Ramin Shayanrad

THE IMPACT OF SMART SUPPLY CHAIN ON BUSINESSES' GREEN PERFORMANCE

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DEPARTMENT OF BUSINESS ADMINISTRATION

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RAMIN SHAYANRAD

Supervisor

Asst. Prof. Dr. Ayşe Hyusein

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Approval

We certify that we have read the thesis submitted by Ramin Shayanrad titled "**THE IMPACT OF SMART SUPPLY CHAIN ON BUSINESSES' GREEN PERFORMANCE**" and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Business Administration Sciences.

Examining Committee	Name-Surname	Signature
Head of the Committee:	Assoc. Prof. Dr. Mehdi Seraj	....
Committee Member*:	Asst. Prof. Dr. Ayşe Gözde Karaatmaca	....
Supervisor:	Asst. Prof. Dr. Ayşe Hyusein	....

Approved by the Head of the Department

26/12/2025

....

Prof. Dr. Şerife Zihni Eyüpoğlu

Head of the Department

Approved by the Institute of Graduate Studies

...../...../20...

Prof. Dr. Kemal Hüsnü Can Başer

Head of the Institute of Graduate Studies

Declaration of Ethical Principles

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Ramin Shayanrad

16 / 01 / 2025

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Ramin Shayanrad

Abstract

The impact of smart supply chain on businesses' green performance

Shayanrad, Ramin

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The objective of this study is to ascertain the effects of smart supply chain configuration on green performance in the petrochemical companies of Iran. Moreover, this study also determines the mediating effects of green operations in the relationship between smart supply chain and green performance. This study was done on the basis of quantitative research method. The participants of this study were employees of steel and petrochemical manufacturing companies in Iran. Convenience sampling method was used in this research and 357 sample participants were involved. The questionnaire was shared via Google forms with participants after the approval of respective human resource representatives. For the purpose of data analysis, the statistical package for social sciences (SPSS27) was used. After the reliability and descriptive analysis, the regression analysis was used in order to investigate the relationship between the independent and dependent variables. The findings of this study demonstrate that the relationship between the independent and dependent variable, the mediation of green operations in the relationship, and the effects of green operations on green performance are significant. Smart supply chain positively influenced green performance and green operations and was significant. Green operations positively affect green performance as well. Lastly, the green operations mediation is supported and significant. From the findings of this study, the configuration of smart supply chain in conjunction with green operations results in higher levels of green performance.

Keywords: Smart Supply Chain, Green Operations, Green Performance.

Öz

Akıllı Tedarik Zincirinin İşletmelerin Yeşil Performansı Üzerindeki Etkisi

Shayanrad, Ramin

Yüksek Lisans, İşletme Ana Bilim Dalı

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Bu çalışmanın amacı, İran'daki petrokimya şirketlerinde akıllı tedarik zinciri konfigürasyonunun yeşil performans üzerindeki etkilerini tespit etmektir. Ayrıca bu çalışma, akıllı tedarik zinciri ile yeşil performans arasındaki ilişkide yeşil operasyonların aracılık etkisini de incelemektedir. Bu çalışma nicel araştırma yöntemi esas alınarak yapılmıştır. Bu çalışmanın katılımcıları İran'daki çelik ve petrokimya üretim şirketlerinin çalışanlarıydı. Kolayda örnekleme yöntemi kullanılan bu araştırmada 357 örneklem katılımcı yer almıştır. Anket, ilgili insan kaynakları temsilcilerinin onayından sonra Google formları aracılığıyla katılımcılarla paylaşıldı. Verilerin analizi amacıyla SPSS 27 kullanılmıştır. Güvenilirlik ve betimsel analizin ardından bağımsız ve bağımlı değişkenler arasındaki ilişkiyi araştırmak amacıyla regresyon analizi kullanıldı. Bu çalışmanın bulguları, bağımsız ve bağımlı değişken arasındaki ilişkinin, ilişkide yeşil operasyonların aracılığının ve yeşil operasyonların yeşil performans üzerindeki etkilerinin anlamlı olduğunu göstermektedir. Akıllı tedarik zincirinin, yeşil performansı ve yeşil operasyonu olumlu yönde etkilediği tespit edilmiştir. Yeşil operasyonların yeşil performansı da olumlu yönde etkilediği tespit edilmiştir. Son olarak yeşil operasyonların aracılığı yapılan analizler sonucunda desteklenmiştir. Bu çalışmanın bulgularına göre, akıllı tedarik zincirinin yeşil operasyonlarla birlikte yapılandırılması, daha yüksek düzeyde yeşil performansın elde edilmesinde önemli rol oynamaktadır.

Anahtar Kelimeler: Akıllı Tedarik Zinciri, Yeşil Operasyonlar, Yeşil Performans

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List of Abbreviations

SC: Supply Chain

SSC: Smart Supply Chain

SCM: Supply Chain Management

SSCM: Smart Supply Chain Management

GSCM: Green Supply Chain Management

SPSS: Statistical Package for Social Sciences

GO: Green Operations

GP: Green Performance

CHAPTER I

Introduction

A network consisting of companies and individual involved in every step of production of a product or service, from raw materials to the delivery to the final product to consumers is described as a supply chain. The network encompasses the delivery of raw or source materials, activities in warehouses, technologies, people handling and responsible in every step, resources, sales, storage of raw materials, storage work in process (if any), storage of final goods, distribution and delivery to consumers (Sanders, 2013). A supply chain is also referred to as distribution channel and is simply a phenomenon that exist in every organization. However, the management of said supply chains are referred to as supply chain management. SCM is the practice that needs management efforts and strategies implemented by the organizations within the SC in order to efficiently handle the entire SC activities, from the base materials to the eventual goods and delivery (Mentzer et al., 2001).

At the fundamental level, the management and monitoring of the flow of materials, goods, data, and financial activities involved with a product or service, from the procurement of source materials to the delivery of product or service to the final consumer is considered as SCM. Potent supply chain management systems can potentially help organizations to reduce costs, waste and production cycle time. Supply chain management is crucial to every organization since a well-oiled supply chain has enormous beneficial effects on maintaining economic stability and functional society. A reliable supply chain can only be achieved by effective SCM and is one of the key drivers of economic growth as the supply chains encompass several sectors within industries (Sanders, 2013). An efficient supply chain is only achievable with a proper management and can create opportunities, improve technology and skills, and grow employment.

Mentzer et al. (2001) described SCM as a concept that its main goal is to integrate, coordinate and manage the source, flow and control over materials applying a total system approach across several functions and several tiers of suppliers. Meanwhile, Cooper et al. (1997) defined SCM as the integration of company processes from original suppliers to the end consumer and the original suppliers provide products, services and information which eventually add value for the consumer. Furthermore, organizations need to have some level of coordination within and between them in the supply chain that exceeds beyond logistics.

With today's applications of new emerging technologies in manufacturing the Industry4.0 is introduced, or the "fourth industrial revolution" (Meindl et al., 2021). With the advancements of technologies, the latest ones that are effective in industrialization are namely artificial intelligence (AI), machine learning (ML), internet of things (IoT), automation, and sensors which are transforming the ways firms manufacture, transport, store and maintain their products and services (Wu et al., 2016). In industry4.0, the supply chains are different and applications of new technologies has changed the supply chains for the better. With smart technologies within a supply chain, real-time data can be made visible to every entity within the supply chain and malfunctions, errors, and many other failures that the traditional supply chains would have encountered can be predicted to a high degree. Smart supply chain management (SSCM) nowadays is about making supply chains more reliable and efficient.

Digital transformation impacts, implies that the nature of business environment is rapidly changing and all industries are required to keep up with technological changes occurring every day in order to maintain their competitive advantages (Wu et al., 2016). Embracing digital technologies is crucial for organizations so that they can compete in the global market and outperform their rivals. Furthermore, acquiring a delicate balance between digital transformation and meeting sustainable goals is an emerging yet vital area. This is peculiarly important to make sure that the digital transformation is achieved in a manner that circumvents overconsumptions and encourages sustainability for society and organizations (Wu et al., 2016).

As the Industry4.0 emerged with new technologies, the petrochemical industry which is recognized by its significant production capacity and investment potential is designed to be the forefront of modernization of the whole industrial complex. In order to keep competitiveness and embrace innovation of models, the petrochemical industry requires the active automation of management processes (Mohseni et al., 2019). With the implementation of digital technologies, the petrochemical industry can operate within an interconnected information space. This results in a smooth collaboration between assets, equipment, each stage of production, and services, making sure of enhanced efficiency, predictive maintenance, and better production procedures within the industry. Moreover, this interaction provides real-time information exchange between members, which results in better decision-making processes, thus ensuring less accidents and downtimes (Shinkevich et al., 2019).

Green performance is a measurement for organizations that assesses how an organization is contributing to environmentally friendly practices. Green performance strategies help companies to decrease their negative impact on environment and increase their sustainability. As technological advancements are optimizing supply chains, green performance of companies that use smart supply chain management can increase. Implementing smart supply chain management can improve green performance in many ways such as decreasing energy consumption, minimizing waste, enhanced warehouse management, and increased efficiency (Meindl et al., 2021).

An important part of an increased green performance for and organization, is to implement strategies in their practice that are considered green and sustainable. These practices are implemented so as to diminish the negative environmental repercussions of an organization's operations. Implementing green operations within a supply chain can help organizations to reduce their negative impact on environment considerably. As the society's knowledge and interest is growing in the subject of "green" activities and actions that companies implement, companies have to measure their operations carefully and in order to increase their competitiveness they need to implement green strategies within their operations (D'Angelo et al., 2023).

Purpose of the Study

In this research, the goal is to determine how digital transformation within supply chain systems and management, also referred to as smart supply chain management, can affect the green performance of organizations. Additionally, this research assesses the mediation role of green operations and how it mediates the effects of SSC on green performance.

This study is significant for several reasons. Firstly, it provides insights on how digitization of supply chain can affect a company, specifically in environmental aspects. Secondly, it provides details on how the digital transformation can be implemented and what technologies and how those technologies affect supply chains and its members. Thirdly, the information provided by this study helps us understand that although digital transformation is necessary, it is important to employ specific technologies needed in an industry in order to gain competitive advantage, rather than implementing any digitalization strategy without assessing them. Also, this study investigates the mediating role of green operations in the relationship between smart supply chain management and green performance within the organization. Finaly, this study can provide managers in the petrochemical and steel manufacturing industries with information and guidance on how the digital transformation within their supply chains can improve their green performance and what factors are more significant in digitalization strategies.

Significance of the Study

This study's results will be beneficial in both organizational and environmental aspects. In recent decades, we have witnessed the growing importance and concerns regarding green activities within companies and their attempts to implement green strategies into their operations. Legal considerations and new legislations implemented by governments are giving directions to organizations to embrace green practices within organizations. Those legal environmental provisions and stakeholder pressures are pushing organizations to develop environmental practices and improve their green performance. Moreover, with the increased public awareness on environmental crisis the demand for better environmental management has increased. Hence, organizations are often obligated to enhance their green performance with environmental strategies. The results of this study will be helpful for companies, specifically petrochemical and steel manufacturing sectors, in order to implement green strategies in their SCM.

Statement of the Problem

As we live in an era where technologies and digitalization affect our everyday life, the need to adapt to emerging new technologies in is becoming increasingly more vital. Work environments are no exception, it is necessary to adapt and implement technologies into businesses so that they can gain competitive advantages in the market, while firms that do not adapt to these changes get wiped off from the market (Ahmad et al., 2020). The supply chains are significantly vulnerable to rapid changes in different aspects; however, the technological integration has proven to be helpful in making supply chains more stable and efficient (Ahmad et al., 2018).

While technological transformation has enabled companies to improve their supply chain management systems in many different areas, the need to recognize its impacts on green performance of companies is necessary. Moreover, the petrochemical and steel industry, known for being highly profitable and necessary for economic developments, are in need of considerations regarding their green performance (Shinkevich et al., 2019). Furthermore, these industries' manufacturing and supply chain processes are responsible for a considerable number of pollutants and carbon footprints; hence, the need to investigate and implement strategies in order to improve their green performance has interested scholars. Not enough attention has been paid to the relationship between digital transformation of SCM and the green performance of these industries, specifically in developing countries such as Iran. Research is necessary since, for example, the availability of technologies and economic feasibility of acquiring new technologies differ in developing countries from those in the developed countries. Hence, the aim of this study is to investigate such factors and to determine the relationship between digital transformation of SCM and green performance.

