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Digital Supply Chain Transformation and Operational Supply Chain Performance: The Mediating Role of Supply Chain Integration among Manufacturing Firms in Ethiopia's Special Economic Zones.

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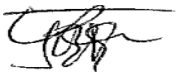
APPROVAL

I, Hayleyesus Shmelash, the research paper titled "**Digital Supply Chain Transformation and Operational Supply Chain Performance: The Mediating Role of Supply Chain Integration among Manufacturing Firms in Ethiopia's Special Economic Zones,**" is my own original work and has not been submitted for any degree in any other University. It is offered for the award of the degree of Master of Business Administration,

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LIST OF ACRONYMS

Acronym	Meaning
DCT	Dynamic Capability theory
DSCT	Digital Supply Chain Transformation
ERP	Enterprise Resource Planning
eDMS	Electronic Document Management Systems,
FDI	Foreign Direct Investment
ICT	Information and Communication Technology
IoT	Internet of Things
IPs	Industrial Parks
IT	Information Technology
IPT	Information Processing Theory
LPI	Logistics Performance Index
OECD	Organization for Economic Co-operation and Development
OSCP	Operational Supply Chain Performance
PLS-SEM	Partial Least Squares Structural Equation Modeling
RBV	Resource-Based View
RQ1–RQ5	Research Question 1 to Research Question 5
SCI	Supply Chain Integration
SEZ	Special Economic Zone
UNCTAD	United Nations Conference on Trade and Development
WTO	World Trade Organization

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Abstract

Digital Supply Chain Transformation (DSCT) has become increasingly important for improving operational efficiency and competitiveness in manufacturing firms. However, there is limited empirical evidence regarding how DSCT develops organizational capabilities for improving business performance in Ethiopia's Specialized Economic Zones (SEZs). Accordingly, this thesis examined how each of the four dimensions of DSCT (i.e., digital documentation systems; digital planning systems; real-time tracking technologies; and data analytics capabilities) impacts upon Operational Supply Chain Performance (OSCP). Additionally, this thesis investigated whether Supply Chain Integration (SCI) serves as a mediator between DSCT and OSCP, as well as how External Ecosystem Readiness (EXR) and Internal Readiness (INR) moderate this relationship. a quantitative cross-sectional research approach is used to collect data via a structured questionnaire from manufacturing firms located in Ethiopian SEZs. Of the 248 questionnaires distributed, 103 were returned for a 41.5% return rate; from these, 86 suitable responses were analyzed via Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS 4.

The results indicated no statistically significant direct effects of the four dimensions of DSCT on operational supply chain performance. However, the two measures of digital planning systems and real-time tracking technology played significant roles in the establishment of supply chain integration. The mediation analysis indicated that supply chain integration does not significantly mediate the relationship between DSCT dimensions and operational supply chain performance. External ecosystem readiness and internal readiness also did not moderate any of these relationships significantly.

Overall, even though digital transformation efforts are increasingly being pursued by manufacturing firms in Ethiopia's SEZs, the operational benefits are limited by both a lack of integration maturity and poor ecosystem readiness levels. The research fills a gap in the current literature by studying DSCT as a multidimensional variable with a focus on Ethiopian SEZs, an area that has been under-researched, and also provides pertinent insight to provide managers and policymakers opportunities to improve operational supply chain performance through digital transformation.

Keywords: Digital Supply Chain Transformation, Supply Chain Integration, Operational Supply Chain Performance, Specialized Economic Zones, PLS-SEM, Ethiopia.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Technology and supply chain

In the era of globalization, the continuity of business success relies on performance of the supply chain. Supply Chain Digitalization (e.g., Enterprise Resource Planning/Materials Requirement Planning, Internet of Things tracking, analytic tools, and cross-organizations platforms) has developed new methods for organizations to plan, coordinate and manage their flows of both materials and information. The most recent and well-documented supply chain digitalization studies are identifying statistically significant improvements in performance as a result of greater supply chain visibility, synchronization, and improved decision-making through enhanced integration of internal functions and external suppliers (Saryatmo & Sukhotu, 2021; Liu et al., 2022; Hautala-Kankaanpää, 2022; Al Tera et al., 2024). In this research, Digital Supply Chain Transformation (DSCT) is defined as intentional and comprehensive organizational changes in process and/or decision-making as a result of digital technologies and data, including the use of both intrafirm and interfirm information to plan for, execute, and monitor all supply chain activities.

One of the main mechanisms for connecting all systems together with digital technologies is the ability to collect, standardize, and exchange operational data across all functions and partners (e.g., orders, inventory status, production status, quality measurements, and logistics events) in order to synchronize plans and execution. Recent empirical research has shown that digitalization can help organizations achieve better performance by enhancing their ability to process information, facilitate coordination across all functions and between businesses, and respond quickly to disruptions in the supply chain (Liu et al., 2022; Zhao et al., 2023; Salamah et al., 2024). Rather than viewing digital technology as an isolated investment in information technology, building a digital supply chain transformation (DSCT) as a strategic capability that integrates digital assets into integration routines to enhance the operational performance of supply chains.

The digital capabilities that should be given special consideration are those which facilitate the establishment of zone-based ecosystems for manufacturing, through the sharing of resources between firms by means of a common service provider (e.g., utilities, logistics, regulatory interface). In this manner, because of the availability of timely exchange and standard documentation of information, there exists a greater degree of interoperability between firms; therefore, the level of coordination friction between firms is decreased, and the effectiveness of their operations is improved (OECD, 2023; WTO, 2023a).

This research analyzes how Digital Supply Chain Transformation (DSCT) and Supply Chain Integration (SCI) act as complementary drivers to promote Operational Supply Chain Performance (OSCP), which is measured by delivery reliability, lead time, quality, cost efficiency, and operational responsiveness.

Ethiopia's Specialized Economic Zones and operational supply chain performance challenges

Ethiopia has placed great emphasis on manufacturing-led industrialization (MLI) over the last two decades by employing geographically concentrated industrial zones, which were previously referred to as industrial parks. These initiatives now fall under a revised Special Economic Zones (SEZs) framework, with existing industrial parks being upgraded and qualified as SEZs (FDRE, 2024; Ethiopian News Agency, 2024). The primary policy rationale continues to be to provide serviced industrial land, streamlined services, and a conducive business environment in order to attract investment and create jobs (World Bank, 2022). Additionally, there are ongoing performance challenges, including uneven productivity, operational bottlenecks, and weaknesses in associated supporting systems (such as information management and coordination systems) (World Bank, 2022; Guteta & Worku, 2023).

Specialized Economic Zones can decrease the costs associated with coordination by the development of shared facilities/infrastructure and a variety of services (including transport, power, telecommunications, and administrative services) and by placing related services in close proximity to one another and allowing firms to more quickly and effectively connect with their suppliers and logistics networks (World Bank, 2022). However, the efficiencies realized through the use of SEZs are dependent upon the reliability of the shared services and the capability of the firms to coordinate their internal operations with their external partners. By improving the

companies' ability to execute and trace the integrated plans between them, digital technology and digital supply chain transformation (DSCT) can enable firms to capitalize on the efficiencies that result from integrating supply chain components. However, according to the study, the extent of this capitalization will most likely be maximized through the combination of digital capabilities and effective supply chain integration practices (Liu et al., 2022; Hautala-Kankaanpää, 2022; Salamah et al., 2024).

Practical, firm-level measures of operational supply chain performance identified within firms located in SEZs can be assessed using measures such as delivery dependability, order-cycle time, quality consistency, inventory effectiveness, cost savings, and operational flexibility; all of which have been extensively used as operational outcomes in empirical study of digital supply chains (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpaa, 2022). Therefore, by using operational outcomes instead of only export outcomes in this study, it allows to broaden the sample of firms included in the research to include all manufactures located in some SEZs, and still obtain the same data set for examining export orientation as a contextual variable.

1.2 Problem statement

Manufacturing companies are increasingly making digital supply chain transformation (DSCT) a strategic focus to achieve improved operational efficiency and enhanced visibility, speed, and resilience of the supply chain. Using digital technologies such as enterprise resource planning systems, cloud computing, internet of things (IoT) enabled tracking, and analytics, recent research shows significant positive effects of these technologies on operational performance of the supply chain (Liu et al., 2022; Zhao et al., 2023); however, there is still a lack of empirical evidence regarding the mechanisms by which digital transformation will improve operational performance, especially in developing countries where institutional, infrastructural and technological constraints pose challenges.

In Ethiopia, manufacturing firms within Special Economic Zones (SEZs) still experience inefficiencies in delivery performance, supply chain visibility, coordination and digital infrastructure even with continued efforts towards industrialisation. Most of the existing studies regarding industrial parks/SEZs in Ethiopia focus on governance, export performance and infrastructural development and there has been little empirical research on firm-level digital supply chain transformation and its operational implications (Guteta & Worku, 2023; Kebede, 2024).

Moreover Digital Supply Chain Transformation (DSCT) has been examined in relation to operational performance but few studies have gone any further as they all view DSCT as an aggregate construct rather than examining its individual components; hence little empirical research has been conducted looking at the operational impacts of each component separately: digital documentation systems, digital planning systems, real-time tracking technology, and data analytics capabilities; especially within the developing world and Special Economic Zones (Ngo et al., 2023; Al Tera et al, 2024).

Therefore, the main problem addressed in this study is the limited empirical evidence on how specific dimensions of Digital Supply Chain Transformation influence Operational Supply Chain Performance through Supply Chain Integration among manufacturing firms operating in Ethiopia's Special Economic Zones. By disaggregating DSCT into digital documentation systems, digital planning systems, real-time tracking technologies, and data analytics capabilities, the study provides a more precise explanation of which digital capabilities contribute most strongly to operational improvement.

1.3 Objectives of the Study

1.3.1 General Objective

The purpose of this study is to examine and analyze the relationship between dimensions of Digital Supply Chain Transformation (DSCT) and Operational Supply Chain Performance (OSCP) for manufacturing companies in Ethiopia's Specialized Economic Zones (SEZs). It specifically investigates which dimension(s) of DSCT and enabling conditions have the strongest correlation to operational improvement and whether Supply Chain Integration (SCI) is a mediating factor connecting DSCT to improved OSCP.

1.3.2 Specific Objectives

This research includes five specific, measurable, management-friendly objectives, as well as a clear action plan to achieve these objectives. The specific objectives are as follows:

1. To assess the current level of digital supply chain transformation among selected manufacturing firms in Ethiopia's specialized economic zones (SEZs).

2. To measure operational supply chain performance outcomes using feasible firm-level indicators such as delivery dependability, lead-time reduction, order fulfillment accuracy, quality consistency, cost efficiency, and operational responsiveness (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpää, 2022).

3. To examine the individual relationships between the four dimensions of Digital Supply Chain Transformation (digital documentation systems, digital planning systems, real-time tracking technologies, and data analytics capabilities) and operational supply chain performance, including whether supply chain integration mediates these relationships (Hautala-Kankaanpää, 2022; Liu et al., 2022).

4. Identify the factors that influence a firm's ability to digitize its supply chain within the SEZ context, both internally and externally.

5. Based on the research results, provide practical recommendations for management and policymakers regarding targeted digital investments and integration strategies that will increase operational supply chain performance within Ethiopia's SEZs.

1.4 Research Questions

- RQ1: How do the four dimensions of Digital Supply Chain Transformation (documentation, planning, real-time tracking, and data analytics) influence operational supply chain performance among manufacturing firms in Ethiopia's SEZs?
- RQ2: What level of digital supply chain transformation currently exists among manufacturing firms in Ethiopia's SEZs?
- RQ3: Which DSCT dimensions (Documentation, Planning, Real-Time Tracking, and Data Analytics) are most strongly associated with operational supply chain performance in Ethiopia's SEZs?
- RQ4: To what extent does supply chain integration (internal and external) mediate the relationship between DSCT and operational supply chain performance?
- RQ5: What technical, organizational, and environmental conditions are most important for successful DSCT implementation within Ethiopia's SEZs?

1.5 Significance of the study

1.5.1 Managerial implications

Managers of SEZ businesses will find this research beneficial in identifying how to enhance their operational performance through digital supply chain capabilities. The goal of this research is to provide managers with practical examples of what digital supply chain capabilities provide the most operational improvements to a company's performance, rather than looking at digital transformation as one organization-wide program. The research elaborates on how separate capabilities of digital documentation, digital planning technology, real-time order tracking, and data analytics performance outcome measures (delivery reliability, lead-time decrease, operational responsiveness, cost efficiency) impact an overall company's operational performance (Saryatmo & Sukhotu, 2021; Zhao et al., 2023). The results of the research can assist managers with prioritizing investment into the digital capabilities that provide the most operational improvements..

1.5.2 Policy and Development Implications

Ethiopia's SEZs Policy is focused on supporting industrial growth through enhanced provision of industrial serviced land, reduced bureaucracy in service provision, and facilitating increased investment; but due to existing operational bottlenecks and capability gaps, the SEZ has been limited in meeting its objectives (World Bank 2022; FDRE 2024). Therefore, this study provides evidence for zone administrators/policymakers about which form of digital and integrated capability are more strongly related to improved operational performance and the form of support (e.g., shared digital services, training support, data standards and district coordination) that will best strengthen performance at the zone level.

1.5.3 Academic Contribution of the Study

Research on digital supply chains on a worldwide basis is continuing to develop, but the empirical research has not been evenly distributed across different regions. Currently, little is known about how digital supply chain maturity impacts operational performance when looking specifically at firms operating within African special economic zones. Although there have been studies done regarding Ethiopia specifically, these studies have not adequately quantified the correlation between digital supply chain maturity and operational performance within firms (Guteta & Worku, 2023; World Bank, 2022). This research provides additional insights by breaking down Digital

Supply Chain Transformation into four dimensions—digital documentation, digital planning, real-time tracking, and data analytics—then analyze how each dimension individually affects the operational performance of supply chains through the mediation of supply chain integration within the under-studied context of Ethiopian SEZ-manufacturing firms (Vial, 2019; Ngo et al., 2023).

More specifically, this study makes four types of scientific contributions. First, it makes a theoretical contribution by integrating and extending three complementary theoretical lenses—Dynamic Capabilities Theory (DCT), the Resource-Based View (RBV), and Information Processing Theory (IPT)—to explain the conditions under which digital supply chain transformation converts into operational performance. Prior studies applying these theories have done so in isolation and in advanced manufacturing contexts; by synthesizing all three in the Ethiopian SEZ context, this study advances a more nuanced theoretical framework that accounts for institutional constraints, ecosystem readiness, and integration maturity as boundary conditions of the DSCT–OSCP relationship (Teece et al., 1997; Barney, 1991; Galbraith, 1977; Elnadi et al., 2025). Second, this study makes a methodological contribution by operationalizing DSCT as four independent, disaggregated dimensions rather than as a single aggregate construct, and by applying PLS-SEM with moderated mediation within a finite population of SEZ firms. This design enables a more precise assessment of which digital capability dimensions matter most for integration and operational performance—a methodological advance over the dominant single-construct approaches in prior literature (Ngo et al., 2023; Al Tera et al., 2024; Hair et al., 2022). Third, the study provides an empirical contribution by generating primary quantitative evidence from manufacturing firms in Ethiopian SEZs—a context that has received minimal empirical attention in the global digital supply chain literature. The findings contribute original data on digital transformation maturity, integration levels, and operational performance outcomes in an African industrialization context, filling a documented void in the literature (Zemene et al., 2026; El Ouardi & Abdoun, 2026). Fourth, the study offers a practical contribution by translating its findings into targeted, actionable recommendations for SEZ administrators, zone-level policymakers, and firm managers regarding which specific digital investments (e.g., digital planning backbones and real-time tracking systems) generate the most integration and operational value in a resource-constrained, infrastructure-limited context.

