S. A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533.
Theodoraki, C., Dana, L.-P., & Caputo, A. (2022). Building sustainable entrepreneurial ecosystems: A holistic approach. *Journal of Business Research*, *140*, 346–360. https://doi.org/10.1016/j.jbusres.2021.11.005
Vanichchinchai, A., & Igel, B. (2009). Total quality management and supply chain management: similarities and differences. *The TQM Journal*, *21*(3), 249–260. https://doi.org/10.1108/17542730910953022
Wamba, S. F., Dubey, R., Gunasekaran, A., & Akter, S. (2020). The performance effects of big data analytics and supply chain ambidexterity: The moderating effect of environmental dynamism. *International Journal of Production Economics*, *222*. https://doi.org/10.1016/j.ijpe.2019.09.019
Wang, C. L., & Ahmed, P. K. (2007). Dynamic capabilities: A review and research agenda. *International Journal of Management Reviews*, *9*(1), 31–51. https://doi.org/10.1111/j.1468-2370.2007.00201.x
Wang, H., Tong, L., Takeuchi, R., & George, G. (2016). Corporate social responsibility: An overview and new research directions. In *Academy of Management Journal* (Vol. 59, Issue 2, pp. 534–544). Academy of Management. https://doi.org/10.5465/amj.2016.5001
Warner, K. S. R., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning*, *52*(3), 326–349. https://doi.org/10.1016/j.lrp.2018.12.001
Wei, S., Ke, W., Lado, A. A., Liu, H., & Wei, K. K. (2020). The Effects of Justice and Top

Management Beliefs and Participation: An Exploratory Study in the Context of Digital Supply Chain Management. *Journal of Business Ethics*, *166*(1), 51–71. https://doi.org/10.1007/s10551-018-04100-9

Whitten, G. D., Kenneth, W. G., & Zelbst, P. J. (2012). Triple-A supply chain performance. *International Journal of Operations and Production Management*, *32*(1), 28–48. https://doi.org/10.1108/01443571211195727

Wilden, R., Gudergan, S. P., Nielsen, B. B., & Lings, I. (2013). Dynamic Capabilities and Performance: Strategy, Structure and Environment. *Long Range Planning*, *46*(1–2), 72–96. https://doi.org/10.1016/j.lrp.2012.12.001

Wilhelm, H., Schlömer, M., & Maurer, I. (2015). How Dynamic Capabilities Affect the Effectiveness and Efficiency of Operating Routines under High and Low Levels of Environmental Dynamism. *British Journal of Management*, *26*(2), 327–345. https://doi.org/10.1111/1467-8551.12085

Willaby, H. W., Costa, D. S. J., Burns, B. D., MacCann, C., & Roberts, R. D. (2015). Testing complex models with small sample sizes: A historical overview and empirical demonstration of what Partial Least Squares (PLS) can offer differential psychology. *Personality and Individual Differences*, *84*, 73–78. https://doi.org/10.1016/j.paid.2014.09.008

William Gemmell Cochran. (1977). Sampling Techniques. *Wiley, 1977*, 96(3, illustrated).

Zhao, N., Hong, J., & Lau, K. H. (2023). Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model. *International Journal of Production Economics*, *259*. https://doi.org/10.1016/j.ijpe.2023.108817

Zhou, H., Wang, Q., Li, L., Teo, T. S. H., & Yang, S. (2023). Supply chain digitalization and performance improvement: a moderated mediation model. *Supply Chain Management*, *28*(6), 993–1008. https://doi.org/10.1108/SCM-11-2022-0434