This research will help SCM managers in steel and petrochemical industries to understand and recognize the effects of digital transformation of supply chain activities on green performance. It will give insights on the impacts of the implementation of green operations and smart supply chain systems on green performance. Moreover, the research will illustrate what technologies might have greater impacts on improving the green performance within the industries.

Research Questions

In this research, the objectives are formulated from the following research questions:

1. What effects does smart supply chain configuration have on green performance?
2. What effects does smart supply chain configuration have on green operations?
3. What are the effects of green operations on green performance?
4. What are the influences of green operations on the effects of SSC on green performance?

Limitations of the Study

For future studies, the following limitations in this study ought to be considered. This study is limited to steel manufacturing and petrochemical manufacturing industries in Iran, which may have limited the findings applicability to other industries or even the same industries but in the developed countries. There was also a limited timeframe regarding the collection of data, which was done in a two-month timeframe. Additionally, this study only considers single sectors of the industries. Thus, future research could follow the investigation of other industries or combining them with the sectors investigated in this research. This research was focused on specific companies in the petrochemical industry, more research on the entire petrochemical industries can be performed for future studies.

This research was concentrated in Iran’s steel manufacturing and petrochemical companies, future research can be done on other countries to assess global implications. Moreover, the researcher suggests that more in-depth research should be performed to determine specific areas and technologies to be implemented within the SSC and green operations and assess their effects on green performance. It is recommended that more research be performed on green operations to determine specific aspects of green operations and how they affect green performance.

Definition of Variables

Smart Supply Chain. Smart supply chain refers to a supply chain system approach that utilizes advanced technologies and automated processes to optimize the flow of goods and services from suppliers to consumers (Wu et al., 2016). SSC consists of three separate dimensions, digital transformation strategy, base digital technologies, and front-end technologies.

Digital transformation strategy refers to creating new models and strategies that provide new perspective on supply chains and green performance for companies (Lerman et al., 2022). Base digital technologies refer to the technologies implemented into SCM which are vital to green performance by implementing advanced technologies into the SCM (Meindl et al., 2021). Front-end technologies refer to SSC implementation, facilitating digital frameworks with customers and suppliers to increase green performance (Meindl et al., 2021).

Green Operations. Green operations refer to the green practices implemented within the supply chain in order to achieve better green performance.

Green Performance. Green performance is defined as the assessment of how well organizations are fulfilling their environmental objectives (Ebinger & Omondi, 2020).

CHAPTER II

Literature Review

Supply Chain

A supply chain is presumed to be a network of firms, organizations, resources and machineries involved in the production, manufacturing and sale of final product. A supply chain comprises everything from the resources to the final product delivered to the final user (La Londe & Masters, 1994). Mentzer et al. (2001) defines SC as a network of three or more entities which could include companies, firms or individuals that are associated with both downstream and upstream flows of final products, services, finances, resources and information from the source to customers. Note that in these definitions and concepts of SC the final consumer is recognized as a part of the SC. This goes to show that the definitions above, recognize the retailers as part of the downstream and upstream flows that comprise a supply chain. Sanders (2013) illustrates a simple supply chain as shown in the figure below:

Figure1.

Stages of the Supply Chain.

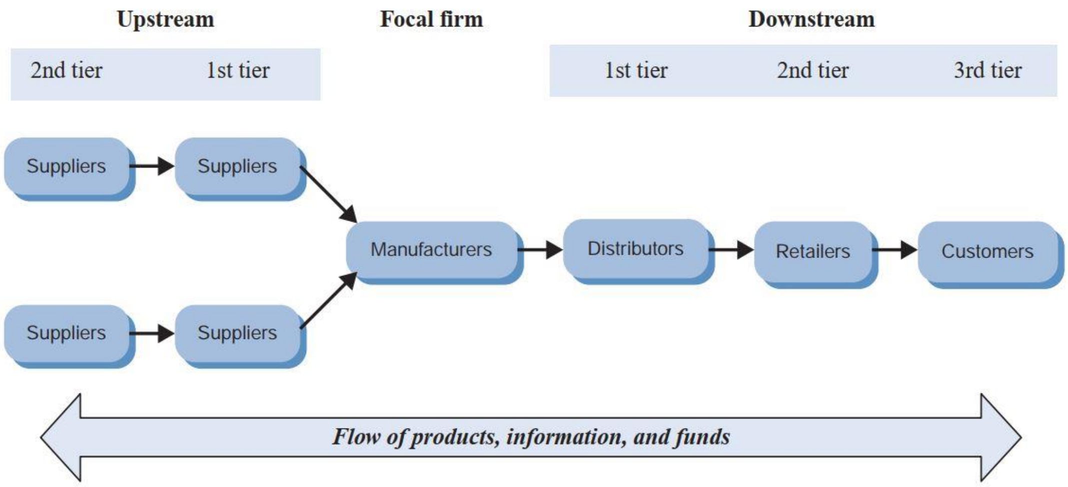


Figure1 shows that the upstream step of the SC are the activities on the SC that are directed to the focal firm. Meanwhile, stages moving away from the focal firm towards final consumers are considered to be the downstream part of the supply chain. Referring to parts of supply chain as “Upstream” and “Downstream” enables a more convenient point of reference, enabling managers and researchers to investigate different aspects of SC with more concentration. With the same logic, "first-tier suppliers", "second-tier suppliers" and so on helps to provide a conventional terminology for organizations to acknowledge the referenced supplier (Sanders, 2013).

Supply Chain Management

Cooper et al. (1997) define SCM as the strategizing, execution, and oversee of a proficient flow and storage of resources, including but not limited to primary materials, in-progress inventories, end products, and related information, from the starting point to the final consumer. In simple words, SCM is an integrated approach to managing activities and processes along a supply chain. Further, Cooper et al. (1997) have highlighted that SCM is based upon a set of principles where every organization, whether directly or indirectly, in the chain has an impact on the efficiency of the other units and the effectiveness of the supply chain itself.

Sanders (2013) points out that SCM constitutes of dynamic and ever-changing processes that necessitate the constant coordination of activities among all members of the supply chain. Key SCM activities encompass coordination, information sharing, and collaboration.

Coordination

Supply chain management involves the coordination of the maneuver of goods and services through the SC, starting from suppliers to the producers to distributers and eventually, the final consumer. However, it can also include the movement of goods in reverse the SC as the final product could be returned. Coordination in supply chain management also includes the movement of funds along supply chain. Supply chain coordination main goal is improving supply chain performance by aligning the strategies and the goals of individual organizations which can result in improved risk mitigation, reduced costs, improved quality control and higher efficiency rate (Sanders, 2013).

Information Sharing

Effective supply chain management relies on the dissemination of appropriate information among the SC members for the purpose of better efficiency and accuracy.

Key types of shared information include demand and sales projections, point-of-sale data, upcoming promotional plans, and inventory status. Sharing such information enables organizations to track vital components of the SC, starting from resource procurement to logistics. It also helps organizations monitor what is going on among the participating parties, such as suppliers, warehouses, transporters, retailers, manufacturers, and customers. The major goal of information sharing within supply chain management is ensuring that an organization is provided with appropriate data for making correct and right business decisions (Sanders, 2013).

Collaboration

Collaboration among supply chain members involves joint planning, operating, and execution of business activities and decisions as if it were one entity. In this regard, it is critical in various areas, such as product design and development, process optimization, and implementation of business strategies or initiatives. Collaboration helps improve accountability amongst the members of SC. The main benefits of collaboration in SCM can be improved communication, improved stability, better decision making, competitive advantage, and lower costs (Sanders, 2013).

Supply Chain Management in the Petrochemical and Steel Industry

SCM in petrochemical industry constitutes of complex activities which usually have a high affiliation between three sectors. Firstly, the upstream activities which include exploration, well drilling, crude oil extraction and production activities right up to the petrochemical firms. Secondly, the midstream activities are responsible for the transportation which is usually by pipeline, rail or oil tankers, storage and marketing of the refined products. Finaly, the downstream activities cover petrochemical productions, distribution and marketing of the final product (Attia et al., 2019).

The petrochemical industry faces many challenges when it comes to its supply chain management. The industry is global in nature and as a result, the products are transferred between locations that are sometimes continents apart. Considering the nature of raw materials in the petrochemical industry, which is refined oil, the transportation is highly inflexible due to safety measures (Al-Husain et al., 2006).

Petrochemical industries are considered to be heavy industries since they create significant air emissions, wastewater and toxic waste to the environment. Meanwhile, the new legislations and measures provided by governments are insisting on industries to implement sustainability strategies in their companies (Mohseni et al., 2019). As supply chains are one of the biggest parts of these industries that include several activities as mentioned before, they face the pressure to green their operations according to the determined global standards. When managing supply chains, organizations must evaluate their sustainability performance in order to ensure success in their business (Abdussalam et al., 2021a).

In the steel manufacturing industry, the supply chain comprises of upstream and downstream activities. The upstream SC would start from mining to the production of steel, while the downstream SC includes the storage of products, distribution, and processing the final products. The use of Information and Communication Technologies (ICT) in steel industry empowers the manufacturers to increase the visibility of value chain among the production (Xiong & Helo, 2008). In this industry, sustainability has emerged as a critical focus. For example, to produce reduced iron instead of scrap directly, 1120 cubic meters of water, 300,000 cubic meters of natural gas and 130,000 kilowatt-hours of electricity is required (Antucheviciene et al., 2020).

Smart Supply Chain Management

Digital transformation within SC, also known as smart supply chain, involves the integration of emerging technologies to enhance the efficiency and flow of supply chain operations, bringing “smart” capabilities to a firm’s processes (Lerman et al., 2022). While the concept of Industry 4.0 refers to manufacturing industries with advanced technologies, it has provided the industry to transform the traditional supply chain into smart supply chain using Industry 4.0 technologies and concepts (Zhang et al., 2023). According to Zhang et al. (2023), it is essential for supply chains to evolve alongside Industry 4.0 because smart manufacturing relies on equally intelligent supply chains to meet its goals. This alignment is critical, as supply chains play a pivotal role in ensuring the availability of raw materials, managing production flows, and overseeing the distribution of finished goods. By adopting digital technologies and implementing them within the SC, the information throughout the SC processes becomes more transparent and available which can result in an improved decision-making procedure between SC partners (Sony, 2019). According to Umar et al. (2022), as a result of advancements in technologies in Industry 4.0 the supply chain processes are able be to planned effectively managed efficiently due to the availability of real time data and smart systems which Can make the SC more flexible and efficient.

With the automation and optimization of supply chain procedures via digital transformation and implemented technologies can result in improved efficiency and agility of the supply chain network. As a result of this enhanced efficiency, organizations are enabled to respond to changes in demand, supply disruptions, or market trends as soon as possible which results in overall improved agility of the supply chain network. Furthermore, the efficiency and agility provided by the smart supply chain can result in a more resilient supply chain network. On another level, manual data entries are prone to inaccuracies which could lead to delays, rework, and unpredicted mistakes. With the help of digital technologies organizations will be able to minimize the risk of human errors and ensure data integrity through the entire supply chain activities. Aside from improved accuracy, it leads to enhanced reliability and trustworthiness of information (Bag et al., 2018).

The agility provided by the digitization of SC can be beneficial since in today's dynamic business environment, agility and fast response to changes is crucial so as to gain competitive advantages in the market. Since digital technologies provide supply chains with real-time data, they provide visibility through every activity of supply chain activities, which in turn, provides organizations to detect changes and respond as quickly as possible (Jabbour et al., 2020).

Meindl et al. (2021) did a thorough review on Industry 4.0 and introduced four smart facets within Industry4.0, namely: Smart Manufacturing, Smart Supply Chain, Smart Products and Service, and Smart Working. The introduced concept of smart supply chain aims to improve the SC operations through the employment of digital technologies. Meindl et al. (2021) considers two main levels for the Industry4.0 technologies: Base-Technologies and Front-End Technologies.

Technologies applied to SC for integrity purposes and control which include sensors and big data analytics, help to make sure correct products are at their correct place, at the correct time and are with adequate quality within the SC (Barreto et al., 2017). On the physical basis of SC and logistics, the smart supply chain can include warehouse handlings via robots and automatic vehicles and tracking systems for inventory controls. This could also involve the smart handling of raw materials, work in progress and the finalized goods, which can be possible with employment of technologies such as robotics (Strandhagen et al., 2017).