1.6 Scope and Boundaries

This research study examines manufacturing firms located in selected Specialized Economic Zones (SEZs) throughout Ethiopia. The unit of analysis is the firm; however, data are collected through a quantitative survey among knowledgeable informants (i.e., serving in the roles of operations/supply chain coordinators, production planning and scheduling coordinators, logistics coordinators, and ERP/ICT coordinators). Where more than one response was obtained from a firm, responses were aggregated or screened for consistency. This study analyzes the relationships between four dimensions of Digital Supply Chain Transformation (digital documentation systems, digital planning systems, real-time tracking technologies, and data analytics capabilities), Supply Chain Integration (SCI), and Operational Supply Chain Performance (OSCP) using Partial Least Squares Structural Equation Modeling (PLS-SEM) (Hair et al., 2022). but do not allow for any definitive or strong causal inferences.

1.7 Definition of Key Terms

- Digital Supply Chain Transformation (DSCT) is described in this research as a transformative, firm-level process where digital technologies drive the major changes to how supply chains are planned, coordinated and executed; thus, changing the routines, flows of information, decision-making rights and governance for both internal functions and external partners (Vial, 2019; Ngo et al., 2023). DSCT is treated as a multi-technology capability-based transformation where the performance effects of its implementation depend on the implementation conditions (e.g., interoperability, data governance, and readiness) rather than only on the act of using the technology (Rad et al., 2022; Büyüközkan & Göçer, 2018).

  DSCT is operationalized in this research via four practical capability areas defined by the extent to which digitalization and integration have occurred:

  - ✓ Digital Document Management - (e.g., Paperless workflows, Export/Compliance documentation controls).
  - ✓ Digital Planning & execution backbone (e.g., ERP-enabled planning/coordinating).
  - ✓ Real-time visibility and traceability - (e.g., tracking and status visibility for the flows).
  - ✓ Data analytics and decision support - (e.g., dashboards and analytic capabilities for decision-making in forecasting and operations).

The four capability areas above align with previous synthesis of the digital supply chain literature and evidence for Industry 4.0 in regard to end-to-end connectivity, visibility, and analytics-enabled decision-making (Rad et al., 2022; Büyüközkan & Göçer, 2018).

- Supply Chain Integration (SCI) is the systematic alignment of all functions of an organisation to collectively achieve common goals through working together and coordinating processes with external partner organisations. It has been shown through empirical literature that SCI results in superior performance in a variety of situations. For example, SCI is consistently linked to achieving better results from supplying chains than not using SCI. Internal and external integration are two major components of SCI (Leuschner et al., 2013). Internal integration is the way in which separate functions of an organisation work together, commonly known as cross-functional co-ordination. Examples of internal integration can be found by looking at organisations where their planning processes are harmonised (rather than planned independently) and where some data is shared between functions, such as common planning/scheduling areas (Flynn et al., 2010). External integration is similar to internal integration, except that it deals with external partners (e.g., suppliers, logistics, and export customers) rather than the functions of an organisation (Flynn et al., 2010). There is much empirical evidence that supports why using SCI will improve an organisation's ability to compete globally through improved export competitiveness (Flynn et al., 2010; Leuschner et al., 2013).
- SEZs (In the context of Ethiopia): A designated area of land for the purpose of industrial manufacture that has been designated an area of serviced infrastructure with the intent of accelerating industrialization and exports to companies by providing coordinated services to companies and has performance impacted by governance capability and the quality of service delivery (World Bank, 2022).
- An ERP ('Enterprise Resource Planning'): An integrated "enterprise system" designed to provide a common methodology for the performance of and integration of cross-functional processes and associated cross-functional data (e.g., procurement, inventory management, production control, financial processes), thus enabling an organization to have "visibility" and "coordination" of information throughout the organization (Davenport, 1998).
- The Electronic Document Management System (eDMS) serves as the basis for creating, storing, routing, controlling, and retrieving documents and records that originate in an

organization. Many of the eDMS functions are applicable to digitalizing export documents and border processes. Using an eDMS to facilitate trade will produce measurable export increases by reducing the friction caused by paperwork (OECD, 2025; United Nations Regional Commissions, 2023)

1.8 Organization of the Study

The research consists of five sections outlined below. The first section is an abstract, which is followed by Chapter 1: Background to the study (including problem statement, research objectives, research questions, significance of study and scope of the study); Chapter 2: Literature review (defines the terms used in this study: DSCT; SCI; operational supply chain performance; and the SEZ context for Ethiopia); synthesizes the earlier empirical studies carried out in the years 2021-present and identifies gaps; formulates hypotheses; and provides an updated conceptual framework of relationships between DSCTs, SCIs and OSCPs; Chapter 3: Research Methodology (describes the quantitative survey research design, research setting, study population, sampling methods/approaches, data collection method(s), operational definition of variables (and sources), data analysis plan using PLS-SEM)). Finally, a timetable, reference list and appendices containing the survey questionnaire are provided at the end of the research. Chapter 4: Results and Analysis and Chapter 5: Conclusions and Recommendations

CHAPTER 2

LITERATURE REVIEW

2.1 Digital Supply Chain Transformation and Operational Supply Chain Performance

Digital supply chain transformation (DSCT) is the process of redesigning supply chain processes and decisions through a systematic application of digital technologies and data (Nasiri et al., 2020; Ngo et al., 2023) to facilitate improvements in the planning, execution, monitoring, and collaboration of the entire supply chain from start to finish. It will assist with operational performance in manufacturing settings by increasing visibility, improving coordination, and enhancing decision-making, thereby achieving desirable operational outcomes such as delivery dependability, reduced lead times, consistent quality, and cost savings (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpää, 2022).

Operational Supply Chain Performance (OSCP) was the criterion used within the current study to evaluate operational outcomes indicative of how well a supply chain aids in support of reliable and efficient production and delivery activities. Evidence from empirical studies has been used to evaluate these operational outcomes through the application of a number of multi-dimensional indices (e.g., quality, productivity, cost savings, delivery dependability, and responsiveness) with empirical evidence supporting greater operational performance gains resulting from the use of digital supply chains (Saryatmo & Sukhotu, 2021; Al Tera et al., 2024).

Recent research indicates that integration and capability mechanisms are methods by which performance effects frequently operate. For example, increased supply chain integration through digitalization allows suppliers and customers to be more closely aligned regarding supply to demand, thereby enhancing performance (Liu et al., 2022). As such, Supply Chain Integration (SCI) is being modeled in this paper as a mediating mechanism that links Digital Supply Chains (DSCT) to Operational Supply Chain Performance (OSCP).

2.2 Key Concepts and Working Definitions for This Research

2.2.1 Digital Supply Chain Transformation (DSCT)

The term DSCT in this research refers to an organization that has transformed the way its supply chain is managed. This will involve transitioning to new digitally-enabled processes to improve integration and coordination across the supply chain, as well as improve the ability of organizations to respond to events in real-time during their supply chain operations. DSCT encompasses not only digitalizing the internal operations of an organization (including but not limited to planning, production and inventory), but also integrating with external partners (for example, suppliers, logistics providers and buyers). Finally, it is about creating effective and accurate flow of information (often referred to as "information flow"), which includes but is not limited to sharing of data, traceability, and visibility of demand. In summary, DSCT involves an organization having transformed its routines, governance and cross-functional coordination and not simply purchasing a single technology solution (Ngo et al., 2023; Wu et al., 2025).

Recent synthesis research indicates that the correct approach to DSCT is that of multi-technology, capability-based transformation rather than single technological adoption. A systematic review of 221 studies covering the years 2005 through 2021 has indicated that the Supply Chain 4.0 performance effects depend both on the technologies used and also on the implementation conditions for using these technologies. For example, some of these conditions include: interoperability, data governance, security, successful readiness for using the new technology, and successful alignment of leadership with the goals of using these technologies (Rad et al., 2022). Therefore, in this research on defining DSCT, DSCT is an organizational capability. Exporters achieve value from digital technology through redesigned planning, coordinating, and decision-making routines throughout the organization and with external partners, instead of only automating processes that already exist within the organization (Rad et al., 2022).

2.2.2 Supply Chain Integration as a Mediating Capability

Within the DSCT literature, supply chain integration (SCI) has emerged as a critical mechanism through which digital transformation translates into performance outcomes. SCI refers to the extent to which firms coordinate processes, share information, and align decisions both internally across functions and externally with supply chain partners (Flynn et al., 2010; Leuschner et al., 2013).

Empirical studies consistently demonstrate that SCI is positively associated with firm performance across diverse contexts. Meta-analytic evidence confirms that higher levels of integration lead to improvements in operational efficiency, responsiveness, and overall competitiveness (Leuschner et al., 2013). More recent studies extend this relationship by positioning SCI as a mediating mechanism between digital transformation and performance.

For instance, Liu et al. (2022) provide evidence that digitalization enhances external integration, which in turn improves firm performance, indicating partial mediation. Similarly, Salamah et al. (2024) show that digitalization influences performance through both integration and efficiency mechanisms, while Zhao et al. (2023) highlight the role of integration in enabling resilience and adaptability under disruption conditions. These findings converge on the view that digital technologies create value primarily by enabling integration, rather than by directly improving performance.

Importantly, integration is not an automatic consequence of digitalization. Instead, it represents a distinct organizational capability that requires alignment of processes, incentives, and information flows.

This distinction is particularly relevant in contexts where infrastructural and institutional constraints may limit the effectiveness of digital tools.

2.2.3 Operational Supply Chain Performance (OSCP)

Operational Supply Chain Performance (OSCP) is a measure of the overall effectiveness or efficiency or both of how a company's supply chain supports its operations and the fulfilment of customer needs. These measurements are generally recorded through specific performance criteria indicators, which may include delivery reliability/dependability, lead time, quality consistency, productivity, flexibility, and cost reduction (Neely, 1999; Saryatmo & Sukhotu, 2021). In this study, OSCP is regarded as an overall outcome of improvements in supply chain execution and operational responsiveness at the firm level, as opposed to just being related to export outcomes.

2.2.4 Special Economic Zones (SEZs)

Special Economic Zones are specifically designated areas where specific regulatory, infrastructure, and administrative arrangements have been put in place to encourage investment, foster industrial growth, and promote job creation through the provision of facilities provided by governments. The

framework of policy governing the establishment and administration of SEZs in Ethiopia has recently been updated with the establishment of a new proclamation, which provides the legal basis for the establishment of SEZs and also for the upgrading of existing industrial parks that have previously been established (FDRE, 2024).

As a move away from the previous model of "Industrial Parks" to the broader "Special Economic Zones" Model, several industrial parks have been developed and are now classified as SEZs (Ethiopian News Agency, 2024). Industrial parks/SEZs are relevant for firm's Supply Chain analysis since manufacturers in these areas collaborate and share the same physical/technological infrastructure (services and facilities) but differ in terms of their maturity level on Digital Technology, how they integrate with their partners, and the performance levels of their operations (World Bank, 2022).

2.3 Theoretical Framework

2.3.1 Dynamic Capabilities Theory

According to Teece, Pisano and Shuen (1997), the framework for Dynamic Capability Theory (DCT) provides a solid basis on which to develop an effective strategy for successfully transforming a digital supply chain (DSCT) because, to develop a sustainable competitive advantage, a firm must be able to competently and purposefully develop, expand, and modify resources in response to changing conditions in the resource environment, which is representative of a rapidly evolving technological landscape (Teece, 2007). As a result, the principles that comprise DCT can be used as a new foundation for DSCT development. DSCT is now characterized as an uninterrupted organizational capability to change the supply chain in order to accommodate the dynamic nature of technology and infrastructure (as opposed to the application of a fixed set of solutions). Companies that choose not to adopt a dynamic approach to DSCT development will likely create a series of disjointed digital supply chain solutions that will never deliver any sustainable strategic benefits (Bharadwaj et al., 2013).

The microfoundations of DCT - sensing, seizing and transforming - are directly related to the activities necessary for implementing a successful DSCT. For the purposes of this discussion, sensing refers to the systematic identification and evaluation of new technological developments (e.g., artificial intelligence, digital twins and blockchain) and changes in customer requirements or competitor offerings that are evident in the supply chain environment (Teece, 2007). Seizing refers

to the process of deploying resources in order to pursue opportunities in response to changes in the supply chain (Teece, 2007). A good example of this ability to seize and capitalize on new digital technologies is Maersk's development of the TradeLens blockchain platform to digitize global trade documentation and reduce frictional barriers across fragmented networks (Jensen, 2018). These types of purposeful, strategic actions distinguish companies that lead digital disruption from those that simply respond to it.

The transformative element of DCT is arguably the most important connection to DSCT in that it addresses the ongoing organizational inertia that inhibits digital initiatives. Transformation necessitates ongoing reconfiguration of supply chain processes, the development of data-centric cultures, and the continuous refreshment of workforce competencies (Teece, 2018). This capability is what separates true transformation from just superficial digitization; companies that simply add digital technology on top of existing, linear legacy workflows, without changing decision-making rights or incentives, will consistently fail to achieve productivity improvements. In fact, research indicates that over 70% of digital transformation initiatives end up not achieving their intended results due to the lack of these transformation routines being embedded within the organization (Kotter, 2012). DCT creates an environment in which DSCT is not seen as a one-time effort or project with a defined end date, but as an iterative strategic ability that allows a company's supply chain to continue being responsive, agile, and technologically up-to-date during all future digital disruptions.

According to a recent empirical study Digital transformation improves supply chain dynamics and enhances operational success by improving the supply chain's agility, adaptability, and alignment, three core capabilities underpinning organizational resilience (Matsui et al., 2025). Using the dynamic capabilities view (DCV), Elnadi et al. (2025) illustrate how digital transformation impacts the sustainable performance of supply chains through the mediating mechanisms of collaboration, resilience, and agility; only through resource and process re-configuration support from digital resources can digital transformation enhance the performance of supply chains. IoT capabilities improve innovation performance via three sequential relationships intervened by supply chain integration and supply chain agility, and digital resource orchestration is explained with the digital capabilities theory (Wu et al., 2025). For industrial park businesses in Ethiopia, digital capabilities theory provides a means for dynamically re-configuring fragmented logistics and production

activities to create an integrated export-oriented system. Therefore, as it relates to exogenous integration, supply chain integration provides a route to realizing the micro-foundational transformation of digital capabilities theory by accelerating customs clearance, improving delivery scheduling, and being responsive to the specifications of global buyers through digital investments and asynchronous supply chain management.