Different Stages of Smart Supply Chain Configuration

Digital Transformation Strategy. This level constitutes of implementing strategies that aim to transform organization's supply chain into a digital one. At this level, companies follow strategies that considers their perspective on the desired SCM system. In this phase, the digital transformation strategy, if designed and implemented effectively, will promote the supply chain activities and impact the SCM significantly (Benitez et al., 2022). Bechtsis et al. (2022) explored the opportunities of digital transformation in supply chain management, specifically the data storage and gathering via new technologies like artificial intelligence and blockchain, and found out that these changes improve organizations performance especially after the COVID19 pandemic.

Base Digital Technologies. At the operational level of the digital transformation of supply chains, the first step is to adopt base technologies according to the strategies and necessities of a company's SC. Base technologies that could be implemented so as to transform to a digital SC are as follows: Internet of Things (IoT), Blockchain Technologies, Artificial Intelligence, Big Data Analytics, Robotics and Cloud Computing. These base technologies allow activities within the SC to share real-time data and help to determine faster decisions. Through base technologies, the integration of supply chain flow and activities can be improved. Aside from being beneficial through intraorganizational activities of SC, base technologies improve different aspects of interorganizational relationships and activities of SC which results in a more transparent and integrated supply chain. One of the key benefits of smart SC is that it provides end to end transparency and visibility across all upstream and downstream activities within the SC as the connections mitigate disruption risks due to physical barriers. The base technologies are also known as back-end technologies which enable the operation of front-end technologies to be executed more efficiently (Meindl et al., 2021).

Front-End Technologies. These technologies in supply chain refer to applications and interfaces that are used to manage several aspects of supply chainFront-end technologies are tools designed to perform tasks like material handling, warehouse management, and quality control within supply chain operations. There are many different front-end technologies introduced in smart supply chains and companies acquire these technologies based on their supply chain and the digital transformation needs. Some of the front-end technologies are collaborative robotics, remote inventory systems, sourcing automation and sensor technologies (Meindl et al., 2021).

Benzidia et al. (2021) showed that innovative technologies like artificial intelligence and machine learning improves the information capacities within a supply chain, specifically in hospitals. Their results also show that with the use of intelligent technologies, hospitals are able to mitigate uncertainties in relation with interdependent units.

The research paper titled "*Matching functions of supply chain management with smart and sustainable Tools: A novel hybrid BWM-QFD based method"* aims to assess the supply chain management level of smartness and sustainability by implementing a hybrid method of BWD-QFD (Best-Worst Method – Quality Function Deployment). The study aims to measure the smartness and sustainability of organizations aiming to transition their activities and operations toward more intelligent and sustainable practices. The approach introduced for supply chain management strategy development in the study provides a scale to juxtapose current with target states of sustainability and smartness, which can be beneficial in practice (Gunduz et al., 2021).

Their proposed smart and sustainable SC design used the QFD technique to assess the link between smartness and sustainability factors with supply chain management tasks. Their method imparts insights to managers on how to prioritize and implement Industry4.0 instruments and technologies to reach the goals and aimed levels of sustainability as well as smartness in supply chain.

Green Supply Chain Management

Belhadi et al. (2022) proposed several approaches to investigate problems and dilemmas regarding interorganizational governance in Industry 4.0 and its capabilities to achieve sustainable and green performance within the SC. The proposed approaches were digital business transformation, organizational ambidexterity and circular business models, which were aimed to investigate their distinct and combined effects on sustainable performance. Their study shows that Industry 4.0 plays as the enabler for digital transformation of supply chains and accelerates the transformation of the supply chain. Moreover, their study shows that companies that rely on digital transformation to increase and accelerate their green performance use circularity in their business model. Furthermore, implementing simultaneous approaches like digital transformation, organizational ambidexterity and circular business models and executing them within the supply chain paradigm can accelerate green performance.

Caiado et al. (2022) investigate the challenges and benefits of Industry 4.0 and its capabilities to help achieve operations and supply chain management sustainability. They mention that the digital transformation of supply chain through Industry 4.0 helps to align the sustainability and green performance goals. They propose a framework for organizations to implement the sustainability actions in operations and supply chain management. They mention that their proposed framework can aid professionals to develop guidelines to execute digitalization strategies in accordance to specific sustainability goals. Furthermore, the proposed framework can represent potential sustainability strategies for companies in order to increase their contributions to sustainable supply chain goals.

Kumar et al. (2023) discussed the complexity of SCM due to the involvement of different agents. They mention that the formation of Industry 4.0 has emerged new technological advancements to enable organizations to implement digital transformation in different aspects of the organization. They specifically investigate the textile industry. They use the Virtual Organization (i.e. automated robotics, blockchain technology, artificial intelligence, etc.) approach and propose a mathematical model to evaluate the environmental performance of SSC (in other words, supply chain adopted from Industry 4.0). they implemented a game theoretic approach in order to analyze the results and their findings show that investing in digital transformation including Industry 4.0 and SSC and also investing in green and sustainable strategies and innovations are beneficial for the overall performance of the supply chain. The result of their study indicates that the elevated levels of green performance a firm has, the higher level of profit of overall supply chain in a market that is sensitive to sustainability. However, they also point out that in order to make the required technological developments, firms require additional investments according to their objectives. Furthermore, the conclusion argues that governments should consider implementing new policies and promotions so that investment in digital technologies become more realistic.

Ebinger & Omondi (2020) conducted research on digital approaches for transparency in sustainable supply chains. The study is carried out based on technologies used in smart supply chains and their impacts on environmental, social and human rights associated with their activities. Moreover, the study mentions that companies are progressively held accountable for their social and environmental issues within the scope of their activities and both downstream and upstream suppliers. Hence, the stakeholders demand transparency and traceability within the organizations scope of actions to meet and comply with standards in their supply chains. With the main focus of the study being transparency in supply chain management, the study further investigates the transparency concept and its importance in supply chains.

Moreover, the study defines transparency information dimension as an element which is responsible for exchange of information between parties as information a firm conveys to its stakeholders related to sustainability of materials, products and different activities. Another concept introduced in the study is operational transparency, which mainly concentrates on information regarding monitoring current operations such as logistics planning.

Since the study investigates the transparency in smart supply chains in a global basis, it proposes several challenges regarding the achievement of transparency in the supply chain. In complex supply chains errors happen at all levels and sometimes, when the errors and shortcomings happen in depth of SCs, it becomes very difficult to assess those shortcomings and decide if the information needs to be disclosed. Another challenge that transparency in SC faces, is deciding whether to pass the massive data available in all companies involved in the SC on to the shared platform or not. Finaly, the study showed that the technological approaches analyzed including artificial intelligence, cloud computing and sensors-driven applications help enabling transparency in SCs and their sustainability performance.

Adam et al. (2021) investigated the integration of Internet of Things (IoT) into green SCM systems and its impacts on firms' performance in green practices and SCM. The study, continues the assessment of the effects of IoT on green performance of supply chains exclusively in the oil and gas industry. Internet of things is introduced as a moderator in the relationship between green supply chain practices and organizational performance, specifically in Nigeria's petroleum industry. The main objectives of the study were twofold:

i. Evaluating the influence of green SCM practices on the performance of companies.
ii. Assessment of the impact of the IoT as a moderator in the industry, on the companies' performance.

The mentioned IoT is considered as different approaches on emerging technologies and is concerned with the connection between physical items and the internet. It is defined as an integrated system in which everything is connected and communicates on a broad network like the internet. Some of IoT technologies can be sensors, communication technologies, actuators and controllers. Moreover, there are many applications of IoT in industries such as health systems, manufacturing, transportation, warehouses, etc.

Specifically, in the manufacturing supply chain management systems, IoT can offer real-time data and visibility into the status of items in inventory, improving the planning and scheduling of production activities and traceability for final goods. Cloud systems in IoT help companies to store massive amounts of data and make it available to be accessed from anywhere in the world.

The study concluded that the IoT have considerable moderating effect on the relationship between green supply chain management and organizations performance. Although, the relationship between green practices and the resulting organization performance exists, the application of IoT works as a moderator to improve and strengthen the impacts and results of that relationship. The findings show that optimization and monitoring given by IoT enables organizations turning green by cutting emissions and diminish waste.

According to the research conducted by Ghorbanpour et al. (2022) on the topic "*Application of green supply chain management in the oil Industries: Modeling and performance analysis"*, the growing global concerns related to environmental crisis and the overall global awareness on environmental damages caused by manufacturing companies, concepts like green supply chain, green efficiency and green production have emerged in order to decrease environmental risks in all production activities. By taking the initiatives and implementing green practices, organizations could increase their performance as well as gain competitive advantage. In the study, the authors introduced an interactive model for green practices and its application to oil industries in order to analyze their green performance. They utilized a fuzzy interpretive approach in order to determine the between practices. Afterwards, the relative significance of each practice was evaluated by the application of fuzzy analysis network process (FANP).

Results of mentioned article shows that GSCM is recognized as a principal phenomenon within organizations in order to reduce environmental risks. On the other hand, this approach is a preventive one that aims to enhance the green performance and achieve a competitive edge in the market. The results in the study indicated that green practices that are significantly more important in green SCM in oil industry are compliance with legal requirements and regulations, effective management of the internal environment, green procurement and supply, eco-friendly design, and the adoption of green technologies.

According to the study performed by Cole et al. (2019) on the topic *"Blockchain technology: implications for operations and supply chain management."*, the blockchain technology which is the technology that is with the Bitcoin cryptocurrency, has the prospects to resolve the end-to-end transparency problems. Blockchain technology popularity is increasing rapidly since it helps business processes which use peer-to-peer (P2P) network to share and verify data easily. By representing a decentralized framework for every transaction, where every entry is recorded either publicly or privately which is easily detectable for users. For example, private blockchains have the potential to be applied in operations and SCM systems so as to enhance system security and efficiency for all users.

The authors, Cole et al. (2019) define blockchain technology as a distributed system which records and holds transactional data or any other information for that matter, secured by cryptography. In 2008, Satoshi Nakamoto introduced the blockchain technology, a pseudonymous creator of the Bitcoin white paper. It is a data structure for maintaining the records in blocks of data linked in a continuous chain. This chain acts as a digital ledger that multiple computers collaborate to maintain. One of the main advantages of blockchain in commercial settings is that it functions without central control. It's great for addressing issues of transparency and accountability, especially when the interests of the parties involved are not aligned. With blockchain, data is shared in real-time, so records are accurate and error-free to match each party's internal system. This capability promotes the visibility of activities occurring within the network for every member. Also, this blockchain technology brings a number of benefits from big data into SCM systems, such as better transparency and operational efficiency, boosting trust among participants in a supply chain.

The authors, Cole et al. (2019) introduce four main characteristics of a blockchain. First, blockchain's distributed and synchronized nature across networks makes it very well-suited for encouraging businesses to share data, particularly in multi-organization networks such as supply chains. Second, blockchain embeds smart contracts-pre-transactional agreements stored on the blockchain. These digital protocols enable and verify the agreed terms of the contract, thus enabling automated and credible transactions without third-party involvement. This automation ensures that all parties keep rules. Thirdly, blockchain is based on P2P networks where a transaction is valid if consensus among the relevant parties has been reached. This makes any wrong or fraudulent transaction impossible to be made into the database. Lastly, blockchain ensures that data is immutable; after a transaction has been agreed upon and recorded, it cannot be changed. This attribute provides for the provenance of assets, whereby the location, history, and status of an asset are traced from its origin.

Furthermore, the article mentions that the integrating blockchain into supply networks has the capability to revolutionize business operations. The decentralized ledger acts as a single, unified data source, ensuring consistency among all vendors, such as those involved in manufacturing assembly. With the application of blockchain technologies, manufacturing companies may be able to improve their response time to issues with products, component or material manufacturer. Furthermore, it can help to improve product safety and authenticity, expand service levels and diminish maintenance costs. The blockchain technology can help firms and complex supply chains to gain transparency within their network which in turn can result in a smarter sustainable supply chain network (Cole et al., 2019).

Hohn & Durach (2021) conducted research titled *"Additive manufacturing in the apparel supply chain – impact on supply chain governance and social sustainability"*, in which they investigate the way additive manufacturing could affect global SCs in the manner of governance and social sustainability issues with a focus on apparel industries. Additive manufacturing is the process of creating three dimensional objects from a CAD model or digital 3D models and produce items in a layer-by-layer process, which represents an alternative approach to traditional manufacturing processes. This technology enables manufacturers to manufacture different items and products with different levels of geometry complexities and shapes with a single machine. Additive manufacturing brings several benefits to the manufacturing processes such as customization and personalization of products and reduce the demand for manual labor as it eliminates assembly tasks. Although application of additive manufacturing can be challenging and has not been completely applied in the industry, scholars are optimistic about future technological advancements for the application of this technologies in industries.

The authors, Hohn & Durach (2021) mention that the supply chain in the apparel industry constitutes of complex network of businesses, services, organizations, people, activities and resources that are responsible for moving a product from the raw material to the end consumer. As for the last decade, the global apparel industry has witnessed growth in demand for more flexible and time-efficient supply chain systems. While many big and famous firms of the apparel industry are located in Europe or North America, the manufacturing and production processes are commonly outsourced to the countries of Global South in order to reduce costs since firms simultaneously demand fast and cheap supply of their goods. As a consequence, the social responsibility is highly influenced by this sort of supply chain system. The outsourcing procedure that takes place in the apparel industry has caused a significant decrease in the amount of control that firms have over the production practices happening in the supply chain of their products. Moreover, the unsupervised production of the goods and the strict demands for cost effectiveness and flexible production has led to disregard of the health and safety standards in the manufacturing factories so that they meet the requirements enforced on them.

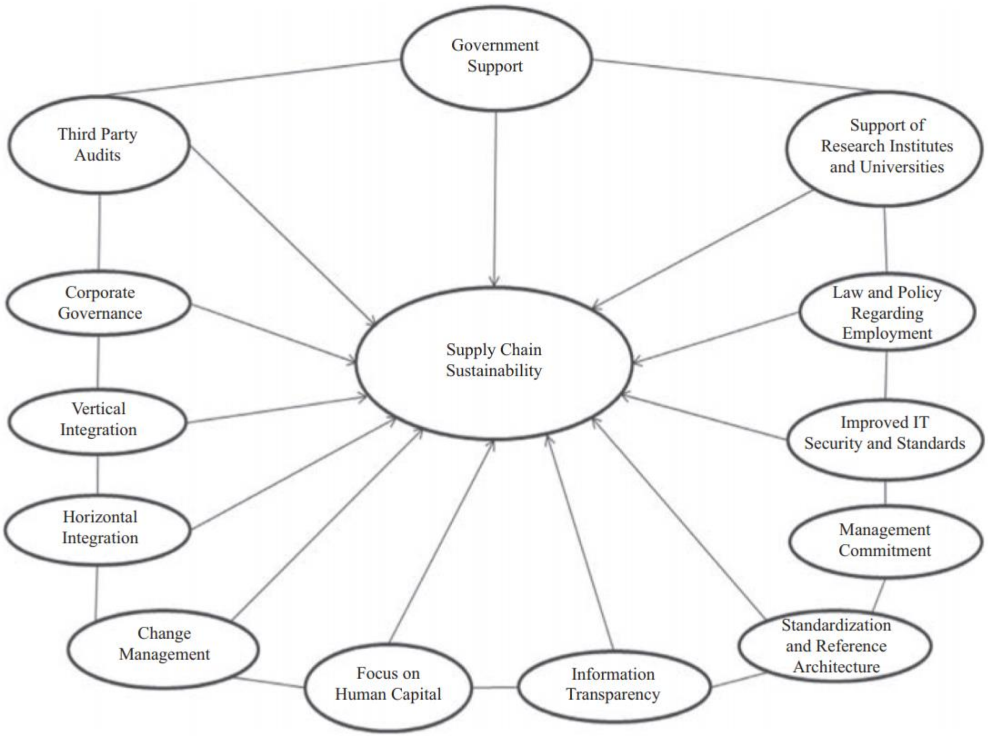
Their findings show that the implementation of additive manufacturing is presumed to strengthen the existing supply chain governance within the apparel retailers. However, contrary to the common belief that technological advancements can lead to increase in societal well-being, the study observes that new technological advancements may, in fact, intensify rather than improve the existing social sustainability problems in the modern production processes.

Bag et al. (2018) conducted research on the relationships between Industry4.0 and supply chain sustainability and the literature and opportunities on the subject. The article points out that the technological transformation in industries which resulted to Industry4.0 concept, brought out greater demand for technological integration in every aspect of almost every industry. The aim of their study, as they point out, is to identify how Industry 4.0 enables supply chain sustainability and how to better approach sustainability issues with Industry4.0 concepts. The main focus of their study is to construct a framework with which, the merging of the concepts of sustainable supply chain and Industry 4.0 can be made possible. Industry4.0 enables manufacturers to enhance integration within the production processes, for instance, it enables machines to become independent and enables them to plan, program and produce products automatically. The concept enhances flexibility, timeliness and efficiency in the manufacturing procedures. However, implementing Industry4.0 technologies into manufacturing comes with challenges which in result, affects different sustainability aspects of supply chain network.

Furthermore, Bag et al. (2018) suggest that managers should consider the mentioned enablers when designing Industry4.0 projects to maximize the positive impacts on supply chain sustainability. While technological advancements brought by Industry4.0 can have many advantages, their implementation are costly and must be carried out according to the exact needs of a firm, otherwise the disadvantages can overweigh the advantages and might end up having negative effects on supply chain network rather that positive ones.

Figure2.

Sustainability Enablers for Supply Chain



The authors, Bag et al. (2018) introduce 13 Industry4.0 enablers of sustainable supply chain management, which play crucial role in building the company's capabilities to acquire Industry4.0 sustainability within the supply chain network. The enablers are represented in the figure 2.

Patidar et al. (2023) carried out research titled *"Supply chain resilience and its key performance indicators: an evaluation under Industry 4.0 and sustainability perspective"*, the results show that enhancing visibility in the SC network improves its resilience. Visibility and sustainability in SC network can be reached with integrating the supply chain with Industry4.0 key technologies. Implementation of Industry4.0 and its emerging technologies can transform the SC into smart SC and result in intelligent decision-making procedures in the SC.

The resilience of SC is defined as a concept that empower companies to prepare and response to unexpected events in a timely manner (Patidar et al., 2023). At the present time, resilience in supply chain has become very important and being able to adapt to changes effectively and efficiently can benefit organizations greatly. While a resilient supply chain is vital and required for companies to gain competitive advantages, implementing resilience in supply chain network is quite challenging. Identifying key performance indicators can enable companies to assess progress, find strength points within the supply chain and enable people to make better decisions.

Furthermore, resilience factors and elements have significant effects on sustainability of supply chain (Patidar et al., 2023). Sustainability priorities in supply chains cannot be added to them in the traditional way, in fact, they need to be integrated into the supply chain from the start and be factored into every facet of supply chain, operations and design. Most firms fear applying digital transformation to their processes because it is complicated. However, it cannot be avoided with the emergence of Industry 4.0 and increasing competition in all industries. It helps companies to enhance their operations and provide better service to their customers with the help of technology. Adopting Industry 4.0 technologies results in a more resilient and transparent digital supply chain that allows for real-time interaction across every supply chain activity.

Establishing supply chain visibility can help create resilience and significantly contribute toward sustainability. However, visibility is possible only with technological integration throughout the network. The ability of supply chains to respond against disruptions and risks that arise from the increasingly open environment demands evolution into smart supply chains that would keep their operational effectiveness under unforeseeable circumstances. Moving to a smart supply chain not only optimizes operations and increases efficiency but also reduces carbon emissions with the help of efficient resource management and scheduling.

A number key technologies are helpful in diminishing environmental risks such as effective forecasting with AI can diminish overproduction, blockchain technologies can help achieve transparency, and IoT appliances can keep track of environmental parameters, rout optimization with AI can result in reduced fossil fuel consumption and emissions.

Research carried out by Tseng et al. (2021) investigates the main areas and criteria in order to understand how digital transformation could lead to enhanced competitiveness in supply chain’s sustainability. The research’s major point of investigation is to ascertain causal interrelationships among the supply chain activities and attributes while investigating a case study related to footwear industry’s supply chain activities in Indonesia. The authors proposed five aspects, supply chain competitiveness, labor conditions, manufacturing processes, digital platform effectiveness, and digital communication. Additionally, they explored the cause-and-effect relationships among these attributes to identify interconnections and significant impacts.

Indeed, this paper's causal attributes were four critical dimensions of GSCM—digital platform effectiveness, digital communication from a perspective of digitalization of the supply chain, labor conditions, and manufacturing process. It was important to establish that both digital communication and platform effectiveness present the very foundation upon which the competitiveness of a supply chain may be brought to an end. Besides, identifying and determining the attributes and linkages among activities in a supply chain was enlightening.

Yet, while the article acknowledges digital platforms, digital communication, real-time inventory updates, and supply chain transparency, it fails to cover the technological and strategic dimensions of supply chain digitization. While the role of collaboration is identified, its focus is mainly internal and on production-related operations. In addition, the article has not provided an integrated framework that might help implement digital technologies and green practices in the pursuit of better green performance objectives for supply chain management.

The study carried out by Machado et al. (2021) titled *"Barriers and enablers for the integration of Industry 4.0 and sustainability in supply chains of MSMEs"*, aims to identify the primary barriers and enablers in the context of digital transformation in the GSCM within Micro, Small and Medium Enterprises (MSMEs). The primary goals of the mentioned article are: (i) identifying the primary barriers and facilitators that help integrate Industry 4.0 and sustainability in the SCs of the enterprises and (ii) analyzing the impacts between those barriers and facilitators and pinpoint the most influential factor

CHAPTER III

Theoretical Framework

Currently, with the increasing legislations risen by governments and stakeholders, green practices within firms' activities and processes are becoming more and more important. The prime goal of green supply chain management is to diminish resource consumptions, waste generation, and emission of pollutants while ensuring environmental sustainability (Lerman et al., 2022). Adopting green supply chain practices enable organizations to achieve several benefits such as cost savings as a result of reduced resource consumption, improved reputation and loyalty, compliance with governments' green regulations and economic growth. However, achieving these goals with the traditional supply chain management practices can be quite challenging, if not impossible. Hence, with the emergence of revolutionizing new technologies supply chain management is changing every day and these technologies are acting as enablers to help improve supply chain management in every aspect possible. As a result, it has become very crucial for every organization to apply new technologies into their supply chains in order to gain competitive advantages. The benefits of digital transformation in supply chains also referred to as smart supply chains isn't recognized recently, as the literature represents, it has been established that digitalization whether in one aspect or more, has benefited businesses as it helps to interlink almost every activity within overall supply chain (Lerman et al., 2022).

Green performance in the supply chain system refers to the measurement and assessment of environmental sustainability practices and results through the entire supply chain activities. It includes several efforts made by organizations in order to lessen their negative impacts on environment, such as diminishing carbon emissions, reducing waste, and promoting environmentally friendly production processes. Organizations can reduce their environmental footprints, improve their sustainability, and meet the rising expectations of customers, government regulators, and stakeholders by measuring and enhancing their green performance (Sony, 2019).

Development of green supply chain systems can lead to a greener and more sustainable performance in an organization. A green supply chain can be described as an improved operational management approach that aims to optimize the reduction of environmental effects of the entire life cycle of the product (Lam et al., 2015).

The main benefits of smart SCM are four-fold, improved transparency within the supply chain, prediction of operational risks, process automation, and improved planning and collaborations (Nasiri et al., 2020). The real-time tracking and visibility of inventory is one of the perks obtained by the configuration of smart supply chain management this feature provides firms with real-time monitoring of inventory and the traditional “estimates” will be out of the picture. Transparency presented by smart SCM enhances product flow by being able to track every step of the production and as a result, the overall supply chain performance improves. The real-time data from sensors within the smart supply chains help with prediction of demand. With the ability to prevent bottlenecks in production, a smart system is able to avoid waste from excess production or not meeting the required demand of product. As a result, the operational efficiency and productivity will improve. Automations in a supply chain enable faster and better data collection and analysis, enhance order processing and enhance accuracy and efficiency of supply chain operations. Improved planning is considered as synchronized supply and demand predictions as forecasting becomes far more precise, dynamic inventory optimization and flexible production planning (Nasiri et al., 2020).