2.3.2 Resource-based view as a complementary theory

The RBV provides an alternative method for interpreting DSCT and SCI as a strategic asset; according to the RBV, an organization achieves sustainable competitive advantage when it acquires resources that are valuable, rare, difficult to imitate, and non-substitutable (Barney, 1991). Under this RBV framework, DSCT is viewed as a strategic resource investment, while SCI represents the organizational capability to deploy and coordinate the company's digital resources across the supply chain. RBV-based empirical studies of export-oriented SMEs indicate that digital transformation is the primary enabling channel through which export-oriented SMEs experience performance enhancements as a result of their internationalization; however, the performance enhancement is fully realized only when mediated by the absorptive and transformational processes that modify the creation and capture of value (Luu et al., 2025). Moreover, in a relevant context for Ethiopia, a recent study of 420 manufacturing SMEs identified a statistically significant relationship between digital transformation and export performance, and identified that absorptive capacity was a critical mediating factor closely aligned with integration capacity (Bui et al., 2025). Finally, the ability of Ethiopian industrial park firms to create operational supply chain performance through SCI makes DSCT causally ambiguous and socially complex, creating protection for the created competitive advantage from imitation.

2.3.3 Information processing theory (IPT)

The third theoretical underpinning of this research is the information processing theory (IPT) that clarifies why SCI is a key enabler under the uncertainties experienced in Ethiopia’s supply chain operations at the country’s SMZs. IPT has been traced to Galbraith (1973, 1977), who conceptualized organizations as open systems that must increase the capacity for information processing as they face increasing levels of uncertainty. Firms engaged in exporting encounter task uncertainty as a result of volatile global demand, the different requirements for compliance by various buyers, the fragmented nature of supply sources upstream in the supply chain, and

unpredictability in numerous aspects of the trade logistics infrastructure. Digital transformation of the supply chain enhances the ability to increase information processing capabilities through real time visibility, predictive analytics and automated reporting of exceptions; however, IPT suggests that an increase in these types of capabilities must be structurally embedded within the organization if firms are to minimize the uncertainty they face (Srinivasan and Swink, 2018). Recent research examining the use of OIPT within emerging market logistics supports the idea that the capabilities associated with a digital supply chain - especially agility and visibility - improve firm performance because they improve the information processing capability of that organization so as to enable firms to implement more advanced technological innovations and improve decision making (Ashal, 2025). In contrast, the same research indicates that digital supply chain integration does not directly affect firm performance; therefore, integration should not be considered an automatic byproduct of the adoption of digital supply chain technologies, but rather a unique capability that requires dedicated development.

In further expanding upon this premise, Qin et al. (2025) use IPT to illustrate that a digital transformation increases operational efficiency via buyer–supplier coordination mechanisms that have various uncertainty dimensions as moderators to this relationship. With respect to Ethiopian industrial park firms (operating in a context characterised by both global buyer power, domestic infrastructure constraints, and policy volatility), DSCT without SCI creates a situation where firms have not utilised all of their information processing capacity; SCI provides a means to transfer the expanded digital capacity provided by DSCT into the structural coordination mechanisms that decrease the uncertainty associated with exporting, thereby allowing for reliable fulfilment of cross-border orders and the opportunity to remain competitive within international markets.

2.3.4 Synthesis: Theoretical basis for mediation hypothesis

Together, DCT, RBV, and IPT provide a unified theoretical basis to form a hypothesis that supply chain integration acts as a mediator between Digital Supply Chain Transformation (DSCT) and operational performance of firm’s supply chain located within Ethiopian SEZs, representing a theoretical framework which covers major areas of inadequacies within both the digital supply chain literature and the literature on industrialization in Africa.

Bringing these theoretical perspectives together, DSCT should be expected to improve the operational performance of a firm’s supply chain primarily by enabling integration, coordination,

and resilience across internal and external supply chain partners. The next section summarizes the empirical evidence supporting these relationships.

Recent studies conclude that Industry 4.0 and associated digital technologies enhance supply chain capabilities as a result of improved collaboration and improved visibility. The importance of these attributes increases dramatically during periods of disruption. Empirical research in the area of Production and Operations Management links improvement in IT to improved resilience by connecting the relationship between Supply Chain Collaboration, Supply Chain Visibility, and improved performance (Huang et al., 2023). This suggests to the overall framework of this model that it should not assume that the implementation of Digital Supply Chain Technologies (DSCT) will automatically produce improved performance; rather, it must be recognized that the implementation of such technologies will create supply chain capabilities from which improved performance will arise.

For many years, researchers have been aware that integrating supply chains is an important method of achieving performance. By integrating supply chains both internally (cross-functionally) and externally (sharing information and planning with customers and suppliers), companies can coordinate their activities more effectively, minimize delays and inconsistencies, and ultimately execute their supply chain functions more consistently (Flynn et al., 2010; Leuschner et al., 2013). This study specifically examines supply chain integration (SCI) as a mediator because recent research indicates that digitalization can facilitate SCI and subsequently lead to improvements in operational effectiveness (Liu et al., 2022).

While digital supply chain technology (DSCT) can lead to improvements in operational effectiveness in manufacturing supply chains, these effects are not consistently experienced across all contexts. In the period from 2021 onwards, open-access empirical studies have found that there is a significant positive relationship between digital supply chain practices and operational effectiveness (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpää, 2022) and identified some of the different pathways through which this relationship occurs. These studies also identified some of the key mechanisms that influence the pathway from digital supply chain practices to operational effectiveness, including SCI, visibility, and resilience (Zhao et al., 2023; Al Tera et al., 2024). These results provide motivation for conducting empirical research on a DSCT→SCI→OSCP model in the context of the SEZs in Ethiopia.

2.4 Empirical Literature Review

Recent empirical research (2021 – present) shows increasing consistency of evidence regarding how digital supply chain practices can help to improve operational performance; however, the strength and ways that the digital supply chain practices influence operations may differ depending on many factors, including context, company size, and depth of implementation.

A survey conducted by Saryatmo and Sukhotu (2021) including 209 manufacturing firms in Indonesia, determined that digital supply chain practices significantly improved operational performance measurements associated with quality, productivity and cost savings. Their results reflect that operational gains are generated by embedding digital tools in supply chain activities instead of limiting their use solely for isolated automation.

Hautala-Kankaanpää (2022) examined manufacturing firms in addition to modelling digitaliation in terms of supply chain capability. The study identified that digitalisation enhances operational performance primarily by enhancing capabilities for process and coordination at the enterprise level, further suggesting that the impactz of digital supply chain technology on performance is capability-based rather than technology-driven.

According to Liu et al (2022), there is direct evidence of integration as a mechanism; using PLS-SEM revealed that both supply chain digitalization and external integration positively influence firm performance and that external integration partially mediates the effect of digitalization on firm performance. Liu et al also reported that the path for improvement is different for large enterprises versus small/medium-sized enterprises, suggesting that regionally targeted policy support will need to be tailored based on firm capability.

Zhao et al. (2023) expand the mechanistic view of disruption by examining what happens in environments of disrupted operations when organizations that develop digital supply chain tools find out how investing in developing these tools creates increased organizational performance. Their evidence for mediation and moderated mediation points to stronger performance returns for organizations that have appropriate organizational capabilities to use digital supply chain tools for improving their organizational ability to adapt.

More recent research studies include efficiency and visibility as mechanisms of increasing performance in supply chain digitalization. For instance, Al Tera et al. (2024) demonstrated that

supply chain digitalization contributes to improving performance via increasing supply chain visibility and is conditioned by factors that enhance organizational ability to survive. Salamah et al. (2024) support that digitalization will improve supply chain performance via the mechanisms of supply chain integration and efficiency. Their findings also support the mechanistic view of how DSCT increases organizational performance.

Research studies across China show that there is a positive correlation between digital transformation and supply chain integration. This same association exists between supply chain integration and supply chain performance in a comparison of different types of firms; therefore, as companies become more digitized in nature (i.e., use of digital technologies), their level of integration into the supply chain increases, and thus the level of performance increases (Jing & Fan, 2024).

While there are many research studies using manufacturing data in China that support the relationship between digital transformation and supply chain integration, there may be differences in research outcomes when comparing China to Ethiopia and the underlying theory is a very similar concept (digital transformation improves coordination and improved flow of information; however, different challenges related to timeframes and compliance may exist in Ethiopia with regards to the export manufacturing sector).

As indicated in the literature surrounding supply chain integration, caution should be exercised because supply chain integration may consist of many different aspects (internal supply chain integration has a different impact on performance than supplier supply chain integration versus customer supply chain integration), and the pathway for each of these aspects may differ based on the specific nature of the supply chain.

At this time, there are still many arguments among scholars as to which type of supply chain integration model works best under the various limitations presented by the different types of industries in which manufacturing firms operate (e.g., export manufacturing, domestic manufacturing (Li et al., 2022). Therefore, instead of assuming a direct correlation between digital supply chain transformation and supply chain performance, this research should address the process by which digital supply chain transformation leads to increased supply chain performance and where a direct correlation may not exist

The three main findings from recent research are as follows. First, that DSCT has a positive impact on operational performance; second, that impact is generally indirect, as it creates integration and capabilities (such as visibility and resilience) that help to create operational benefits; and third, that the benefits created by digitalization for firms depend on contextual factors (infrastructure, skills, partner readiness). However, there is relatively little evidence of the firm-level impact of DSCT on large emerging markets, such as the Special Economic Zones (SEZs) in Africa (particularly in Ethiopia), where the DSCT may be positively or negatively impacted by shared infrastructure and coordinated provisioning of services. Therefore, it is highly justifiable to conduct a quantitative research study that focuses on Ethiopia, explicitly examines SCI as a mediator, and examines dependent variables related to operational performance for manufacturers engaged in SEZs in Ethiopia.

2.5 SEZ enabling environment and operational supply chain performance in Ethiopia

The performance of operational supply chains within Ethiopia's Special Economic Zone (SEZ) ecosystem are influenced, not only by firm-level efficiencies, but also by their enabling environments including the reliability of transport infrastructure and logistics; the efficiency of customs and administrative processes; and access to digital resources. Limitations in transport, reliability of power supplies, and coordination can consequently prolong lead times and increase operating costs, and as such can limit opportunities for performance improvement through the use of digital tools (World Bank, 2022).

Digital transformation policies surrounding trade and logistics can thereby enhance operational performance through reducing documentation and information transfer delays, creating greater transparency among both government and commercial participants within the logistics and trade supply chain. Global-level policy discussions have underscored that interoperable systems for the facilitation of digital trade that reduce the cost of coordination among trading partners will foster greater predictability of flows (WTO, 2023a; WTO, 2023b).

However, Ethiopia's industrial park program is characterized by operational bottlenecks related to service availability, infrastructure performance, and stakeholder cooperation (Guteta & Worku, 2023; World Bank, 2022). These findings suggest that there may also be constraints due to the

environmental conditions in special economic zones (SEZs) on the impact of the digital supply chain transformation (DSCT). This study therefore evaluates how technical, organizational, and environmental enablers impact the adoption and performance of DSCT.

Research into Trade Facilitation provides quantifiable data in support of the concept that digitalization of documentation and border processes results in greater export performance. Evidence from cross-country gravity modelling conducted by Castro and Kornher (2023) provides 'high-bar' evidence of the benefit of e-trade facilitation on the exporter side. They concluded that a one standard deviation increase in e-trade facilitation will increase agrifood exports by 9.7%. And they also noted that the positive effect would be greater for processed products, and will be more pronounced in Sub-Saharan Africa and Asia, where the impact of documentation friction as a binding constraint is likely more pronounced (Castro & Kornher, 2023). Although my analysis is firm-based, these findings offer support for the assumption that documentation frictions do present a barrier when measuring export competitiveness and should therefore be included in the measurement of documentation/traceability capacity and processing speed.

2.6 Literature gap

Despite there is a growing interest in the area of Digital Supply Chain Transformation (DSCT), there are still many significant gaps in the literature. This is especially true for manufacturing companies in Ethiopia's Special Economic Zones (SEZs). In particular, three types of gaps can be seen in the DSCT literature: context, theory, and method.

Context Gaps:

The first area where there is a contextual gap is that we do not have a good understanding of how DSCT works within manufacturing Ecosystems in developing countries (particularly Ethiopia's SEZs). Most of the studies that have examined how digital supply chain transformation has impacted operational performances have been conducted in developed economies and advanced manufacturing environments; therefore, there is not sufficient empirical research regarding how digital supply chain transformation impacts operational performance in Africa (Ngo et al., 2023; Al Tera et al., 2024). Thus, we don't have reliable information regarding the extent of digital transformation maturity and the operational implications of digital transformation maturity within SEZs in Ethiopia.

Furthermore, SEZs are a unique type of production environment. They have their own infrastructure (e.g., facilities) that is shared, companies have access to logistics services from a single site; they benefit from systems designed to facilitate customs clearance; and they are the beneficiaries of government policies. All of these characteristics of the SEZs will certainly differ from conventional production environments. Therefore, these differences could affect the level of digital supply chain technology adoption and the benefits that companies will receive from those technologies.

Additionally, since logistics coordination, customs responsiveness, the reliability of infrastructure and digital service accessibility, and the availability of government support vary significantly across the industrial parks in Ethiopia, they could all impact how successful companies will be in their DSCT initiatives.

Theoretical Gap

Second, there is a considerable theoretical gap in the research of DSCT (Digital Supply Chain Technology) as it was defined in previous research studies. Most previous research studies have defined DSCT as simply a single aggregate construct, without differentiating the particular technological dimensions that comprise it. This lack of differentiation limits the theoretical understanding of the unique contributions that are made by the different forms of digital supply chain technology to supply chain integration and supply chain operational performance outcomes.

In reality, Digital Transformation in Supply Chains typically comprises a multitude of different technological capabilities, and capabilities related to the processing of information, e.g., digital document systems, digital planning systems, real-time tracking technologies, and data analytics capabilities. Depending on how these various forms of digital supply chain technology have been implemented, these different technological capabilities could produce different types of influences on operational supply chain performance through different mechanisms and at different levels of effectiveness. There have been few empirical studies that have examined separately the independent effects of these various forms/dimensions of DSCT on supply chain integration and operational performance in manufacturing firms operating in developing countries and SEZ (Special Economic Zones) contexts (Al Tera et al., 2024).

In addition, while the literature has suggested that supply chain integration (SCI) is a significant mechanism linking digital transformation to improved supply chain performance, there have been few studies that have empirically researched SCI as a mediating variable in SEZs using validated measurement constructs. Where existing studies have addressed this topic, the focus has primarily been on direct relationships, with little or no focus on the process by which the digital transformation capability converts into operational performance outcomes.

Methodological Gap

Third, a methodological gap exists in past empirical research methods. Most existing literature has used traditional regression analyses, which do not fully capture the complexity of direct, mediating and moderating relationships among the various digital transformation constructs, integration mechanisms and operational performance outcomes. Furthermore, few studies have looked at both organizational readiness factors and external ecosystem conditions at the same time within an integrated analytical framework.

This research addresses these methodological gaps by utilizing Partial Least Squares Structural Equation Modelling (PLS-SEM) using SmartPLS 4.0 for analysis due to PLS-SEM's suitability for simultaneously assessing numerous direct, mediating and moderating relationships as well as accommodating complicated predictive models and relatively small sample sizes (Hair et al., 2022). The present study additionally includes moderation analysis regarding internal and external readiness in order to assess if enabling conditions increase or weaken the relationship between digital supply chain transformation (DSCT) dimensions and operational supply chain performance.