In the investigation of literature review on the digitization and green supply chain management, we see that most of the works done lack an overall conceptual framework for smart GSCM (Barreto et al., 2017; Cole et al., 2019; Lerman et al., 2022; Umar et al., 2022). In particular, the effects that the transformational technologies, on their own, have on green performance. Moreover, the concept of SCM has been studied extensively in the oil industry however, digital transformation of SCM and its impacts on green performance of companies in the oil industry still need more research (Abdussalam et al., 2021a; Al-Husain et al., 2006; Antucheviciene et al., 2020; Attia et al., 2019; Mohseni et al., 2019; Xiong & Helo, 2008). Meanwhile, the petrochemical industry which is one of the next destinations of refined oil produced by the oil industry, which produce a significant number of goods vital to the everyday life of everyone on the planet, requires more investigation. Most of the research conducted in the literature regarding oil or petrochemical industry consider sustainability of SCM rather than having a focus on green and environmental aspects. On the other hand, the steel industry is another example of industries that are vital to development all around the world and as mentioned in the literature review chapter the production of steel consumes a lot of resources and digital transformation of it SCM and implementing green practices to it are necessary. Following, we discuss the development of hypotheses proposed in details.

Smart Supply Chain Management and Green Performance

In the SSCM literature, the concepts like Industry4.0, digital technologies or digital transformation and their connection with green performance has been acknowledged. Several articles have discussed the connection between digital transformation of supply chains and sustainable practices rather than solely focusing on environmental issues. As discussed in the literature, the studies conducted typically concentrate on particular aspects of digital transformation (e.g. blockchain, AI, IoT, cloud computing, etc.) rather than considering the whole process and effects of the digital transformation of SCM and the assessment of the green performance. In this context, SSC consists of three different layers with each of them having contributions on green performance. The three layers are: digital transformation strategy, base technology, and front-end technologies. Implementing a digital transformation strategy enables businesses to develop new business models that offer a green perspective, allowing organizations to leverage data to gain competitive advantages as green performers in the marketplace (Lerman et al., 2022).

Base technologies are vital to achieving green performance, base technologies such as IoT, cloud computing, blockchain technology, artificial intelligence and big data help companies' data flow all the way through supply chain management. As mentioned in the literature review, several studies focused on this dimension of digital transformation and its impacts on green performance, which is achieved by improving transactions and monitoring of green practices within supply chain (Meindl et al., 2021).

Frank et al. (2019) suggested that data driven technologies help firms in implementing front-end technologies to their supply chain management. Front-end technologies such as simulation and 3D printing are accountable for implementation of SSC, empower digital platforms on both customer and supplier sides such as virtual testing instead of physical prototypes, to maximize green performance. Using front-end technologies properly and strategically enable companies to create new industrial applications which consequently improves the competitiveness and sustainability of said companies (Zhao et al., 2010). Hence, the following hypothesis is presented so as to represent the relationship between smart supply chain management and green performance:

Hypothesis 1.

The configuration of smart supply chain has positive effects on green performance.

As explained in the literature review, the configuration of smart SCM comprises of three different stages that are: Digital transformation strategy, Base digital technologies, and Front-End technologies (Lerman et al., 2022). In the digital transformation stage, the goal is to carry out strategies that enable organizations to digitize their supply chain network. By implementing this stage effectively, organizations can improve their supply chain activities and its impact on green performance significantly. As for the Base technologies stage, they are vital for green performance as cutting-edge technologies such as IoT, cloud computing, and AI can make data flow and management smoother. Such base technologies enable real-time data sharing among the SC activities, facilitating faster and more precise decision-making processes. Furthermore, the use of base technologies, enhances the integration of supply chain flows and activities. Beyond their intraorganizational supply chain activities benefits, base technologies also improve many aspects of interorganizational relationships and activities within the supply chain network. This concept can lead to a more integrated and transparent supply chain network. A crucial advantage of smart supply chains is their ability to offer comprehensive transparency and visibility throughout all upstream and downstream activities within the supply chain. This transparency and visibility among the activities of SC helps mitigate disruption risks due to physical barriers. Base technologies are also referred to as back-end technologies which help the front-end technologies to be executed more efficiently.

The third stage of smart SC configuration, front-end technologies, encompass applications and interfaces deployed to oversee several aspects of the supply chain network. Front-end technologies are mostly responsible for handling tasks such as material handling, warehouse management, and performance quality control within supply chain operations (Zhang et al., 2023). Smart supply chains introduce a variety of front-end technologies, and companies procure these technologies based on their specific supply chain needs and digital transformation requirements. Examples of front-end technologies include collaborative robotics, remote inventory systems, sourcing automation, and sensor technologies. The strategic adoption of front-end technologies in smart supply chains can have a positive impact on green performance by improving operational efficiency, reducing resource consumption, minimizing waste, and enhancing supply chain visibility and traceability. By integrating these technologies into their operations, companies can achieve their sustainability goals while simultaneously driving business success in a rapidly evolving marketplace.

Smart Supply Chain and Green Operations

The green supply chain configuration is important for each company to be set in a specific way that meets the company's requirements and goals, since there is not a single configuration to implement for every supply chain in any company. It is crucial that companies to structure their operational practices according to their needs and objectives (Sarkis et al., 2010). So, according to the configurational approach needed by the company, by implementing only digital strategies and technologies the green performance objectives cannot be achieved. Hence, the implementation of digital configurations needs to be aligned with operational activities (green operations). This alignment helps the companies to have a clear perspective the improvements on their processes and practices, and makes changes that will improve long-term sustainability performance rather than short-term results (Lerman et al., 2022).

As SSC encourages the employment of base technologies to enhance relationships between supply chain parties, the technologies are providing opportunities to collect and analyze data that would result in new data management approaches toward sustainability (Frank et al., 2019).

With consideration of mentioned studies and explanations, we propose the following hypothesis regarding the implementation of green operations in smart supply chain.

Hypothesis 2.

The configuration of smart supply chain has positive effects on green operations.

Activities and practices in the supply chain can have significant effects on firms' performance. In the traditional concept of SCM, the supply chain operations aim to increase revenue while keeping the value chain at a high level with low risk

(Abdussalam et al., 2021b). According to Mohseni et al. (2019) As the concerns for environmental health increased by governments and stakeholders, firms started to implement changes to their supply chain activities, taking green initiatives within this specific part of supply chain(Mohseni et al., 2019). This results in green operations which is also known as green supply chain management which indicates the application of green strategies into the operational layer of the supply chain(Frank et al., 2019). Umar et al. (2022) defined green supply chain management as the integration of environmentally accountable benchmarks into the conventional supply chain in a manner that enables organizations to pursue both supply chain goals and environmental goals. GSCM is also defined as the strategic implementation and integration of environmental objectives into the supply chain practices in order to enhance green performance (Wu et al., 2024). However, in this study, the green operations are considered to work in conjunction with SSCM which illustrates that the green operations within the SSCM are operation that adopt new technologies (Wu et al., 2024). In the operational layer of SSC, the use of technologies such as AI, IoT, and Machine Learning in supply chain processes. In this context, green operations could mean the use of renewable energy, AI adaptation, enhanced transparency. Hence, the following hypothesis is proposed so as to demonstrate the relationship between green operations and green performance:

Hypothesis 3.

Green operations affect green performance positively.

While green operations contribute to green performance on its own, the configurational view considers the green operations' role on green performance of smart supply chain. Although green operations can independently contribute to enhancing green performance in a supply chain, the configurational approach takes a broader perspective. It assesses the role of green operations as a mediator for the relationship between the adoption smart supply chain practices and green performance.

Viewing green operations as a mediator, the configurational perspective recognizes the interdependence between smart supply chain practices and environmentally sustainable operations. It acknowledges that the success of smart supply chain initiatives in enhancing environmental performance relies not solely on advanced technology adoption but also on integrating eco-friendly practices across the supply chain. Thus, emphasizing the mediating role highlights the necessity of combining smart supply chain practices and green operations strategies to attain comprehensive and sustainable enhancements in environmental performance across supply chain operations.

When the mediator variable is quantified, its effects are known as indirect or mediated effect. The reason on why it is called indirect is that it illustrates the influence of independent variable on the dependent variable that is passed on indirectly through the mediating variable. The mediating variable elaborates the relationship between the independent and dependent variables by explaining why or how the outcome occurs (MacKinnon, 2015).

Mediating variables are vital in comprehension of the fundamental processes that define the relationship between the independent and dependent variables. Identifying the mediator can help researchers to find better ways to approach a model (MacKinnon, 2015). Researchers can be able to figure out targeted interventions to enhance the relationship with the help of the mediator. Moreover, by showing that changes in the mediator can affect the changes on the dependent variable, researchers can improve their findings.

Hence, the green operations are considered as a mediator for the relationship between smart supply chain and green performance, which results in the following hypothesis:

Hypothesis 4.

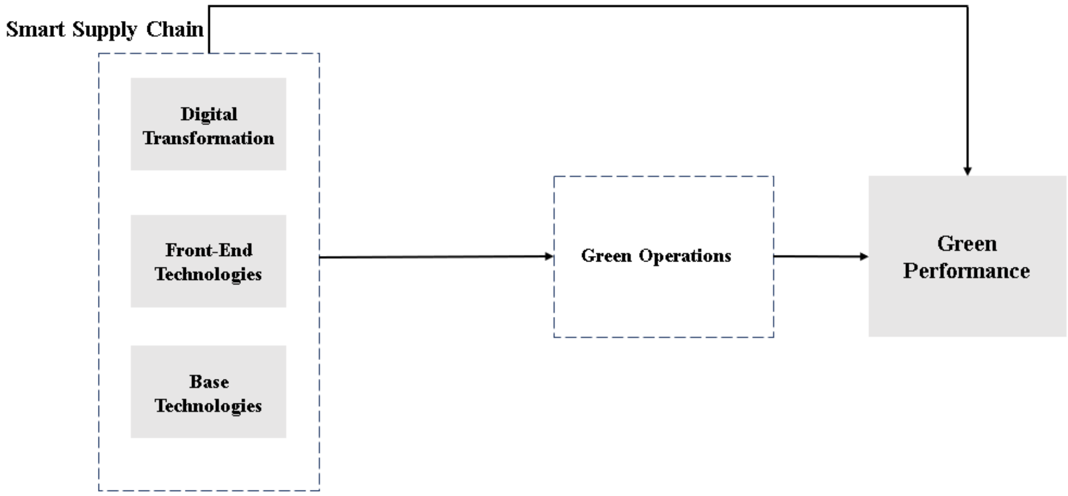
Green operations mediate the positive relationship between smart supply chain and green performance.

Research Model

The conceptual model for the illustration of the research problem is presented in the figure below. The independent variable is considered the configuration of SSC and the dependent variable is the green performance, with the green operations as the mediator in the model.

Figure3.

Research Model



CHAPTER IV

Methodology

This chapter encompasses comprehensive in-depth overview regarding the research design, participants/sample, data collection procedure, and analysis processes as well as elucidation on how the obtained results of this research are interpreted and analyzed.

Research Design

In this study, a quantitative method is implemented. A quantitative research approach in a study involves gathering information and data from processes and individuals and transforming them into numerical data. Quantitative research gathers statistically significant data from existing and potential participants, which based on the objective of the research can be employees or customers and etc., by sending out surveys, polls or questionnaires. Quantitative research relies on statistical analysis and software tools to analyze gathered data. This analytical procedure is aimed to benefit several purposes such as data description, pattern identification, assessing the relationships between variables, and forecasting based on findings (Kotronoulas & Papadopoulou, 2023).

The statistics methods used in quantitative research are an essential part of mathematics and is broadly used for several scenarios: firstly, when it is necessary to analyze large volumes of quantitative data to validate hypotheses and test theories. Secondly, when the theories being investigated have uncertainties surrounding them. Third, when it is possible to conduct the research effectively through simple questionnaires with concise responses. Lastly, when the obtained data can be quantified and compared (Basias & Pollalis, 2018).

In the quantitative methodology, researchers approach a specific phenomenon and theory with the use of scientific method to guide research procedures. They aim to achieve and acquire data that is comprehensive, rich, deep, and reliable. Viewing the problem as objective and strive to determine measurable relationships among variables of the problem and to test and validate their study hypotheses (Mohajan, 2020). Since the research can be rigorously and reliably measured, it is often referred as empirical research. Researchers are able to use different methods to organize, rank, or evaluate the gathered data. Graphs, tables and charts are examples of data illustration methods used to help the interpretation of results (Fryer et al., 2018).

Procedures

The steps and procedures carried out by researchers in order to collect, investigate, and illuminate data are referred to as research procedure. It comprises finding, selecting, processing, and assessing the data. The employed steps in this study are as follows:

1. A review of the literature on the research topic.
2. Choosing the research population and an appropriate and convenient sample size with the help of the table constructed by Sekaran and Bougie.
3. Distribution of the questionnaire to the participants.
4. Choosing the appropriate statistical approach for data analysis and interpretation.

Research Participants

The population for this study was chosen as employees of two manufacturing companies, Yazd steel manufacturing and Bandar-e-Imam Petrochemical manufacturing. According to their representatives and official websites, the combination of both companies comprises of 5,000 employees. The Yazd steel manufacturing has 1,600 employees and the Bandar-e-Imam Petrochemical manufacturing has approximately 3,400 employees. Sekaran & Bougie (2009) introduced a table in order to determine the sample size for different population sizes. Based on the introduced table, the appropriate sample size for this research is suggested to be 357 with a confidence level of 95% and the marginal error of 5%. For the selection of participants, the convenience sampling method was used.

Sample and Sampling Methods

In this study, convenience sampling was employed for the sampling approach. This method was selected because of its practical uses and accessibility that it provides. This method was used because of its advantages and straightforward data gathering procedure. For the scope and objective of this study, convenience sampling imparted a practical and applicable approach to data collection. Convenience sampling is considered as a non-probability sampling procedure that researchers select participants based on their accessibility (Sekaran & Bougie, 2009). It allows researchers to collect data as quickly as possible without the need for extra planning. However, convenience sampling may include biases in data, since individuals that are more accessible may not represent the entire population's interests (Sekaran & Bougie, 2009).

Data Collection Tools and Materials

A survey questionnaire was adopted and employed in order to assess the relationship between SSC configuration and green performance and the role of green operations as the mediator of mentioned relationship. In order to assess this research quantitatively, a questionnaire was adopted from (Lerman et al., 2022) that were used to measure different aspects of the relationships between green performance and smart supply chains. Moreover, the questionnaire adopted from (Lerman et al., 2022) is also designed to measure the relationship between sub variables in the configuration of smart supply chain and their individual effects on green performance. An email was sent to the corresponding author for the permission that their questionnaire be used in this study, which was granted. The questionnaire comprises of demographic questions, 5 scales and 27 items in total.

The survey includes six sections which are demographic section, digital transformation scale, front-end technologies scale, base digital technologies scale, manufacturing operations scale, and green performance scale. The contents of each section and scale used in the questionnaire are described below.

Demographic Section

In this section, the survey collects demographic information regarding participants. The information collected in this section includes age, gender, education level, and working experience.

Digital Transformation Scale

The digital transformation scale was used in order to measure how companies are moving towards a more digital and automated supply chain network. This scale was adopted from Lerman et al. (2022). This scale consists of five questions that aims to determine what objectives and goals companies are pursuing towards achieving a smarter supply chain network. An example question for digital transformation scale is: We aim to create a stronger communication network between different sectors of the supply chain with digital technologies.

Base Digital Technologies Scale

The base digital technologies scale was used in order to determine what base technologies are the companies implementing or have implemented in their supply chain network. This scale was adopted from Lerman et al. (2022). This scale enables us to assess the effects of base digital technologies on green performance. An example question from base digital technologies scale is: We use Big Data Analytics in our company processes as well as supply chain.

Front-End Technologies

The front-end technologies scale was used in order to measure the digital and smart interfaces used in the supply chain network which are helpful to achieve green performance on both supplier and customer sides of supply chain network. This scale was adopted from Lerman et al. (2022). This scale enables us to assess and analyze how the companies are benefiting from these technologies. An example question of front-end technologies scale is: We use collaborative robotics in our firm processes as well as our supply chain.

Green Operations Scale

The green operation scale was used in this study in order to measure its role as a mediator for the relationship between SSC and green performance. This scale was adopted from Lerman et al. (2022). This scale enables us to understand and analyze the mediating role of green manufacturing. This scale includes five questions. An example of green manufacturing scale question is: Our company assesses the environmental impact to its production processes.

Green Performance Scale

The green performance scale was used in order to measure the green performance of the companies as a result of implementing smart supply chain management. This scale was adopted from Lerman et al. (2022). This scale comprises four questions. An example of a green performance scale question is: Our company has reduced its use of hazardous/environmentally harmful materials over the past three years.

In this study, an accurate five-point-Likert scale for the study was used. The five-point-Likert scale represents the opinion of participants regarding each question. The scale was used to investigate the effects of digital transformation, base digital technologies, and front-end technologies on the green performance as well as the mediating role of green manufacturing on the smart supply chain and green performance relationship. The table below represents the five-point-Likert scale.

Table 1.

Five-point-Likert Scale

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Data Collection Procedures

Therefore, an online version of the survey questionnaire was developed using Google Forms to make it easier for participants to access online. Known employees distributed the questionnaire link to their Yazd Steel Manufacturing and Bandar Imam Petrochemical Company colleagues. In order to reach the targeted sample size, employees who knew the researcher distributed the questionnaire within their companies. Data collection occurred approximately two months, from 2nd of April 2024 to 2nd of June 2024. Participation was voluntarily. In addition to the questionnaire, an information sheet explaining the study and an informed consent form were provided. The participants were employees of said companies.

Ethical Considerations

The adopted questionnaire was forwarded to the participants only upon obtaining approval from the Near East University Ethical Committee. It was done with an Approval document number NEU/SS/2024/1790. Before the answering process, participants received information regarding the study and gave consent forms. The data will be used solely for research purposes and may be presented at national or international academic conferences and/or published in scholarly works. Data will be stored on Google Forms for two years and will then be deleted permanently. No names or email addresses were collected or recorded on Google Forms to protect the anonymity of the participants.

The participants were approached individually, and the participation was strictly voluntary, with no coercion involved. The researcher followed ethical standards to ensure that only accurate data was collected and no falsified or fabricated information was used. Moreover, the research was in line with the Near East University thesis guidelines, including its plagiarism acceptability criteria, and all cited sources were adequately formatted and referenced in accordance with academic standards.

Data Analysis Plan

The data collected was analyzed by SPSS 27. Before processing, the data was carefully edited, coded, and categorized. Descriptive analysis was carried out to examine the demographic variables and to find out the mean and standard deviation regarding the scale items. This is useful in the identification of patterns and summarizing data through measures like mean, mode, median, standard deviation, variance, and range. In the analysis of the relationship between the variables, correlation analysis was done prior to testing the hypotheses (Basias & Pollalis, 2018). Regression analysis was also used to test the relationship between the variables and the hypotheses under study. Both the correlation and regression analyses were part of the data analysis in this study.

When investigating the relationship between variables, the correlation analysis has become one crucial part of these investigations. Due to its wide range of application and its practicality, the correlation analysis is used in all areas of science on a regular basis (Selvamuthu & Das, 2024). Moreover, the correlation analysis is mostly used in order to find patterns in the datasets. When the correlation is positive, it represents that if one variable increases, the other one will increase as well. In other words, a positive correlation between two variables means that the direction that they move is similar to each other. Meanwhile, if the correlation is negative, demonstrates that if one variable increases, the other one will decrease and vice versa. Lastly, if the correlation equals to 0, then the variables have no relationship with each other. While, the correlation analysis demonstrates the relationship between variables, it does not imply causation. The main point of correlation analysis is that it will allow researchers to recognize which variables are dependent on each other and how they are dependent to each other, the result of which can give valuable insights for further investigation (Selvamuthu & Das, 2024).

The basis of regression as a statistical technique centers around determining the strength and nature of the relationship that may exist between dependent and independent variables. From performing a regression, one could have the confidence to state which factor has been significant or not and, in turn, is being influenced or otherwise (Selvamuthu & Das, 2024). Correlation analysis depicts the degree of the relationship but does not explain it. Regression analysis is, therefore, employed to show explanations between these variable relationships. It does the correlation and regression analyses, which are important in quantitative research when testing hypotheses (Pal & Bharati, 2019).

CHAPTER V

Data Analysis and Results

In this chapter, the data gathered from participants is carried out and analyzed and the results are presented and elucidated. The data analysis in this study aims to represent the interrelation between digital transformation, front-end technologies, base technologies, green operations and green performance.

Number of Respondents

In accordance with the findings of this research, 357 participants filled out the distributed survey. The study showed a 100% response rate for the survey. The main focus on this study for the purpose of data analysis was to interpret the demographic data and the descriptive analysis of "green performance scale" representing the dependent variable and the "configuration of smart supply chain" with three sub variables "digital transformation, base technologies, and front-end technologies" as the independent variable. Moreover, the mediating variable also known as the mediator the "green operations" is investigated for further analysis. Correlation and regression analysis was carried out by the researcher in order to further comprehend the relationship between variables.

Reliability

In order to test the reliability of the gathered data, a Cronbach's Alpha reliability analysis was performed on the research data. Based on the reliability analysis of this research, the total reliability of the research for the total items of the questionnaire is 94.3%. The Cronbach's Alpha for the smart supply chain scale was 90.5%, for green operations scale was 86.1%, and for the green performance scale was 76.6%. The objective of this analysis was to assess whether the scales and items used in the questionnaire are reliable or not. Since the Cronbach's Alpha for all of the items and scales is above 70%, the statistical data for the developed hypotheses are reliable. Table 2 represents the findings regarding Cronbach's Alpha analysis of this research's variables.

Table 2.
Reliability Analysis

Variables	No. of Items	Cronbach's Alpha
Smart Supply Chain	14	0.905
Green Operations	5	0.861
Green Performance	4	0.766
Total	23	0.943

Demographic Data

The demographic information includes each participant's age, gender, education and their experience on the job. The statistical data gathered from the demographic data of the questionnaire consisting age, gender, educational level and participants' experience is provided in table 3 below. In the questionnaire, the age of the participants was grouped in four different categories, namely: 21-29, 30-39, 40-49, and over 50. The table illustrates that 23.8% of the participants' age was categorized in the 21-29 group, 28.85% of the participants' age was categorized in the 30-39 category, 25.2% of the participants' age was categorized in the 40-49 category, and lastly, 22.15% of the participants' age was categorized in the over 50 categories. The table also provides information on the gender data of the distributed questionnaire, 46.2% of the participants were female and 53.8% of the participants were male.

Moreover, the education section of the questionnaire has three levels namely, diploma, undergraduate, and graduate. Diploma option refers to participants that are holding a high school diploma degree which accounts for 29.5% of the participants. Undergraduate level refers to participants with a bachelors' or any associate university degree, which accounts for 36.5% of the participants. Lastly, the graduate option of the questionnaire refers to any higher university degree including master's and PhD degrees, this accounts for 34% of the participants. The last demographic data gathered by the questionnaire is the experience which is categorized in four different categories consisting of: work experience of 1-2 years, work experience of 2-5 years, work experience of 5-10 years, and over 10 years of work experience. From the table we can see that 24.9% of participants have 1-2 years of experience, 20.2% of the participant have 2-5 years of experience, 25.2% of the participants have 5-10 years of experience and 29.7% of the participants have over 10 years of experience.

Table 3.
Respondent's Demographic Data

Variable	Categories	Frequency	Percentage
Age	21-29	85	23.8
	30-39	103	28.85
	40-49	90	25.2
	Over 50	79	22.15
	Total	357	100
Gender	Male	192	53.8
	Female	165	46.2
	Total	357	100
Educational Level	Diploma	105	29.5
	Undergraduate	130	36.5
	Graduate	122	34
	Total	357	100
Experience	1-2 years	89	24.9
	2-5 years	72	20.2
	5-10 years	90	25.2
	Over 10 years	106	29.7
	Total	357	100

Descriptive Analysis of Smart Supply Chain

As the aim of the present research was to determine the effects of digital transformation of SC on green performance of steel and petrochemical manufacturing companies, a 5-Point Likert Scale was adopted in order to gather responses from participants with the options: 1, 2, 3, 4, and 5; representing “Strongly Disagree”, “Disagree”, “Neutral”, “Agree”, and “Strongly Agree” respectively. For the interpretation of the resulted mean values, table 4 shows the encoded 5-point Likert scale for interpretation of the resulted means (Pagaran et al., 2023).