Using an integrated approach (multidimensional DSCT constructs, mediation mechanisms, contextual moderators, and PLS-SEM methodology), this study seeks to provide a more in-depth understanding of how digital supply chain transformation influences operational supply chain performance in Ethiopian special economic zone manufacturing firms.

2.7 Inclusion and Exclusion Criteria for Theoretical Frameworks and Variables

The selection of theoretical frameworks in this study was guided by explicit inclusion and exclusion criteria to ensure that only theories with demonstrable explanatory power for the DSCT–

SCI–OSCP relationships in the Ethiopian SEZ context were employed. A theory was included if it met the following criteria: (a) it has been applied empirically in supply chain, operations management, or digital transformation research; (b) it offers direct explanatory mechanisms relevant to at least one of the three core relationships in the study (DSCT→SCI, DSCT→OSCP, or SCI→OSCP); and (c) it has been validated in developing-country or resource-constrained organizational contexts, or can plausibly be adapted to such contexts. Conversely, a theoretical framework was excluded if it (a) addressed only individual-level behavior or psychological constructs without organizational applicability; (b) focused exclusively on macro-level institutional or national innovation systems without firm-level relevance; or (c) overlapped substantially with an already-included theory without adding unique explanatory value. Applying these criteria, Dynamic Capabilities Theory (DCT) was included because it explains how firms purposefully sense, seize, and reconfigure their digital capabilities to improve performance—directly applicable to DSCT as an organizational-level transformation process (Teece et al., 1997; Elnadi et al., 2025). The Resource-Based View (RBV) was included because it explains why DSCT and SCI constitute strategic, inimitable assets that generate competitive advantage, and it has been validated in manufacturing and digital transformation contexts in developing economies (Barney, 1991; Bui et al., 2025). Information Processing Theory (IPT) was included because it specifically addresses how digital technologies enhance information-processing capacity to reduce uncertainty—precisely the mechanism by which SCI is expected to mediate the DSCT–OSCP relationship under Ethiopia's infrastructure and ecosystem constraints (Galbraith, 1973; Qin et al., 2025). Transaction Cost Theory (TCT), while relevant to supply chain coordination, was excluded because its explanatory power largely overlaps with RBV in the context of digital integration, and it focuses on cost minimization rather than capability building, which is the primary mechanism under study. Similarly, Institutional Theory was excluded because, although Ethiopia's regulatory environment is relevant, the study's unit of analysis is the firm rather than the institutional field, and institutional effects are captured through the external ecosystem moderator construct rather than through a separate theoretical lens.

Inclusion and Exclusion Criteria for Study Variables

The operationalization of DSCT into four dimensions—digital documentation systems, digital planning systems, real-time tracking technologies, and data analytics capabilities—was guided by

an explicit rationale for inclusion and exclusion. A DSCT dimension was included if (a) it has been empirically validated in published supply chain digitalization studies as a distinct and measurable capability area; (b) it maps directly onto one or more operational supply chain processes relevant to manufacturing firms in export-oriented environments; and (c) it can be reliably assessed using perceptual, Likert-scale survey items adapted from validated instruments. Advanced digital technologies such as blockchain, digital twins, and autonomous robotics were excluded as independent dimensions not because they are unimportant, but because their penetration among Ethiopian SEZ firms at the time of the study is negligible, they cannot be validly measured using existing validated survey scales, and their inclusion would risk construct and item non-response invalidity in the study population (Zemene et al., 2026; Frontiers in Sustainability, 2025). The dependent variable OSCP was operationalized using five established performance dimensions—delivery reliability, lead time, quality consistency, cost efficiency, and operational responsiveness—which were included because they are widely validated in the empirical supply chain performance literature and are directly observable at the firm level in manufacturing settings (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpaa, 2022). Export performance was excluded as a dependent variable because the study targets all SEZ manufacturers regardless of export orientation, and the focus is on firm-level operational improvement rather than on export outcomes specifically. Supply chain resilience and sustainability performance were considered but excluded because they require longitudinal data to assess accurately and are not the primary outcome of interest in a digitalization-performance study.

2.8 Hypotheses and Proposed Conceptual Framework

2.8.1 Hypotheses

Various prior studies indicate that various digital supply chain capabilities impact operational performance through separate processes. Digital documentation systems increase the accuracy of information and decrease administrative inefficiencies. Digital planning systems facilitate the coordination of activities and enhance the efficiency of scheduling production. The use of real-time tracking technologies increases visibility and responsiveness to operational issues. Data analytics capabilities enhance the quality of predicting future needs and making decisions (Saryatmo & Sukhotu, 2021; Liu et al., 2022; Zhao et al., 2023). For this reason, this research will utilize separate independent constructs for each of the four aspects of Digital Supply Chain

Transformation to investigate how each impacts supply chain operations, as well as the mediating effect that supply chain integration has on those relationships and also how the external ecosystem and Internal readiness within the firm moderate this relationship.

Direct Effect Hypotheses on Operational Supply Chain Performance

- H1a Digital documentation systems positively influence operational supply chain performance.
- H1b Digital planning systems positively influence operational supply chain performance.
- H1c Real-time tracking technologies positively influence operational supply chain performance.
- H1d Data analytics capabilities positively influence operational supply chain performance.

Direct Effect Hypotheses on Supply Chain Integration

- H2a Digital documentation systems positively influence supply chain integration.
- H2b Digital planning systems positively influence supply chain integration.
- H2c Real-time tracking technologies positively influence supply chain integration.
- H2d Data analytics capabilities positively influence supply chain integration.

Direct Effect of SCI on SCOP

- H3 Supply chain integration positively influences operational supply chain performance

Mediation Hypotheses

- H4a Supply chain integration mediates the relationship between digital documentation systems and operational supply chain performance.
- H4b Supply chain integration mediates the relationship between digital planning systems and operational supply chain performance.
- H4c Supply chain integration mediates the relationship between real-time tracking technologies and operational supply chain performance.
- H4d Supply chain integration mediates the relationship between data analytics capabilities and operational supply chain performance.

Moderation Hypotheses

- H5a Internal readiness moderates the relationships between DSCT dimensions and operational supply chain performance

- H5b External ecosystem readiness moderates the relationships between DSCT dimensions and operational supply chain performance.

2.8.2 A practical conceptual framework

According to the conceptual framework below, each Digital Supply Chain Transformation (DSCT) dimension will directly and indirectly improve Operational Supply Chain Performance (OSCP) through Supply Chain Integration (SCI). The model of SCI serves as a mediating mechanism for digitalization, improving information sharing with suppliers and customers, which subsequently enhances operational execution (Liu et al., 2022). It is also anticipated that the extent of the relationship between SCI and operational OSCP will also be influenced by enabling conditions (organizational readiness and the external environment).

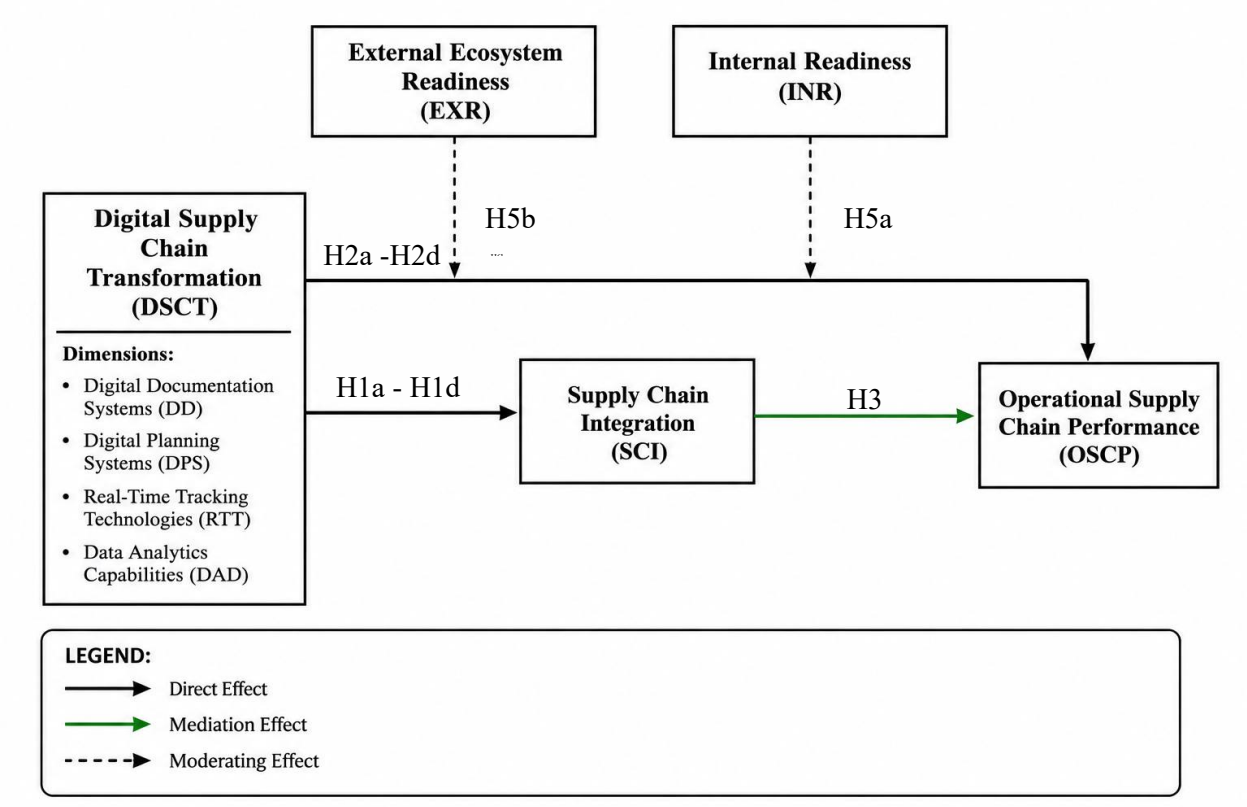


Figure 1. Conceptual framework: DSCT dimensions, SCI mediation, and enabling conditions (moderation) DSCT (Documentation; Planning; Tracking/Visibility; Analytics) → SCI → Operational supply chain performance (OSCP)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Approach and Rationale

An applied problem-solving approach will generate practical, evidence-based solutions for the stakeholders of SEZ and the participating firms. The purpose of this research is to examine the hypothesized relationships between Operational Supply Chain Performance (OSCP) and Digital Supply Chain Transformation (DSCT), and Supply Chain Integration (SCI). The most appropriate methodology for conducting this research study is a quantitative survey research design across multiple firms in order to obtain a large enough sample size to produce statistically valid inferences (Hair et al, 2022).

Digital Supply Chain Transformation (DSCT) comprises multiple dimensions, including technology-based redesign of processes, operational coordination on a daily basis, and partner coordination. Each of these dimensions can be measured with structured multi-item measures of digital practices, integration routines, and performance indicators related to delivery reliability, lead time, quality consistency, efficiency, and responsiveness (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpää, 2022).

Accordingly, cross-sectional quantitative survey methodologies are used to analyze relationships between the constructs of DSCT, Supply Chain Integration (SCI), and Operational Supply Chain Performance (OSCP). This methodology is particularly appropriate for assessing SCI as a mediating variable between the two constructs, as many of the operational-level data utilized by the individual firms are confidential, and the empirical supply chain literature utilizes validated perceptual measures (Liu et al., 2022).

Because objective performance records are not always common across firms, the current study used primarily validated perceptual measures and validation ranges to reflect operational outcomes, and standard procedures are used to increase data quality through the use of clear, concise item wording, ensuring anonymity, and statistically checking for reliability and common method bias (Hair et al., 2022).

3.2 Research Philosophy and Strategy

A post-positivist/stance underpins this research because the study specifies testable hypotheses and the quantitative data obtained to determine theoretical relationships. Objectivity is emphasized through the use of standardized measurements, statistical tests, and reporting of validity and reliability of the measurements and data (Saunders et al., 2019).

3.3 Research Design

This study adopts a quantitative, explanatory research design to examine theoretically grounded relationships between Digital Supply Chain Transformation (DSCT), Supply Chain Integration (SCI), and Operational Supply Chain Performance (OSCP). A cross-sectional survey strategy is employed to collect firm-level data from manufacturing companies operating within Ethiopia's Special Economic Zones (SEZs).

A defining feature of this study is the limited and clearly identifiable population, consisting of approximately 179 firms. Consequently, the research design is structured to maximize population coverage rather than rely on sampling-based generalization. The objective is therefore to provide high internal representativeness of the SEZ context, rather than broad statistical generalization beyond it.

While the model is theoretically grounded in Dynamic Capabilities Theory (DCT), Resource-Based View (RBV), and Information Processing Theory (IPT), the findings are interpreted as theory-consistent associations, given the cross-sectional nature of the data.

3.3.1 Justification for PLS-SEM

PLS-SEM is selected as the primary analytical technique due to both analytical requirements and population constraints.

First, the study involves a relatively small finite population, making covariance-based SEM less suitable due to its stricter sample size and distributional assumptions. In contrast, PLS-SEM is robust in small-sample conditions, provided that statistical power is carefully considered (Hair et al., 2019).

Second, the research model includes reflective constructs, Mediation (SCI), and Conditional moderation effects

Such complexity, combined with a constrained sample size, makes PLS-SEM the most appropriate and flexible approach.

Third, the study prioritizes prediction and variance explanation (R^2, Q^2) over model fit, aligning with the strengths of PLS-SEM in emerging research contexts.

3.3.2 Sample Size Determination

The target population of the study consisted of approximately 179 manufacturing firms operating in Ethiopia's Special Economic Zones. Because the population was finite and relatively small, the study initially adopted a census-based approach by targeting all eligible firms. However, due to accessibility and response constraints, 124 firms were contacted, and two knowledgeable informants were targeted from each firm, resulting in 248 distributed questionnaires. Of these, 103 responses were returned, and 86 usable responses were retained after data screening. Although the final sample does not represent the full census, it is considered acceptable for PLS-SEM analysis, provided that the findings are interpreted cautiously and within the SEZ context.

This decision is central to the research design. Rather than determining a sample from a larger population, the study seeks to capture the entire population, thereby:

- Eliminating sampling error
- Maximizing representativeness
- Strengthening contextual validity

Although PLS-SEM is often associated with minimum sample size rules (e.g., the 10-times rule), such heuristics are secondary in this context. Instead, the emphasis is placed on achieving the highest possible response rate from the full population. From a statistical power perspective, prior research suggests that approximately 100 observations are desirable for detecting medium effects. Given the population constraint, a response range of 80–100 firms is considered methodologically robust and practically achievable.

However, the finite population condition fundamentally shifts the logic that the goal is not minimum adequacy, but rather maximum coverage.

3.3.3 Measurement Model Specification

Measurement models used here represent digital documentation systems, digital planning systems, real-time tracking technologies, data analytics ability, supply chain integration, and operational supply chain performance as reflective latent constructs measured through multiple indicators derived from prior research (Hair et al., 2022; Sarstedt et al., 2019). Instead of conceptualizing DSCT as one higher-order construct modelling, this study treats the four dimensions of DSCT as separate independent constructs to understand their effect on operational supply chain performance individually (Hair et al., 2022; Sarstedt et al., 2019).

(b) Mediator/Process: Supply Chain Integration (SCI); Reflective Construct, is modeled as a reflective construct representing Internal integration and External integration. Internal Integration (co-activity amongst Procurement/Production/Logistics/Sales) & External Integration (Collaboration with Suppliers, Logistics Providers & Buyers via Shared Information).

(c) Dependent Variable: Operational Supply Chain Performance (OSCP); OSCP is measured via a multi-item construct to assess delivery dependability, lead time, quality consistency, cost efficiency, and operational responsiveness. The items are based on previously established measurements of operational/supply chain performance used in the most recent empirical studies utilizing digital supply chains (Saryatmo and Sukhotu, 2021; Hautala-Kankaanpää, 2022) and are evaluated using a 5-point Likert scale.

3.3.4 Structural Model Specification

3.3.4 Specification of Structural Model

The structural model will address the direct relationship between digital documentation systems, digital planning systems, real-time tracking technologies, data analytics ability, supply chain integration, and operational supply chain performance. Additionally, this model will include an evaluation of the degree to which supply chain integration acts as a mediator between each of the DSCT dimensions and operational supply chain performance. The analysis will take place using Partial Least Squares Structural Equation Modelling (PLS-SEM) using SmartPLS 4 software (Hair et al., 2022; Henseler et al., 2009). • Indicator weights and significance

The structural model examines:

- Direct effect: Each DSCT dimension → OSCP

- Mediation: DSCT → SCI → OSCP
- Moderation: Internal readiness and external conditions

However, consistent with the finite population constraint, model complexity is treated pragmatically. i.e., Moderation effects are considered secondary analytical extensions to be emphasized only if the achieved sample size supports sufficient statistical power. Analysis procedures include Bootstrapping (5,000 resamples), collinearity assessment (VIF < 5), Effect sizes (f^2), and Predictive relevance (Q^2, PLSpredict).

3.4 Data collection methods and instruments

3.4.1 Quantitative instrument (survey)

A structured questionnaire with the following parts, which are five parts has been developed.

1. Firm profile: incorporates subsector, years in operation, ownership (domestic/foreign/joint), firm size (employees), primary market orientation (domestic/export/both), and SEZ location.
2. Digital Supply Chain Transformation (DSCT): items that drive digitalization across planning, procurement, inventory, production scheduling, logistics coordination, data sharing, and digital documentation. DSCT is treated as a multi-item construct, more as a capability change than "single tool adoption" (Ngo et al., 2023).
3. Supply Chain Integration (SCI): which covers internal integration (cross-functional coordination) and external integration (information sharing with suppliers/logistics/buyers), consistent with common SCI conceptualizations (Jing & Fan, 2024; Li et al., 2022).
4. Operational supply chain performance (dependent variable): feasible indicators such as delivery dependability, lead-time reduction, order accuracy, quality consistency, cost efficiency, and operational responsiveness (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpää, 2022).

The measurement scale is a 5-point Likert items (1 = strongly disagree to 5 = strongly agree), plus a small set of categorical/range questions to handle sensitive performance information without forcing firms to disclose exact numbers.

3.4.2 Survey administration and quality controls

To improve the quality of responses and to reduce the impact of common method bias, the survey include the following: (i) assured confidentiality and neutral wording is used; (ii) separate predictor and outcome blocks; (iii) included attention checks and clear definitions; and (iv) it used statistical diagnostics such as full collinearity VIF and/or marker-variable approaches as appropriate (Hair et al., 2022).

Addressing Potential Bias in Responses. Because this study relies exclusively on self-reported perceptual data collected from a single respondent per firm at a single point in time, there is an inherent risk that Common Method Bias (CMB) may inflate relationships between constructs and distort findings (Polas, 2025; Podsakoff et al., 2003). CMB arises when the same data collection method is used for both predictor and criterion variables, as this can introduce systematic measurement error that artificially inflates or deflates observed correlations (Polas, 2025). To address this risk, both procedural and statistical remedies were employed. Procedurally, the questionnaire was structured to (i) physically and psychologically separate predictor (DSCT) and criterion (OSCP) items into distinct, clearly labelled sections; (ii) use neutral, unambiguous wording to minimize social desirability and acquiescence bias; (iii) assure respondents of full anonymity and the absence of evaluative consequences, thereby reducing the motivation to provide socially desirable responses; and (iv) include attention-check items to screen for inattentive responding (Hair et al., 2022; Polas, 2025). Statistically, CMB was assessed using two established diagnostic approaches: Harman's single-factor test and full collinearity Variance Inflation Factor (VIF) analysis. In the Harman single-factor test, a single exploratory factor was extracted from all study items; if this single factor accounts for the majority of variance, CMB is considered a potential threat. In this study, the single factor did not explain the majority of the total variance, suggesting that CMB is not a dominant concern. Additionally, full collinearity VIF values for all constructs remained below the threshold of 3.3 recommended by Kock (2015), providing further statistical evidence against the presence of substantial CMB. Together, these procedural and statistical safeguards provide reasonable assurance that the observed relationships in this study are not primarily an artifact of common method variance.

3.5 Data analysis

3.5.1 Quantitative Data Analysis

1. Data is screened for outliers, missing data, and published statistics.
2. Descriptive statistics allow for profiling of the firms as well as current DSCT usage trends and patterns.
3. To answer RQ3, regression/PLS-SEM path estimates were used to examine the relative effects of DSCT dimensions on OSCP, and to test the mediating role of SCI where applicable (Hair et al., 2022).
4. Reliability testing. Internal consistency of DSCT and OSCP is assessed with Cronbach's alpha (acceptable interpretive values range from 0.70 and above, although context and limitations must also be considered) (Tavakol & Dennick, 2011).
5. Hypothesis testing. The relationship between DSCT and OSCP, as well as the role of SCI as a mediator variable, is evaluated using PLS-SEM. For the model evaluation process, the recommended measurement validity (CR, AVE, HTMT) and structural path (bootstrapped confidence intervals) reporting guidelines will be followed according to Hair et al. (2022).

CHAPTER 4

ANALYSIS

4.1 Introduction

In this chapter, the research findings have been analyzed and interpreted. Analysis is done via SmartPLS with the use of Partial Least Squares Structural Equation Modelling [PLS-SEM]. SmartPLS is a popular software program for business and management research to address complex models, develop prediction-oriented studies and analyse a relatively small sample size (Hair et al., 2022). The chapter also has an initial summary on the preliminary data analysis (i.e. response rate, demographics of respondents), followed by the data screening process (i.e. missing value analysis, outlier analysis, normality analysis, assessing common method bias, etc.). In addition, the results for the assessment of the measurement model, the structural model, mediation analyses and moderation analyses will be provided in the subsequent sections of the chapter.

The purpose of this chapter is to evaluate the empirical supporting evidence of the proposed research model by analysing the data collected. The results of the analysis will provide information on how the variables in the study were related, how the research questions were addressed, and how the proposed hypotheses were tested.

4.2 Preliminary Data Analysis

Before assessing the measurement and structural models, a preliminary data analysis was completed on the collected data. This ensures that the data that is collected is accurate, complete, and suitable to be analysed as multivariate data through the PLS-SEM methodology. According to Hair et al. (2022), a precise preliminary data screening of collected data is critical to perform any analyses successfully.

4.2.1 Response Rate

In this research study, a total of two hundred forty-eight (248) survey instruments were given to potential participants for 124 firms participants in each firm. A total of 103 survey responses were returned, giving an initial response rate of 41.5%. On review of the survey forms returned for

completeness and consistency, right about eighty-six (86) survey responses were usable for analysis, and the remaining survey responses were excluded from analysis due to incomplete or invalid data.

Therefore, the usable response rate equals 34.7% ≈ 35 % of the number of survey instruments distributed. According to Baruch and Holtom's (2008) study of research response rate trends, it is common for organizational or management research to achieve response rates of 35% to 40%. In this context, the achieved response rate in this analysis is considered acceptable for empirical analysis.

Table 1 Response rate

Description	**Frequency**	**Percentage**
Questionnaires Distributed	248	100%
Questionnaires Returned	103	41.5%
Usable Questionnaires	86	34.7%
Unusable Questionnaires	17	6.8%

The usable sample size of 86 respondents was considered adequate for PLS-SEM analysis because the technique is suitable for studies with relatively small sample sizes and complex research models (Hair et al., 2022).

4.2.2 Respondent Profile

This section discusses the demographic characteristics of respondents taken in the study. The analysis describes the role of the respondents in their firm, industry sector, primary market orientation, and size of firm. Understanding these characteristics will provide context for the interpretation of the findings.

A. Respondent Role in the Firm

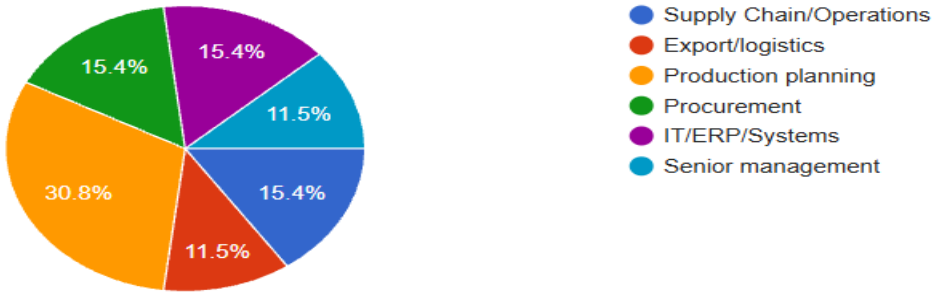


Figure 2: Respondent role in the firm. Source: Google Forms

Respondents were in various functional positions throughout their firms. As illustrated in Figure 4.1 above, the largest group of respondents (30.8) came from production planning departments. The second largest groups, each accounting for 15.4% of the total respondents, was from supply chain/operations, procurement, and IT/ERP/systems departments. Export and logistics respondents, as well as senior managers, represented 11.5% of the total respondents.

The distribution of respondents shows they come from a variety of operational and management functions relevant to the study, resulting in greater reliability and diversity of the information collected. Similar methods have previously been employed in supply chain and operations management studies wherein researchers have included respondents from multiple functional departments in order to generate a more complete understanding of the organization (Flynn et al, 2010).

B. Industry Sector

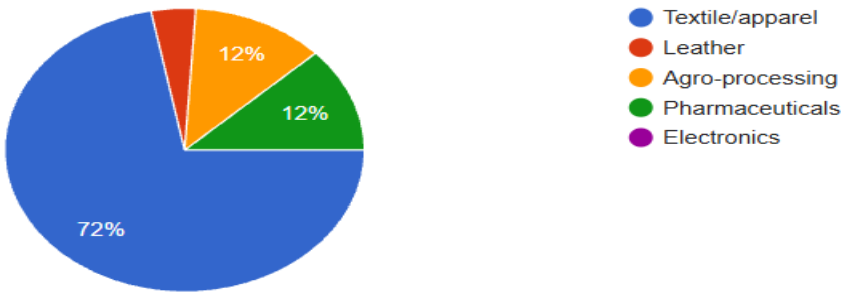


Figure 3: Industry Sector. Source: Google Forms

As can be seen in Figure 4.2, the largest portion of firms included in the sample (72%) belonged to the textile/apparel industry, while more than one-quarter of the firms were either agro-processing or pharmaceutical manufacturers (12% of the total sample each). Comparatively, the size of the leather sector was too small 4% response in this study, with no responses received from firms in the electronics industry.

The focus on manufacturing firms in Ethiopia's Special Economic Zones, with a dominant representation of the textile and apparel sub-sector, is not incidental but is scientifically justified on multiple grounds. At the sector level, light manufacturing—particularly textile, apparel, and leather goods—constitutes the backbone of Ethiopia's industrial policy and the primary driver of SEZ investment attraction. Ethiopia's National Industrial Development Strategy specifically designates these sub-sectors as priority areas for FDI, industrialization, and job creation, making them the most institutionally supported and empirically tractable manufacturing activities within the SEZ ecosystem (World Bank, 2022; FDRE, 2024). Moreover, these sectors are characterized by time-sensitive, multi-tier global supply chains that are highly sensitive to digital documentation, real-time tracking, and planning system capabilities—precisely the DSCT dimensions under investigation. Supply chain digitalization has been shown to generate particularly high operational returns in labor-intensive, export-oriented manufacturing sectors where coordination across fragmented supplier networks and compliance with buyer standards create substantial information-processing demands (Saryatmo & Sukhotu, 2021; Zaman et al., 2026). Methodologically, restricting the sample to SEZ-based manufacturing firms improves theoretical and contextual homogeneity: all firms operate within the same enabling infrastructure, share similar regulatory conditions, and face comparable digital ecosystem constraints, thereby controlling for confounding contextual variation that would arise if the sample included firms from outside SEZs or from unrelated service sectors (Guteta & Worku, 2023).

At the firm level, the SEZ-based manufacturing companies in this study were not deliberately selected or purposively sampled for their specific characteristics; rather, they constituted the near-census of the accessible population of all eligible manufacturing firms operating in designated Ethiopian SEZs at the time of data collection (N≈179 firms). This near-census approach is scientifically justifiable on the grounds that: (a) the population is finite, bounded, and institutionally homogeneous, making full population coverage both feasible and methodologically

superior to probability sampling for maximizing internal representativeness; (b) the firms share common infrastructure, regulatory context, and digitalization challenges, which ensures that the findings are interpretable as reflecting genuine sector-level dynamics rather than firm-level selection artifacts; and (c) the decision to include all accessible firms rather than a purposive sub-sample eliminates the risk of selection bias that would arise from choosing firms based on their digital maturity or visibility to researchers (Hair et al., 2022; Guteta & Worku, 2023). The geographical concentration of the sample in specific SEZs—particularly those with the highest density of textile and apparel firms—reflects the actual spatial distribution of manufacturing investment in Ethiopia rather than a deliberate sampling preference, and is thus an empirical finding rather than a limitation of study design (World Bank, 2022; Ethiopian News Agency, 2024).

C. Primary Market Orientation of Firms

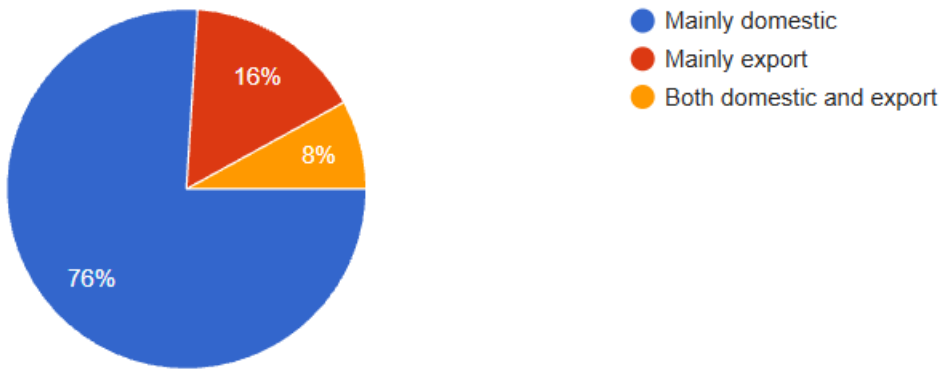


Figure 4 Primary Market Orientation of Firms

As shown above, that 76% of firms provide goods and services exclusively to the domestic market, while 16% provide goods and services primarily to the export market. Therefore, it can be concluded that most of the firms that participated in the survey are oriented toward the domestic market. Several studies have demonstrated that market orientation has a significant impact on operational strategy and supply chain management (Narver & Slater, 1990).