Table 4.
Interpretation of 5-Point Likert Scale for Mean Values

Likert Scale	Mean Value	Description
1	1 – 1.79	Strongly Disagree
2	1.80 – 2.59	Disagree
3	2.60 – 3.39	Neutral
4	3.4 – 4.19	Agree
5	4.20 – 5.0	Strongly Agree

Table 5 represents the descriptive analysis for smart supply chain configuration scale and how it influences the green performance. The mean values in this scale range from 2.39 to 4.21. Based on the results of the descriptive analysis. For the item stating that the company aims to digitize everything in the SC, the mean value of responses is 3.68. As for the item stating that the company aims to collect large scales of data from different sources in the SC the mean value is 4.02, and the item stating that the company aims to create a stronger network in the SC the mean value is 4.21. Moreover, the mean value of 4.08 is for the item stating that the company aims to exchange information in the SC with digitization, and the mean value of 4.21 is for the item stating that the company aims to enhance the customer interface with digitization efficiency. The use pf collaborative robotics in the SC has a mean value of 3 in the SSC survey item. The use of computer simulation in the SC has a mean value of 3.55, and the use of augmented reality in the SC has a mean value of 2.92. Moreover, the use of 3D printing in the SC processes has a mean value of 2.39, and the item stating that the company uses IoT in their SC processes has a mean value of 2.77.

Table 5.
Descriptive Analysis of Smart Supply Chain

Smart Supply Chain	Mean	Standard Deviation
We aim to digitize everything in the supply chain.	3.68	1.15
We aim to collect large amounts of data from different sources in the supply chain.	4.02	0.824
We aim to create a stronger communication network among different sectors of the supply chain by digitalization.	4.21	0.88
We aim to exchange information in the supply chain with digitalization.	4.08	0.97
We aim to enhance the customer interface with digitization efficiency.	4.21	1.04
We use collaborative robotics in our company processes and in the supply chain.	3	1.1
We use computer simulation in supply chain processes.	3.55	0.99
We use augmented reality in supply chain processes.	2.92	0.94
We use 3D printing in supply chain processes.	2.39	1.28
We use Internet of Things in our supply chain processes.	2.77	1.19
We use cloud computing in our supply chain processes.	3.08	1.14
We use Big Data analytics in our company processes and supply chain.	2.84	1.18
We use artificial intelligence in our supply chain processes.	2.88	1.02
We use block chain in the supply chain processes.	3.04	1.2

The use of cloud computing in the SC has a mean value of 3.08, and the mean value of 2.84 belongs to the item stating that the company uses Big Data analytics in their SC processes. The use of AI in the SC processes has a mean value of 2.88, and the item stating that they use blockchain technologies in their SC processes has a mean value of 3.04.

Descriptive Analysis of Green Operations

Table 6 shows the results of the descriptive analysis for the green operations scale of the survey and its influence on the green performance. Based on the analysis, the mean values range 2.76 to 3.08. For the item stating that the company assesses the environmental impacts to develop/improve products, the mean value is 3.03, and for the item stating that the company develops products with recyclable raw materials has a mean value of 2.76. The mean value of 3.08 is for the item stating that the company develops products with lowest consumption of resources, and for the item stating that the company develops products with low impact on environment the mean value is 2.84. Lastly, the item stating that the company develops products with a high lifespan has a mean value of 2.87.

Table 6.
Descriptive Analysis of Green Operations

Green Operations	Mean	Standard Deviation
Our company assesses the environmental impact to develop/improve products	3.03	1.2
Our company develops products with recyclable raw material.	2.76	1.19
Our company develops products with lowest consumption of resources.	3.08	1.14
Our company develops products with low impact on the environment.	2.84	1.18
Our company develops products with a high life span.	2.87	1.02

Descriptive Analysis of Green Performance

Table 7 shows the results of descriptive analysis of green performance which is the dependent variable of this study and the objective of the research is to assess the effects of SSC configuration and green operations on the green performance. Based on the results of the descriptive analysis of green performance scale, the items mean values range from 3.16 to 3.55. The mean value of 3.38 belongs to the item stating that the company has increased material recycling in over the past three years, and the mean value of 3.16 is for the item stating that the company reduced emissions over the past three years. The highest mean value of 3.55 in this scale is for the item stating that the company has reduced use/waste of resources over the past three years. Lastly, the item stating that the company has decreased its use of hazardous/environmentally harmful materials over the past three years has a mean value of 3.36.

Table 7.
Descriptive Analysis of Green Performance

Green Performance	Mean	Standard Deviation
Our company has increased material recycling over the past three years.	3.38	0.94
Our company has reduced emissions over the past three years.	3.16	1.14
Our company has reduced use/waste of resources over the past three years.	3.55	1.25
Our company has decreased its use of hazardous/environmentally harmful materials in the past three years.	3.36	1.07

Correlation Analysis

Correlation analysis was used in this research in order to test and check whether there is a relationship between variables or not. Correlation analysis helps researchers to find out whether two variables have a positive, negative or no relationship between each other. In order to determine the correlations between this research's variables, the Pearson correlation coefficient was employed and the variables were assessed on a continuous scale.

After performing the Bivariate Correlation analysis on SPSS, the relationship between variables can be interpreted. The relationship between smart supply chain and green operations was positively correlated with values (0.773, $p < 0.001$), which illustrates that there is a strong positive linear relationship between smart supply chain and green operations.

The correlation coefficient for the variables smart supply chain and green performance shows a strong positive linear relationship between those two variables with values of (0.768, $p < 0.001$). This illustrates that smart supply chain configuration is highly correlated with higher levels of green performance.

Lastly, the relationship between green operations and green performance is a moderate positive linear one according to the correlation analysis with the r value of 0.762 and $p < 0.001$. By calculating the coefficient of determination or r^2, which equals to 0.581, it can be interpreted that 58.1% of the variation in green performance can be explained by the green operations variable. In the table 8, the Pearson's correlation results are presented for the scales.

Table 8.
Correlation Analysis

Scale	Smart Supply Chain	Green Operation	Green Performance
Smart Supply Chain	1	0.773	0.768
Green Operations	0.773	1	0.762
Green Performance	0.768	0.762	1

Note: ** Correlation is significant at 0.01 level (2-tailed).

Hypotheses Testing and Results

In this research the regression analysis with SPSS v.27 was employed in order to test the proposed hypotheses. This research, as previously demonstrated, comprises of four hypotheses which includes the determination of the mediating role of green operations in the proposed model. The relationships between the variables in the proposed hypotheses are as follows:

H1: The configuration of smart supply chain has positive effects on green performance.

H2: The configuration of smart supply chain has positive effects on green operations.

H3: Green operations have positive effects on green performance.

H4: Green operations mediate the positive relationship between smart supply chain and green performance.

H1: The Configuration of the Smart Supply Chain Has Positive Effects on Green Performance

Hypothesis H1 assumes that smart supply chain positively impacts the green performance. Tables 9 to 11 demonstrate the regression analysis results of the relationship between smart supply chain management and green performance. The analysis shows that the path between SSC and green performance was significant since the p-value is less than 0.05 ($F_{(1,355)} = 510.37$, $p < 0.05$, $R^2 = 0.589$). The R^2 value interprets that 58.9% of variation or change in the green performance of the organization can be explained by smart supply chain. The model coefficient demonstrates that smart supply chain was positive and significant to green performance ($T_{(355)} = 22.591$, $\beta = 0.226$, $p < 0.05$). Therefore, hypothesis H1 was accepted.

Table 9.
Model Summary of the Regression analysis of SSC on Green Performance

Model Summary							
				Change Statistic			
Model	R	R Square	Adjusted R Square	F Change	df1	df2	Sig. F Change
1	0.768	0.590	0.589	510.37	1	355	< .001
Predictors: (Constant), Smart Supply Chain							

Table 10.
Anova Results of the Regression analysis of SSC on Green Performance

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2415.002	1	1519.270	510.37	< 0.001[b]
	Residual	1679.811	355	4.732		
	Total	4094.812	356			

a. Dependent Variable: Green Performance

b. Predictors: (Constant), Smart Supply Chain

Table 11.
Coefficients Results of Regression analysis of SSC on Green Performance

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.346	0.549		2.453	0.015	0.267	2.425
	SSC	0.26	0.011	0.768	22.259	0.001	0.237	0.282

a. Dependent variable: Green Performance

H2: The Configuration of Smart Supply Chain Has Positive Effects on Green Operations.

The next proposed hypothesis posits that smart supply chain positively affects green operations. As demonstrated in Tables 12 to 14, the results from linear regression analysis show that the path between smart supply chain and green operations is significant since the p-value is less than 0.05 ($F_{(1,355)} = 526.186$, $p < 0.05$, $R^2 = 0.596$). The R^2 value shows that 59.6% of variation or change in the green operations of the supply chain can be explained by smart supply chain configuration. Moreover, the coefficients results show that the smart supply chain was positive and significant to green performance ($T_{(355)} = 22.939$, $\beta = 0.355$, $p < 0.05$). Hence, the hypothesis H2 is supported.

Table 12.
Model Summary of the Regression analysis of SSC on Green Operations

Model Summary							
				Change Statistic			
Model	R	R Square	Adjusted R Square	F Change	df1	df2	Sig. F Change
1	0.773	0.597	0.596	526.186	1	355	< .001
Predictors: (Constant), Smart Supply Chain							

Table 13.
Anova Results of the Regression analysis of SSC on Green Operations

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4514.716	1	4514.716	526.186	< 0.001[b]
	Residual	3045.928	355	8.58		
	Total	7560.644	356			

c. Dependent Variable: Green Operations

d. Predictors: (Constant), Smart Supply Chain

Table 14.
The Coefficients Results of the Regression analysis of SSC on Green Operations

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-1.985	0.739		-2.687	0.008	-3.438	-0.532
	SSC	0.355	0.015	0.773	22.939	0.001	0.325	0.385

b. Dependent variable: Green Operations

H3: Green Operations Have Positive Effects on Green Performance.

The third proposed hypothesis H3 posits that green operations have positive effects on green performance. Table 15 to table 17 show the results from the performed linear regression analysis on the green operations and green performance. The results of the analysis show that the path between green operations and green performance is significant since the p-value is less than 0.05 ($F_{(1,355)} = 491.514$, $p < 0.05$, $R^2 = 0.579$). The R^2 value shows that 57.9% of variation or change in the green performance can be explained by green operations in the supply chain. Also, the coefficients results show that green operations were positive and significant to green performance ($T_{(355)} = 22.17$, $\beta = 0.561$, $p < 0.05$). Hence, the hypothesis H3 is supported.

Table 15.
Model Summary of the Regression analysis of Green Operations on Green Performance

Model Summary							
				Change Statistic			
Model	R	R Square	Adjusted R Square	F Change	df1	df2	Sig. F Change
1	0.762	0.581	0.579	491.514	1	355	< .001
Predictors: (Constant), Green Operations							

Table 16.
Anova Results of the Regression analysis of Green Operations on Green Performance

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2377.583	1	2377.583	491.514	< 0.001[b]
	Residual	1717.23	355	4.837		
	Total	4094.812	356			
e. Dependent Variable: Green Performance						
f. Predictors: (Constant), Green Operations						

Table 17.
Coefficients Results of the Regression analysis of Green Operations on Green Performance

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound
1	(Constant)	5.286	0.387		13.664	0.001	4.525	6.047
	Green Operations	0.561	0.025	0.762	22.17	0.001	0.511	0.611

Coefficients[a]

c. Dependent variable: Green Performance

H4: Green Operations Mediate the Positive Relationship Between Smart Supply Chain and Green Performance.

Lastly, the mediating role of green operations in the relationship between smart supply chain and green performance is analyzed. The regression analysis done on the data shows that smart supply chain management is positively associated with green performance and green operations. Moreover, the green operations regression analysis on green performance demonstrated that green operations is positively associated with green performance. The regression results were all statistically significant which support the proposed hypotheses in this study. Hypothesis H1, stating that SSC has positive effects on green performance was supported and significant ($F_{(1,355)} = 510.37$, $p < 0.05$, $R^2 = 0.589$). Hypothesis H2, stating that SSC has positive effects on green operations was supported and significant ($F_{(1,355)} = 526.186$, $p < 0.05$, $R^2 = 0.596$). Additionally, hypothesis H3, which states that green operations have positive effects on green performance was supported and significant ($F_{(1,355)} = 491.514$, $p < 0.05$, $R^2 = 0.579$). Since the obtained results were supporting the hypotheses proposed and were significant, it can be conferred that the mediating role of green operations in the SSC effects on green performance is significant and supported. Table 12 shows the results of multiple regression analysis performed to confirm the significance of the mediating effect of green operations on the SSC's effects on green performance.