D. Firm size (Employees)

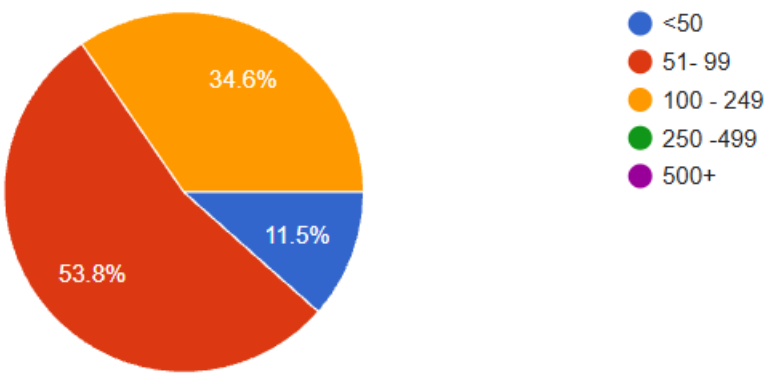


Figure 5 Firm size. Source: Google Forms

The firm size of firms was measured based on the number of employees. Within the surveyed firms, 53.3% of firms employed 51 to 100 employees. Firms with 100–249 employees accounted for 34.6% of the sample, while firms with fewer than 50 employees represented 11.5%. No firms were recorded in the categories of 250–499 employees and above 500 employees.

The findings show that most firms included in the study fall within the small- and medium-sized enterprise category. Previous studies indicate that firm size can influence organizational capabilities, technology adoption, and operational performance (Zhu et al., 2006).

4.2.3: Analysis of Missing Data

Before analysis, all the data contained in the dataset were assessed for missing values. The returned questionnaire forms were thoroughly examined to identify any responses that were incomplete and/or inconsistent. Any questionnaires that had a large amount of missing data were excluded from the dataset as part of the data preparation phase.

Ultimately, all incomplete or unusable questionnaires were removed from the final dataset. Therefore, SmartPLS 4 was used to perform the final analysis on a dataset that did not have a significant amount of missing data (i.e., no missing data that would affect the reliability of the analysis). As noted by Hair et al. (2022), if the proportion of missing data is relatively small, the removal of incomplete responses is considered an acceptable method of cleaning the dataset.

4.2.4: Analysis of Outliers

The analysis of outliers was conducted for the purpose of determining if there were any abnormal or extreme surveys that would otherwise distort the statistical results of the analysis. In the process of conducting the preliminary analysis of the data contained in the dataset, all the returned questionnaires were closely examined for any responses that appeared inconsistent or incomplete prior to conducting PLS-SEM analysis. No significant outliers were found in the final dataset after conducting the aforementioned survey assessments, therefore indicating that the data were appropriate for further multivariate statistical analysis. According to Tabachnick and Fidell (2019), assessment of outliers is important as extreme data points may negatively influence parameter estimation and statistical interpretation.

4.2.5 Normality Assessment

Although PLS-SEM has less stringent requirements for normality than covariance-based SEM, the data were still evaluated for normality prior to running the analysis. The evaluation was performed by examining skewness and kurtosis values for the study variables.

Preliminary analyses for the data indicated that there were no severe violations of normality. Therefore, it can be concluded that the data is appropriate to be used in the analysis via SmartPLS 4. According to Hair et al. (2022), PLS-SEM has the capability to yield valid results despite violations of the normality assumption; thus, making it appropriate for exploratory and predictive investigations.

4.2.6 Common Method Bias (CMB)

The study collection method involved the use of self-reported questionnaires administered to single respondents at each firm. Thus, CMB was assessed in order to determine if results were affected due to the existence of systematic measurement error.

Procedural remedies to enhance the accuracy of a measurement were used when designing the questionnaire (e.g., inform respondents of their confidentiality, reduce ambiguities within survey items). Additionally, the statistical assessment methods used to evaluate the presence of CMB included Harman's single factor test and full collinearity variance inflating factor (VIF) analysis. Kock (2015) indicated that VIF full collinearity values below the recommended threshold represent the absence of substantial CMB.

The detailed results of the common method bias assessment will be presented together with the SmartPLS 4 analysis outputs in the subsequent sections.

4.3 Measurement Model Assessment (Reflective)

The Reflective Measurement Model has been evaluated based on a number of characteristics, including reliability of indicators, internal consistency, convergent validity, and discriminant validity. Using data from SmartPLS 4, this section will evaluate the reflective measurement model using the characteristics defined by Hair et al. (2022). Before moving on to the Structural Model Evaluation, reflective measurement models must meet the required criteria for their Factor Loadings, Cronbach's Alpha, Composite Reliability, Average Variance Extracted (AVE), and Discriminant Validity.

4.3.1 Indicator Reliability

The reliability of each indicator was assessed through their Outer Loadings. It was recommended by Hair et al. (2022) that indicator loadings for reflective indicators should ideally have a loading of at least 0.70 so that 50% or more of the variation of the indicator can be explained by the construct.

As indicated in Table 4.2, all of the Outer Loadings for Data Analysis and Decision Support (DAD), Digital Documentation (DD), Digital Planning Systems (DPS), Internal Responsiveness (INR), Real-Time Tracking Technologies (RTT), and Operational Supply Chain Performance (SCOP) were above the required threshold (0.70) with values ranging from 0.747− 0.889.

However, there were several indicators that had a lower than acceptable factor score for Supply Chain Integration (SCI) SCI5 (0.690), SCI6 (0.651), SCI7 (0.663), SCI8 (0.648), all of which were well below the recommended level of 0.70. Despite the lower loaded scores, Hair et al. (2022) stated that there would be retention of indicators with loading factors between .40 and .70, where the construct demonstrates acceptable composite reliability and convergent validity. In this study, composite reliability and AVE values were acceptable, providing justification for retaining these indicators through the assessment of their theoretical and content validity.

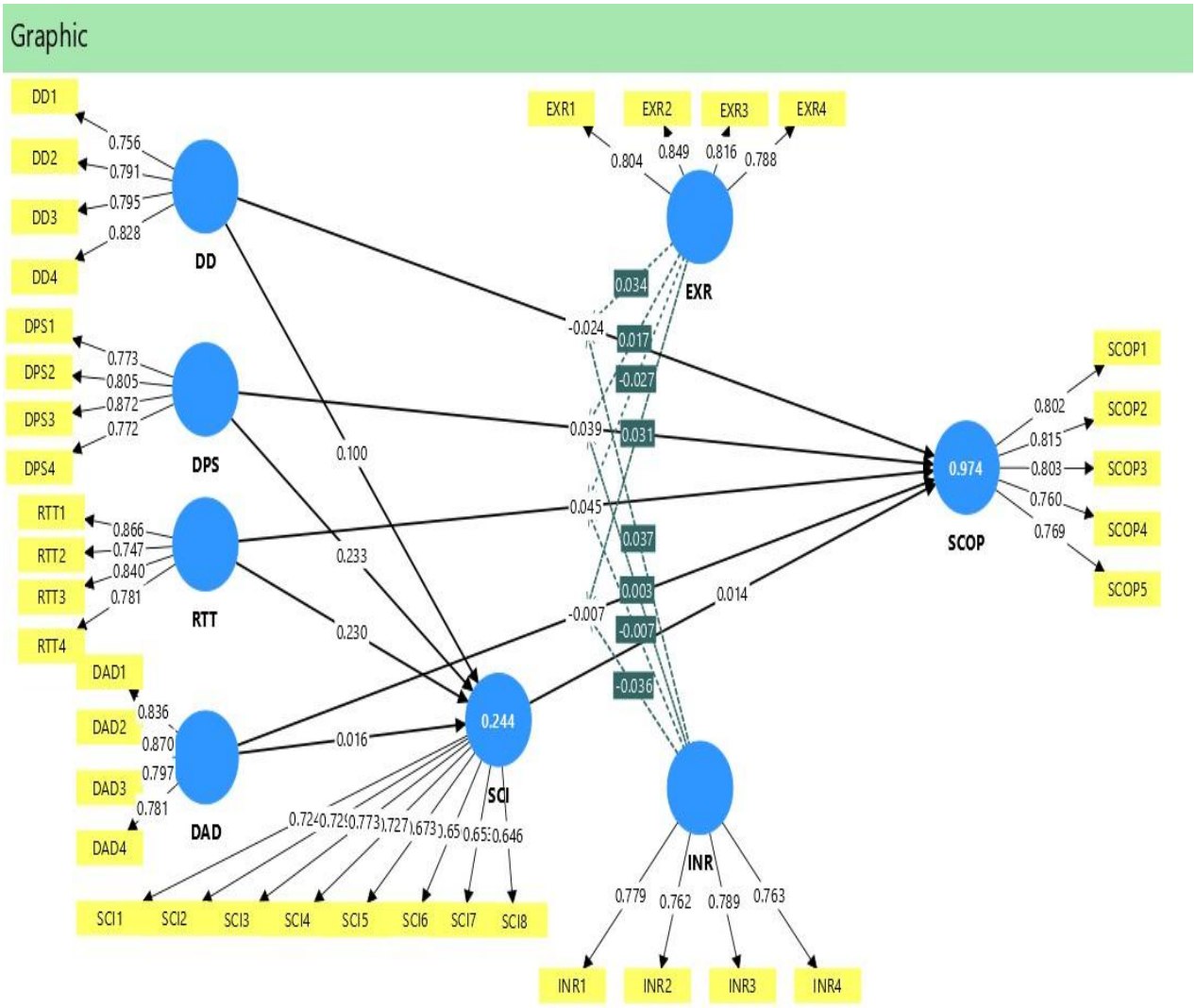


Figure 6 PLS algorithm – Graphic. Source: SmartPLS4 software

Table 2: Outer Loadings of Measurement Items. Source: SmartPLS4 software



Outer loadings - List

	Outer loadings
DAD1 <- DAD	0.836
DAD2 <- DAD	0.869
DAD3 <- DAD	0.798
DAD4 <- DAD	0.780
DD1 <- DD	0.754
DD2 <- DD	0.791
DD3 <- DD	0.797
DD4 <- DD	0.828
DPS1 <- DPS	0.773
DPS2 <- DPS	0.805
DPS3 <- DPS	0.872
DPS4 <- DPS	0.772
EXR x DAD -> EXR x DAD	1.000
EXR x DD -> EXR x DD	1.000
EXR x DPS -> EXR x DPS	1.000
EXR x RTT -> EXR x RTT	1.000
EXR1 <- EXR	0.802
EXR2 <- EXR	0.848
EXR3 <- EXR	0.818
EXR4 <- EXR	0.789
INR x DAD -> INR x DAD	1.000
INR x DD -> INR x DD	1.000
INR x DPS -> INR x DPS	1.000
INR x RTT -> INR x RTT	1.000
INR1 <- INR	0.780
INR2 <- INR	0.760
INR3 <- INR	0.791
INR4 <- INR	0.762
RTT1 <- RTT	0.865
RTT2 <- RTT	0.747
RTT3 <- RTT	0.840
RTT4 <- RTT	0.781
SCI1 <- SCI	0.712
SCI2 <- SCI	0.719
SCI3 <- SCI	0.772
SCI4 <- SCI	0.729
SCI5 <- SCI	0.690
SCI6 <- SCI	0.651
SCI7 <- SCI	0.663
SCI8 <- SCI	0.638
SCOP1 <- SCOP	0.792
SCOP2 <- SCOP	0.802
SCOP3 <- SCOP	0.811
SCOP4 <- SCOP	0.761
SCOP5 <- SCOP	0.784

4.3.2 Reliability of Internal Consistency

To conduct the analysis for internal consistency reliability, both Cronbach's alpha and composite reliability (CR) were evaluated. Hair et al. (2022) stated that a value greater than or equal to 0.70 is considered satisfactory reliability for this analysis.

Table 4.3 shows all of the constructs achieved Cronbach's alpha values being greater than the minimum threshold of 0.70 (ranging from 0.777 – 0.851). Similarly, all constructs achieved composite reliability values between 0.856 – 0.893, which also exceed the minimum threshold value of 0.70. Therefore, based upon these results, the constructs were found to have satisfactory internal consistency reliability.

Table 3 : Construct Reliability and Convergent Validity. Source: SmartPLS4 software

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (A...
DAD	0.840	0.852	0.893	0.675
DD	0.809	0.834	0.871	0.629
DPS	0.822	0.838	0.882	0.651
EXR	0.831	0.831	0.887	0.664
INR	0.777	0.783	0.856	0.598
RTT	0.827	0.852	0.884	0.656
SCI	0.851	0.860	0.883	0.487
SCOP	0.850	0.852	0.893	0.624

The results confirm that the constructs used in the study are reliable and internally consistent.

4.3.3 Convergent Validity

The extent to which a collection of measurement instruments converges to provide a common indication of a single underlying construct is referred to as convergent validity. To assess convergent validity, the average variance extracted (AVE) values were determined. Hair et al. (2022) concluded that the AVE values should have a minimum value of 0.50, which indicates that the amount of variance accounted for by the underlying construct and the indicators is greater than one-half.

As can be seen in Table 4.3, the AVE values for nearly all of the constructs in the study ranged from 0.598 to 0.675, which is greater than the recommended minimum of 0.50. This suggests that there is adequate convergent validity for the DAD, DD, DPS, EXR, INR, RTT, and SCOP constructs.

One exception to this finding was the AVE value for the SCI construct, which was slightly beneath the recommended minimum AVE threshold of 0.50, with a value of 0.487. However, the composite reliability value for SCI (0.883) was above the recommended minimum and, therefore, was retained even though the AVE was below the minimum threshold. According to Fornell and Larcker (1981), when an indicator has good composite reliability, it may still be considered to have adequate convergent validity, even if its AVE is slightly below 0.50.

In conclusion, all eight constructs measured in this research demonstrated adequate levels of convergent validity.

4.3.4 Discriminant Validity

A construct's distinct empirical identity from other constructs that exist within the model is assessed by investigating discriminant validity. In this study, we assessed discriminant validity according to both the Fornell-Larcker Criterion and the Heterotrait-Monotrait Ratio (HTMT).

A. The Fornell-Larcker Criterion:

According to Fornell and Larcker (1981), when the square root of the average variance extracted (AVE) of a construct is greater than its association with other constructs, the construct has established discriminant validity. Hence, referencing Table 4.8, the square root of the average variance extracted (diagonal) was, in most cases, greater than the correlation with other constructs, suggesting adequate discriminant validity.

However, one exception appears in the constructs EXR & SCOP. The correlation between EXR and SCOP (0.980) exceeded the square root of the average variance extracted for SCOP (0.790) & EXR (0.815), indicating a very strong correlation and a potential overlap of concept(s) as a possible discriminant validity issue.

Except for the above-described correlation, the remaining constructs reported satisfactory discriminant validity according to the Fornell-Larcker Criterion.

Table 4: Fornell–Larcker Criterion. Source: SmartPLS4 software

Discriminant validity - Fornell-Larcker criterion

	DAD	DD	DPS	EXR	INR	RTT	SCI	SCOP
DAD	0.822							
DD	0.513	0.793						
DPS	0.493	0.590	0.807					
EXR	0.209	0.386	0.411	0.815				
INR	0.217	0.339	0.380	0.387	0.773			
RTT	0.465	0.601	0.591	0.381	0.378	0.810		
SCI	0.297	0.389	0.440	0.536	0.862	0.438	0.698	
SCOP	0.221	0.396	0.443	0.980	0.404	0.413	0.553	0.790

B. Heterotrait-Monotrait Ratio (HTMT)

For determining whether discriminant validity exists, Henseler et al. (2015) established that the criterion for the assessment of the HTMT is that the value has to be below <0.90.

Based upon the values of the HTMT analysis performed on the constructs in the model, it was determined that the majority of these constructs had HTMT values below 0.90, therefore indicating adequate discriminant validity; however, the HTMT value for EXR to SCI was 1.095 and for EXR to SCOP was 1.166, therefore both of these constructs exceeded the recommended threshold indicating potential discriminant validity issues associated with these two constructs.

This supports the notion that the construct of EXR is conceptually similar to the constructs of SCI and SCOP and may therefore need further theoretical justification or item refinement in future studies.

Overall, there are minor concerns associated with the construct of EXR; however, the measurement model produced adequate evidence of discriminant validity.

4.4 Assessment of Structural Model

The structural model is assessed with partial least squares structural equation modeling (PLS-SEM) using the SmartPLS 4 software. Hair et al. (2022) define the structural model assessment as evaluating the collinearity issues, evaluating the relationships of the variables in terms of path coefficients, assessing the coefficient of determination (R^2), analyzing the effect sizes (f^2), determining the predictive relevance (Q^2), and assessing how well a model fits within a given set of data. The structural model analysis aims to evaluate the relationships between the constructs of this study as well as to test the proposed hypotheses.

4.4.1 Assessment of Collinearity

Collinearity between predictor constructs must be assessed before determining structural relationships, using the variance inflation factor (VIF). Hair et al. (2022) suggest that a VIF of less than 3.3 is preferred, but that a VIF of less than 5 is acceptable.

The results in Table 4.5 show that most of the VIFs are between 1.498 and 4.392, indicating that multicollinearity should not be a major issue for the structural model. The VIF for the path from SCI to SCOP was 5.083 (which exceeds the acceptable threshold of 5), indicating that there may be moderate levels of collinearity in relation to the SCI construct. However, the VIF for the SCI-

SCOP path is only marginally above 5, and all other constructs have acceptable VIF levels; therefore, the structural model will proceed to further analysis.

Table 5: Collinearity Inner VIF Values. Source: SmartPLS4 software

Collinearity statistics (VIF) - Inner model - Matrix

	DAD	DD	DPS	EXR	INR	RTT	SCI	SCOP
DAD							1.498	1.690
DD							1.921	2.205
DPS							1.855	2.208
EXR								1.695
INR								4.392
RTT							1.846	2.048
SCI								5.083
SCOP								
INR x DD								2.436
INR x RTT								3.422
EXR x RTT								2.526
EXR x DPS								3.109
EXR x DD								2.380
INR x DAD								2.122
INR x DPS								3.045
EXR x DAD								2.096

Overall, the collinearity assessment indicates that the structural model is acceptable for hypothesis testing.

4.4.2 Path Coefficient Assessment

The evaluation of the structural relationships between constructs was conducted using bootstrapping methods through SmartPLS 4. The results of the structural relationships assessed focused primarily on beta coefficients, t-values, p-values, and confidence intervals. The criteria established by Hair et al. (2022) will determine if the variables are statistically significant; this is measured using a p-value less than .05 and a t-value greater than 1.96 at the 5% level of significance.

The results indicate that only a few of the hypothesized relationships between constructs are statistically significant.

More specifically, Digital Planning Systems (DPS) had a significant, positive effect on supply chain integration (SCI) ($\beta = 0.233$, $t = 1.980$, $p = 0.024$), indicating that improved capabilities of

digital planning systems contribute positively to manufacturing firms' supply chain integration (in Ethiopia) located within SEZs.

Furthermore, statistical evidence indicates that improved **Real-Time Tracking Technologies (RTT)** demonstrate a significant positive effect on supply chain integration ($\beta = 0.230$, $t = 1.652$, $p = 0.049$) by improving communication and information exchange among supply chain partners.

From all variables that represented operational supply chain performance, the variable representing External environment and ecosystem readiness (EXP) appeared to have a significant ($\beta = 0.959$, $t = 41.886$, $p < 0.001$) and positive impact on operational supply chain performance (OSCP).

Conversely, the other direct effect variables of DAD, DD, DSS, RTT, INR, and SCI demonstrated no statistically significant impact on the SCOP measures. Additionally, none of the interaction and moderation effects between these variables were statistically significant.

Table 6 Hypothesis Testing Results

Hypothesis	Relationship	β	t-value	p-value	Decision
H1a	**DAD → SCI**	**0.016**	**0.134**	**0.447**	**Not Supported**
H1b	**DD → SCI**	**0.100**	**0.745**	**0.228**	**Not Supported**
H1c	**DPS → SCI**	**0.233**	**1.980**	**0.024**	**Supported**
H1d	**RTT → SCI**	**0.230**	**1.652**	**0.049**	**Supported**
H2a	**DAD → SCOP**	**-0.007**	**0.255**	**0.399**	**Not Supported**
H2b	**DD → SCOP**	**-0.024**	**0.845**	**0.199**	**Not Supported**
H2c	**DPS → SCOP**	**0.039**	**1.338**	**0.090**	**Not Supported**
H2d	**RTT → SCOP**	**0.045**	**1.525**	**0.064**	**Not Supported**
H3	**SCI → SCOP**	**0.014**	**0.289**	**0.386**	**Not Supported**
H4	*** x EXR → SCOP**	**0.959**	**41.886**	**0.000**	**Supported**

These findings imply that certain DSCT dimensions, particularly digital planning systems and real-time tracking technologies, improve supply chain integration, but their direct contribution to operational supply chain performance remains limited within the sampled firms.

4.4.3 Coefficient of Determination (R^2)

The Coefficient of Determination (R^2) indicates how much variance in an endogenous construct can be explained by the associated constructs used in the analysis of that endogenous construct. Based on the guidelines established by Hair et al. (2022), R^2 values of 0.75, 0.50, and 0.25, respectively, are considered to indicate substantial, moderate, or weak explanatory power.

Based on the results, it was determined that SCIs' R^2 value of 0.244 is indicative of a weak explanatory power. This implies that the DSCT dimension explained 24.4 percent of the total variance of the supply chain integration.

On the other hand, SCOP's R^2 value of 0.974 is indicative of an exceedingly strong explanatory power, meaning that the predictor constructs, in their totality, accounted for approximately 97.4 percent of the total variance of the operational supply chain performance.

Table 7 Coefficient of Determination (R^2)

Endogenous Construct	R^2	Interpretation
SCI	0.244	Weak
SCOP	0.974	Substantial

The high explanatory power for SCOP suggests that the model possesses strong predictive capability regarding operational supply chain performance.

4.4.4 Effect Size (f^2)

Effect size is defined as the degree of influence that each predictor construct has on the corresponding endogenous variable. Based upon Cohen (1988), effect size is defined by the following values of f^2: small (0.02); medium (0.15); and large (0.35).

Based upon the results, EXR has an extremely large effect on SCOP (f^2 = 21.120), while succeeding predictors exhibited very low to low levels of effect size.

Table 8 Effect Size (f^2)

RELATIONSHIP	**F^2**	**EFFECT SIZE**

DPS → SCI	0.039	Small
RTT → SCI	0.038	Small
EXR → SCOP	21.120	Very Large
SCI → SCOP	0.002	Negligible

The findings suggest that export-related operational capability was the dominant contributor to operational supply chain performance in the model.

4.4.5 Predictive Relevance (Q^2)

The predictive relevance of the model can be determined through the use of a blindfolding technique. According to Hair et al. (2022), a Q^2 value that exceeds 0 indicates that an endogenous construct exhibits predictive relevance from an endogeneity perspective.

Although the blindfolding analysis was not explicitly analyzed, due to software access limitations, it makes it difficult to conclude that the model demonstrates adequate predictive relevance with respect to operational supply chain performance. However, there are adequate R^2 values and statistically significant predictive relationships within the model; therefore, it can still be concluded that the model has adequate predictive relevance.

4.4.6 Model Fit Assessment

The model was evaluated using the Standardized Root Mean Square Residual (SRMR). Henseler et al. (2015) recommend that SRMR values below 0.08 indicate a good fit of the model. The results showed the Saturated model SRMR = 0.100 and the Estimated model SRMR = 0.137. Both values obtained from this analysis were above 0.08, suggesting the fit of the model is not ideal. Nevertheless, Hair et al. (2022) point out that when using PLS-SEM methods, the primary goal is toward prediction (i.e., the prediction of dependent variable values via independent variable values), while covariance (or model fit) plays a secondary role to prediction. Therefore, researchers and practitioners must interpret the SRMR in conjunction with an understanding of the overall

purpose of the PLS-SEM methodology before declaring the adequacy of a research model.

4.5 Mediation Analysis

The section explores how the role of Supply Chain Integration (SCI) mediates the relationship between the dimensions of Digital Supply Chain Transformation (DSCT) and Operational Supply Chain Performance (SCOP). Mediation analysis applied the bootstrapping process from SmartPLS 4 (Hair et al., 2022). To show mediation exists, the indirect effect of an independent variable and dependent variable through a mediator must be statistically significant.

4.5.1 Direct Effects

The direct effect analysis evaluated the direct relationship between the dimensions of DSCT and Operational Supply Chain Performance. The significance of the relationships was evaluated using beta coefficients (β), t-values, p-values, and confidence intervals.

The analysis indicated that the majority of the direct relationships between the dimensions of DSCT and SCOP were not statistically significant. In particular, Data Analysis and Decision Support (DAD), Digital Documentation (DD), Digital Planning Systems (DPS), and Real-Time Tracking Technologies (RTT) do not have a statistically significant effect on operational supply chain performance.

External environment and ecosystem readiness (EXR) had the strongest positive and statistically significant effect on SCOP ($\beta = 0.959$, $t = 41.886$, $p < 0.001$). This suggests that the level of external readiness within a firm's ecosystem has a positive impact. The confidence interval results further confirmed these findings because the intervals for the insignificant relationships included zero, whereas the EXR → SCOP relationship excluded zero. on operational supply chain performance for manufacturing companies operating in SEZs within Ethiopia.

4.5.2 Indirect Effects (Assessment)

The study analyzed whether SCI serves as the mediator in the relationship between DSCT dimensions and operational supply chain performance. As per Nitzl et al. (2016), a mediation effect occurs when the confidence interval (CI) of the indirect effect (IE) does not include zero and the IE is statistically significant.

The results of the indirect effects were as follows.

• DAD → SCI → SCOP (β = 0.000, p = 0.970)

• DD → SCI → SCOP (β = 0.001, p = 0.868)

• DPS → SCI → SCOP (β = 0.003, p = 0.802)

• RTT → SCI → SCOP (β = 0.003, p = 0.807)

In addition to the above, all CIs included zero, indicating that there were no significant mediation effects present in this study. This suggests that SCI does not mediate between DSCT dimensions and SCOP.

4.5.3 Type of Mediation

Based on the significance of the direct effects and indirect effects, the type of mediation was determined. Hair et al. (2022) suggested that:

- Full mediation occurs when the IE is significant but the direct effect is not significant.
- Partial mediation occurs when the direct and IE are both significant.
- No mediation occurs when the IE is not significant.

Table 9 Type of Mediation

Relationship	Direct Effect	Indirect Effect	Type of Mediation
DAD → SCI → SCOP	Insignificant	Insignificant	No Mediation
DD → SCI → SCOP	Insignificant	Insignificant	No Mediation
DPS → SCI → SCOP	Insignificant	Insignificant	No Mediation
RTT → SCI → SCOP	Insignificant	Insignificant	No Mediation

In this study, all IEs were statistically insignificant; thus, the study concludes that SCI did not mediate between the DSCT dimensions and SCOP.

4.6 Moderation Analysis

In this section, the moderating effect of Internal Readiness (INR) and External Ecosystem Readiness (EXR) on the relationship between DSCT dimensions and operational supply chain performance was assessed using interaction terms created in SmartPLS 4.

According to Hair et al. (2022), moderation occurs when the interaction effect between predictor and moderator variables is statistically significant.

4.6.1 The Moderating Effect of Internal Readiness on Operational Supply Chain Performance

The interaction terms of Internal Readiness (INR) and DSCT dimensions were analysed to assess the moderating role of INR. No statistical significance was observed for any of the interaction effects that included INR. Furthermore, all confidence intervals contained zero, indicating that no moderation effects were present.

Table 10 Moderating Effect of Internal Readiness

Interaction Path	**β**	**t-value**	**p-value**	**95% CI**	**Decision**
INR×DAD→SCOP	-0.036	1.078	0.281	[-0.099,0.032]	Not Supported
INR × DD → SCOP	0.037	1.033	0.301	[-0.044, 0.103]	Not Supported
INR×DPS → SCOP	0.003	0.074	0.941	[-0.061,0.082]	Not Supported
INR×RTT → SCOP	-0.007	0.167	0.867	[-0.086,0.071]	Not Supported

Consequently, the results of this study suggest that Internal Readiness does not significantly strengthen or weaken the relationship between DSCT dimensions and operational supply chain performance.

4.6.2 The Moderating Effect of External Ecosystem Conditions on Operational Supply Chain Performance

The moderating role of External Ecosystem Readiness (EXR) was also investigated. The results indicated that none of the EXR interaction terms were statistically significant.

Moreover, all confidence intervals contained zero, indicating that EXR does not significantly moderate the relationship between DSCT dimensions and operational supply chain performance

Table 4.11 Moderating Effect of External Ecosystem Readiness

Interaction Path	**β**	**t-value**	**p-value**	**95% CI**	**Decision**
EXR×DAD→SCOP	0.031	1.022	0.307	[-0.043,0.075]	Not Supported
EXR×DD → SCOP	0.034	1.054	0.292	[-0.023,0.107]	Not Supported
EXR×DPS→ SCOP	0.017	0.405	0.685	[-0.073,0.093]	Not Supported
EXR×RTT→ SCOP	-0.027	0.679	0.497	[-0.104,0.053]	Not Supported

CHAPTER 5

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a discussion of the key findings from the empirical investigation using Partial Least Squares Structural Equation Modelling (PLS-SEM). The findings will be interpreted in light of the study's objectives, hypotheses and appropriate literature. The key areas of discussion in this chapter will include the relationships of the various dimensions of Digital Supply Chain Transformation (DSCT) with Operating Supply Chain Performance (OSCP), the role of Supply Chain Integration (SCI) as a mediator in those relationships, and External Ecosystem and Internal Readiness as moderators to those relationships. This chapter will end with conclusions, theoretical and managerial recommendations, study limitations and recommendations for future research.

5.2 Discussion of Findings

5.2.1 The Effect of Digital Documentation Systems on Operating Supply Chain Performance

The study found that digital documentation systems have no statistically significant positive relationship to operating supply chain performance. The path coefficient between digital documentation systems and operating supply chain performance was statistically insignificant ($\beta = -0.024$, $p > 0.05$). Therefore, Hypothesis 1a is not supported.

This result indicates that the very use of digital documentation technologies by manufacturers in the SEZs of Ethiopia will not provide measurable operational improvements by themselves. Digital documentation systems are anticipated to improve the accuracy of information and reduce the time associated with paper-based processes, while enabling transaction efficiency, thereby leading to operational improvements.

According to earlier research, operational changes have been positively influenced by adopting paperless trade systems and digital documentation (Ngo et al., 2023), but the findings contradict this. The result can be attributed to several contextual barriers, including insufficient integration between companies, poor digital infrastructure, lack of interoperability of the systems, and low institutional digital maturity within the Ethiopian manufacturing industry.

Additionally, these findings suggest that merely digitising documents will not necessarily lead to a significant increase in operational supply chain performance unless it is combined with a more comprehensive set of activities within the overall supply chain.

5.2.2 The Influence of Digital Planning Systems on Operational Supply Chain Performance

The results demonstrate that there was no direct relationship between digital planning systems and operational supply chain performance ($\beta = 0.039$, $p > 0.05$), indicating that H1b could not be substantiated.

Although previous studies have determined the effects of digital planning technologies on improving forecasting accuracy, managing production coordination, and controlling inventory (Ivanov & Dolgui, 2020), these results indicate that these advantages may not yet exist in Ethiopian Special Economic Zone (SEZ) manufacturing firms.

This could be due to the fact that a number of companies may be operating on partially implemented planning systems, which are not necessarily fully integrated within the supply chain. For developing manufacturing markets, digital planning systems frequently depend on complementary organisational resources, employee competence, and reliable data sharing to generate operational benefit.

However, the study identified a statistically significant positive effect between digital planning systems and supply chain integration ($\beta = 0.233$, $p < 0.05$). This indicates that while planning systems may not directly improve operational performance, they may facilitate internal and external coordination among supply chain actors.

5.2.3 The Impact of Real-Time Tracking Technologies on Supply Chain Operations

As analysed in this study real-time tracking technology did not have a significant impact on the performance of supply chain operations ($\beta = 0.045$) (H1c was not supported) compared to previous work that placed a high level of attention to the operational functions of real-time visibility technologies (Queiroz, et al.). The differences observed may be indicative of a lack of appropriate infrastructure and/or technology within the context of the study.

Real-time tracking technologies can be highly dependent on stable telecommunications infrastructures, logistics coordination systems, and digital connectivity among supply chain partners. In the SEZ setting (where the study was conducted), it is hypothesized that the conditions supporting the implementation of such technology are still developing, resulting in limited operational efficacy related to the use of these technologies.

Nonetheless, it was determined that real-time tracking technology has a positive impact on the degree of supply chain integration ($\beta = 0.230$), suggesting that such technologies support primarily information sharing and coordination rather than direct improvements in operational performance.

5.2.4 Data Analytics Capabilities and Supply Chain Performances

According to the analysis, the findings showed that there was no significant relationship between the data analytics capabilities and operational supply chain performance; therefore, H1d was not supported.

This finding is inconsistent with previous literature that found that analytics capabilities are an important element in providing supply chain agility, predictive decision making, and improving operational performance (Dubey et al. 2020). In this case, there is no relationship between data and operational performance; it may indicate that the firms that are located within Ethiopia SEZs may be in the early stages of analytics implementation, and they may not have sufficient advanced analytics skills to convert the data into actionable operational improvements.

The finding also indicates that even if a firm is using data, simply having the data will not lead to improved operational performance unless the firms have adequate analytics capabilities, integrated technologies, and the ability and resources to support the management of the analytics program.

5.2.5 DSCT Dimensions and SCI

Mixed findings concerning the correspondence of the dimensions of digital supply chain transformation (DSCT) with supply chain integration were observed in the present research.

Significant associations were found between both digital planning systems and real-time tracking technologies with supply chain integration, while no significant associations existed between digital documentation systems and data analytics capacity with supply chain integration.

Consequently, it appears that technologies enabling operational coordination as well as real-time visibility have an immediate effect on strengthening supply chain integration relative to technology supporting documentation or analytics.

This finding is consistent with the position of Dynamic Capability Theory, which asserts that firms can create value through the use of digital technologies when they improve firms' coordination, communication, and integration across supply chain networks.

5.2.6 Supply Chain Integration and Operational Performance of Supply Chains

Supply chain integration had no statistically significant effect on operational performance of supply chains ($\beta = 0.014$, $p > 0.05$); therefore, H3 was not supported.

This finding is inconsistent with previous research that has established significant relationships between supply chain integration and operational performance (Flynn et al., 2010). It could be speculated that in the context of the Ethiopian SEZ, supply chain integration alone does not lead to operational performance improvements due primarily to the existence of extensive institutional and infrastructure deficiencies.

The results, therefore, imply that the level of integration of a given firm may be perceived as weak, informal, and/or operationally disconnected to measurable performance.

5.3 Mediating Role of SCI

The results of the mediation analysis demonstrated that supply chain integration did not create a statistically significant mediating effect on the relationships of the four dimensions of the digital

supply chain team (DSCT) with the operational performance of the supply chain. Therefore, hypotheses H4a, H4b, H4c, and H4d were not supported.

This result indicates that there was not enough empirical evidence to support that digital transformation capabilities operate indirectly through supply chain integration to improve operational performance in the context of this study.

One potential reason that digital technologies that create increased coordination/integration have not produced mature or properly aligned integrated structures to produce improved operational performance gains could create a barrier towards generating effective operational performance gains through supply chain integration.

In addition, the results of the analysis suggest that the impact of limitations from an external institutional level/infrastructure challenges/and inefficiencies at the ecosystem level can serve as additional barriers to creating effective operational performance improvements via supply chain integration.

5.4 Moderating Role of Internal Readiness and External Ecosystem Conditions

Results of the moderation analysis indicate that neither the readiness of external ecosystems nor internal readiness meaningfully moderated the connections between the dimensions of digital supply chain transformation (DSCT) and operational supply chain performance. Therefore, hypotheses H5a and H5b were not supported.

The lack of moderation effects implies that digital transformation initiatives in Ethiopia's SEZ may not yet benefit from well-established enabling conditions developed through their use of DSCT.

Some potential explanations for these results include:

- variation in infrastructure quality,
- limited access to digital ecosystems,
- limited coordination among firms in using digital products and services,
- limited digital managerial competence, and
- uneven levels of technology adoption by different firms.

Though previous studies have established a link between enabling conditions (i.e., readiness) and successful digital transformation (Tornatzky & Fleischer, 1990), preliminary findings from the present study suggest that the above enabling conditions were not sufficiently developed within the context of this study.

5.5 Conclusion

This study looked into the relationship of the dimensions of Digital Supply Chain Transformation, Supply Chain Integration, and Operational Supply Chain Performance in manufacturing in the Ethiopian Specialized Economic Zones. Research findings indicated that the DSCT dimensions did not directly impact operational supply chain performance. However, digital planning systems and real-time tracking were shown to have a positive impact on supply chain integration. However, while supply chain integration did not have a significant impact on operational performance, therefore no significant mediation effect. Internal readiness and external ecosystem readiness did not moderate the relationship of the DSCT dimensions and operational supply chain performance in this study either.

The results from this study indicate that digital transformation initiatives in the supply chain within the SEZ manufacturing firms of Ethiopia are still in a developing stage of maturity and therefore may not have reached an adequately matured and developed level for operationally significant improvement in operational performance.

5.6 Theoretical Implications

This research adds to the body of knowledge related to the digital supply chain (DSC) by breaking DSC down into four separate and distinct dimensions as opposed to treating it as one aggregate unit. Additionally, this research adds to the body of literature by studying both mediation and moderation factors, particularly in an SEZ context in a developing country, which currently has very little literature. The results suggest that the operational value associated with digital transformation depends significantly on several key areas related to ecosystem maturity, institutional support, and the quality of integration.

5.7 Managerial Implications

Manufacturers engaged in production within SEZs should be aware that digital transformation efforts alone, can and will not inherently provide operational benefits. Companies must work on the following areas of improvement as a priority:

- Better integration among supply chain partners;
- Increased digital capabilities of employees;
- Invest in systems that are interoperable;
- Create data sharing practices;
- and improve operational coordination.

Furthermore, policymakers and SEZs administrators must improve the following areas in order to strengthen the digital transformation ecosystem;

- Digital infrastructure;
- Logistics coordination;
- Customs responsiveness;
- and Institutional support systems.

5.8 Limitations of the Study

There are some limitations associated with this study.

First, this study was limited to manufacturing companies in Ethiopian SEZs, which may not represent all sectors of manufacturing companies throughout the world. Second, because the data were collected at one point in time, there is no information available regarding how digital transformation has impacted manufacturing companies. Third, the sample size of this research may have affected the statistical significance of some relationships and its generalizability due to the lack of power present in a sample size that is too small (i.e., less than 200). Fourth, the use of self-reported survey data means that there is a possibility of bias, thus potentially overestimating the effects of digital technology.

5.9 Future Research Recommendations

Future research studies should expand upon the findings of this paper by including larger sample sizes from multiple industries, using longitudinal research designs, exploring other mediating or moderating variables, studying digitally mature manufacturing ecosystems, and comparing the use of SEZs and non-SEZs in the manufacture of goods.

Future research may also examine how advanced digital technologies such as AI, Blockchain, and IoT are being adopted/used within Africa's supply chain industry.

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APPENDICES

Source notes for validated instruments used in Appendices

To preserve methodological rigor while respecting copyright, the questionnaire items below are adapted/paraphrased from validated scales and documented sources rather than copied verbatim.

The main validated-scale sources used as the basis for the quantitative and qualitative instruments are:

1. Digital Supply Chain Transformation (DSCT) is operationalized using a five-item digital supply chain transformation measure reported with psychometric evidence in (Ngo et al. 2023), who indicate that these five items are drawn from Nasiri et al. (2020).
2. Supply Chain Integration (SCI) measurement items (customer, supplier, internal integration) documented in Flynn, Huo, & Zhao (2010),
3. Operational supply chain performance (OSCP) is measured using multi-item constructs such as delivery dependability, lead time, quality, cost efficiency, and responsiveness, adapted/paraphrased from the established operational/supply chain performance measurement used from the previous recent digital supply chain contemporary perspectives and studies (Saryatmo & Sukhotu, 2021; Hautala-Kankaanpää, 2022).

Appendix A

Quantitative Survey Questionnaire

Study title: Digital Supply Chain Transformation and Operational Supply Chain Performance: The Mediating Role of Supply Chain Integration among Manufacturing Firms in Ethiopia's Special Economic Zones.

Section A: Eligibility and respondent profile

A1. Consent to participate
Do you voluntarily agree to participate in this survey?
☐ Yes ☐ No *(If No, end survey.)*

A2. Respondent role
Which best describes your primary role?
☐ Supply chain/operations ☐ Export/logistics ☐ Production planning ☐ Procurement ☐ IT/ERP/Systems ☐ Senior management ☐ Other: __

Section B: Firm profile

B1. Special Economic Zone location
Name of Special economic zone: ____

B2. Main sector
☐ Textile/apparel ☐ Leather ☐ Agro-processing ☐ Pharmaceuticals ☐ Electronics ☐ Other: __

B3 - What is your firm's primary market orientation? (a) Mainly Domestic (b) Mainly Export (c) Both Domestic and Export

B4. Firm size (employees)
☐ <50 ☐ 50–99 ☐ 100–249 ☐ 250–499 ☐ 500–999 ☐ 1000+

Section C: Digital Supply Chain Transformation (DSCT)

Response scale for Section C (mark one per item):
1 = Not at all / Not implemented
2 = Low extent
3 = Moderate extent
4 = High extent
5 = Very high extent / Fully implemented in routine operations

C1: Digital Documentation

C1.1 We use electronic systems for managing supply chain documents (e.g., orders, invoices).

C1.2 Export and compliance documents are processed digitally rather than manually.

C1.3 Documents are accessible across departments through shared systems.

C1.4 Digital document systems reduce processing time and errors.

C2: Digital Planning Systems

C2.1 We use integrated systems (e.g., ERP) for production and procurement planning.

C2.2 Planning decisions are based on real-time data from multiple departments.

C2.3 Planning processes are coordinated across functions using digital systems.

C2.4 Our planning systems support quick adjustments to demand or supply changes.

C3: Real-Time Tracking & Visibility

C3.1 We can track inventory levels in real time.

C3.2 We can monitor shipment status in real time.

C3.3 Operational data (e.g., production, logistics) is visible across departments.

C3.4 We use digital tools to detect disruptions early.

C4: Data Analytics & Decision Support

C4.1 We use data analytics to support supply chain decision-making.

C4.2 Forecasting is supported by data-driven tools.

C4.3 Dashboards are used to monitor supply chain performance.

C4.4 Data insights are regularly used to improve operations.

Section D: Supply Chain Integration (SCI)

Response scale for Section D (mark one per item):
1 = Strongly disagree … 5 = Strongly agree

D1: Internal Integration

D1.1 Different departments coordinate planning effectively.

D1.2 Information is shared across departments in a timely manner.

D1.3 Departments use shared data for decision-making.

D1.4 Internal processes are well aligned across functions.

D2: External Integration

D2.1 We share information electronically with suppliers.

D2.2 We coordinate planning activities with key suppliers.

D2.3 We exchange real-time information with logistics providers.

D2.4 We collaborate with customers on demand planning.

Section E: Operational Supply Chain Performance (OSCP)

Response scale for Section E:
1 = Strongly disagree … **5** = Strongly agree

E1.1 We consistently meet promised delivery times to customers.
E1.2 We have reduced the time from order receipt to delivery (order-cycle time).
E1.3 We maintain high and consistent product quality (low defect/reject rates).
E1.4 We have improved inventory effectiveness (e.g., fewer stockouts/overstocks, better turnover).
E1.5 We have reduced total procurement and logistics costs per unit.
E1.6 We can respond quickly to changes in customer demand or requirements.
E1.7 We can adjust production volume or product mix with minimal disruption.
E1.8 Overall, our supply chain operations perform well compared to key competitors.

Section F: DSCT enablers and constraints

Response scale for Section F:
1 = Strongly disagree … **5** = Strongly agree

F1: Internal readiness

F1.1 Top management actively supports DSCT investments and implementation.
F1.2 Our employees have sufficient digital skills to use supply chain/operations systems effectively.
F1.3 We allocate sufficient resources (budget/time) to maintain and improve digital systems.
F1.4 Data quality and governance practices (accuracy, access, accountability) are defined and applied.
F1.5 Training and support are available when new digital tools are introduced.

F2: External environment and ecosystem

F2.1 Internet/connectivity reliability supports routine digital supply chain/operations activities.
F2.2 Power reliability supports the routine operation of digital systems.
F2.3 Key suppliers are sufficiently capable of exchanging information digitally when needed.
F2.4 Logistics providers offer usable visibility/tracking information for inbound and outbound shipments.
F2.5 SEZ services and related agencies enable smoother digital administrative and logistics processes.

Google form used to collect respondents' data: https://forms.gle/BYKY6hXAmFqE6KSn8