Table18 represents the results of a multiple regression analysis performed in SPSS27 and its model summary. As the table shows, the analysis was significant and the hypothesis stating that green operations mediate the effects of SSC on green performance is supported since the p-value is less than 0.05 ($F_{(1,355)} = 344.032$, $p < 0.05$, $R^2 = 0.658$).

As for table19, which represents the ANOVA test results which is significant. Lastly, table20, shows the regression results which has two independent variables which are SSC and green operations. Both of the results are significant, the LLCI and ULCI does not include zeros in both cases which mean that the results are statistically significant.

Table 18.
Model Summary of the Multiple Regression Analysis of SSC and Green Operations on Green Performance

Model Summary							
				Change Statistic			
Model	R	R Square	Adjusted R Square	F Change	df1	df2	Sig. F Change
1	0.813	0.66	0.658	344.032	1	355	< .001
Predictors: (Constant), Green Operations, SSC							

Table 19.
Anova Results of the Multiple Regression Analysis of SSC and Green Operations on Green Performance

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2703.763	2	1351.882	344.032	< 0.001[b]
	Residual	1391.049	354	3.930		
	Total	4094.812	356			

g. Dependent Variable: Green Performance

h. Predictors: (Constant), Smart Supply Chain, Green Operations

Table 20.
Coefficients Results of the Multiple Regression Analysis of SSC and Green Operations on Green Performance

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.957	0.505		3.875	0.001	0.964	2.95
	Green Operations	0.308	0.036	0.418	8.572	0.001	0.237	0.379
	SSC	0.15	0.016	0.445	9.111	0.001	0.118	0.183

d. Dependent variable: Green Performance

Table 21.
The Results of Research Hypotheses

The Developed Hypothesis for This Study	Results
1. Hypothesis1: The configuration of smart supply chain has positive effects on green performance.	Supported
2. Hypothesis 2: The configuration of smart supply chain has positive effects on green operations.	Supported
3. Hypothesis 3: Green operations have positive effects on green performance.	Supported
4. Hypothesis 4: Green operations mediate the positive relationship between smart supply chain and green performance.	Supported

CHAPTER VI

Discussion and Conclusion

In this chapter, a brief explanation on the findings of the study is provided. Also, conclusion and interpretation of the results of the analysis of this study, as well as suggestions for practical and academic take aways are presented.

Discussions

This study suggests that smart supply chain effects green performance. Also, in this research the mediating role of green operations is evaluated in the SSCM and green performance relationship in said industries. The objective of this research was to figure out how smart supply chain configuration with a holistic approach rather than specific technological advancements can impact the green performance of the companies. Furthermore, considering that the chosen industries are quite polluting and vital to every day's life, the role of green operations in the supply chain as a mediator was evaluated as well. Based on the achieved results, this study's reliability analysis showed a reliability of 94% which shows that the responses were reliable for further analysis. The participants of this study's questionnaire were 53.8% male and 46.2% female.

The first hypothesis stating that SSC has positive effects on green performance was tested via linear regression analysis. The results presented in the data analysis chapter show that the hypothesis is supported and is significant. The findings suggest that the configuration of SSC has positive impacts on green performance. Hence, the adoption of advanced technologies in the supply chain is suggested and will positively influence green performance. From the first hypothesis of this study, supporting the positive effects of smart supply chain on green performance; the results confirm that SSC configurations significantly contribute towards enhanced green performance results that are in tune with recent studies such as Bechtsis et al. (2022) which investigated the role of digital transformation and smart supply chain technologies in enhancing sustainability performance. The study focused on how real-time data, automation, and predictive analytics influence operational efficiency. Their findings show that digital technologies such as AI, IoT, and blockchain improve supply chain transparency and operational optimization, which leads to reduced waste, lower emissions, and better resource utilization. The study also found that firms integrating digital tools within supply chains reported a 20–30% reduction in environmental impact.

Caiado et al. (2022), who stated that digital transformation is an enabler of GSCM, developed a conceptual framework for aligning smart supply chain strategies with sustainability objectives, emphasizing digital business transformation and predictive analytics. The study demonstrated that firms that integrate digital strategies with sustainability initiatives achieve better green performance and long-term cost savings. Additionally, proactive investment in smart supply chains leads to an 18% improvement in sustainability scores, as companies optimize energy consumption and minimize production waste.

Kumar et al. (2023) also note that organizations' adoption of SSCs leads to considerable cost reductions and improvement in sustainability metrics. This study's results corroborate these findings, demonstrating lower emissions, higher energy efficiency, and optimization of supply chain operations. This study also points out the same fact as earlier research, which states that technological integration needs strategic alignment to reap long-term sustainability benefits.

The second hypothesis states that SSC positively affects green operations and was tested via linear regression analysis. The results presented in the data analysis chapter show that the hypothesis is supported and is significant. The findings suggest that the configuration of SSC has positive impacts on green operations. As a results, SSC, implemented thoroughly, will positively improve green operations within the supply chain. The results from the second hypothesis, H2, indicate that SSC benefits green operations through improved supply chain visibility, process automation, and the ability to make real-time decisions. Benzidia et al. (2021) explored the role of big data and AI-driven supply chain monitoring in improving sustainability, focusing on how firms implement real-time analytics and automation to reduce inefficiencies. Their study found that companies that employ data-driven automation in their supply chains reduce excess inventory by 25% and cut waste by 15%. It also highlighted that green operations are more effective when supported by AI-driven decision-making and predictive maintenance systems. Mohseni et al. (2019) Studied how smart supply chains enhance green operations in industries with high resource consumption, particularly focusing on predictive analytics, automated waste reduction, and energy-efficient production. Their research found that companies using digital transformation strategies reduced their environmental footprint by 30%, as automated energy management systems and smart logistics led to better resource allocation. The study also emphasized that firms adopting AI-powered waste monitoring saw a 40% improvement in process efficiency. Lerman et al. (2022) Investigated how smart supply chain configurations improve green operations, emphasizing the integration of base digital technologies and front-end applications. The study found that companies implementing SSC technologies experienced a 28% increase in operational efficiency due to real-time tracking, automated sourcing, and AI-driven inventory control. It also highlighted that firms that align green operations with digital transformation strategies see greater sustainability gains compared to those that adopt SSC without structured environmental initiatives.

The third hypothesis states that green operations positively affect green performance and was tested via linear regression analysis. The results presented in the data analysis chapter show that the hypothesis is supported and is significant. The findings suggest that the green operations have positive effects on green performance. Hence, Implementing green operations within the SC will positively increase a company's green performance. This study finds a strong and significant relationship between green operations and green performance, supporting hypothesis H3. Umar et al. (2022) analyzed the impact of AI, IoT, and machine learning in green supply chain operations, emphasizing how technology improves sustainability. The study showed that firms using AI-driven demand forecasting reduced energy waste by 30%, while automated logistics and route optimization led to an 18% decrease in transportation emissions. The study also found that companies with integrated smart manufacturing strategies saw measurable improvements in green performance.

Wu et al. (2024) explored the use of IoT, cloud computing, and blockchain to optimize green supply chain processes, particularly in manufacturing and logistics. Their research found that green supply chains leveraging real-time tracking and AI-based sustainability planning reduced material waste by 22%. Moreover, companies using cloud-based resource allocation tools improved green efficiency by 19%, showing a strong link between smart operations and sustainability. Adam et al. (2021) assessed the influence of IoT-based sustainability measures in the oil and gas industry, focusing on supply chain transparency and efficiency. Their research found that IoT-driven monitoring systems reduced greenhouse gas emissions by 27% in participating firms. Additionally, companies adopting predictive analytics for resource consumption saw a measurable improvement in their sustainability performance and operational efficiency.

Lastly, the fourth hypothesis states that green operations have mediating effects on the impacts of SSC on green performance. Based on the findings of previous hypotheses which were all significant and supported, the mediation brought by green operations was supported and significant. This suggests that the integration of SSC and green operations which works as a mediator, will result in an increase in their green performance. The findings confirm that GO mediates SSC and GP, supporting H4. Patidar et al. (2023) Studied the mediating role of sustainability-driven operations in digital supply chains, assessing how companies leverage smart technologies for green performance. Their study concluded that green operations act as a key intermediary, ensuring that smart supply chain benefits translate into long-term sustainability. Companies that strategically integrated green initiatives within SSC frameworks saw a 35% improvement in green performance. Cole et al. (2019) investigated the effects of blockchain, AI, and digital transparency on supply chain sustainability, particularly in industries with high environmental impact. Their study confirmed that blockchain-driven transparency allows firms to monitor sustainability metrics more effectively, leading to better regulatory compliance and green performance. It also found that without structured green operations, SSC benefits do not directly translate into environmental improvements. Hohn & Durach (2021) analyzed the effects of digital transformation, supply chain governance, and smart manufacturing on environmental sustainability. Their research concluded that firms integrating green operations within digital supply chains improved sustainability scores by 32%. It also found that automated green operations (such as AI-based waste monitoring) significantly enhanced smart supply chain efficiency.

All the hypotheses have received support through empirical evidence, and hence, they show the greater relevance of smart supply chain configuration to green operations and attaining environmental goals. The current study contributes to the increasing literature that concentrates on the digital transition of green SCM and the green performance of industrial sectors.

Theoretical Implications

The findings from this study's analysis suggests that smart supply chain implemented thoroughly with the three dimensions has positive effects on the companies' green performance. Moreover, the mediation analysis of green operations in the model showed that green operations mediate the impacts of SSC on green performance.

First, the findings of this study showed that SSC effects on green performance were statistically significant. The configuration of SSC with the three dimensions (digital transformation strategy, base technology, and front-end technology) aims to fully transform the traditional SC into a SSC in every aspect possible with advanced digital technologies. The SSC configuration concept suggests that SSC can have positive effects on green performance due to its use of advanced technologies. The dependent variable in this study, green performance, aims to evaluate the company's environmental performance with specific criteria i.e. the company's carbon footprint, energy use, and produced waste. Implementing digital technologies in supply chain can enable firms to achieve higher levels of transparency and real-time data sharing which can lead to higher levels of green performance. Digital transformation strategies enable firms to build the ground for further digitization of the supply chain and open new opportunities for the firm. Base technologies and front-end technologies enable the firms to complete their digitization and make better use of advanced technologies in the SCM, which can result in smart supply chain configuration. The SSCM can enable a company to increase its transparency, workflow, data sharing which in turn can enhance its green performance. Technologies that are used in SSCM such as AI, Blockchain and cloud computing enhances companies' environmental performance by diminishing their negative impact on environment (Benzidia et al., 2021; Cole et al., 2019; Sony, 2019). While these previous studies mainly discussed one or two aspects of digitization of SCM, in this study, the holistic approach into the digitization of supply chain and its effects on green performance was empirically investigated. The results of the analysis supported the positive effect of SSC on green performance and was statistically significant.

Secondly, the results of the analysis support the hypothesis stating that SSC has positive effects on green operations within the supply chain. Advanced technologies can enable companies to enhance their operations with technologies such as robotics and AI, so that their environmental footprint diminishes resulting in a higher level of green performance. According to Mohseni et al. (2019) As the concerns for environmental health increased by governments and stakeholders, firms started to implement changes to their supply chain activities, taking green initiatives within this specific part of supply chain. The SSC configuration needs to be aligned with the operational level of supply chain in order to achieve the intended goals, specifically environmental goals. This alignment, implemented meticulously, can result in better long-term sustainability performance. The empirical investigation done in this study supported the proposed hypothesis that the configuration of SSC has positive effects on green operations. The results show that advanced technologies in supply chain can positively influence the green operations of the supply chain.

Thirdly, as for the green operations, this study's analysis shows that green operations can have its sole positive impacts on green performance which supports the proposed hypothesis H3 of this study. Hypothesis H3 which stated that green operations positively affect green performance was supported based on the regression analysis performed on the data. Green operations within the supply chain which is also known as green supply chain management indicates the application of green strategies into the operational layer of the supply chain(Frank et al., 2019). Umar et al. (2022) defined green supply chain management as the integration of environmentally accountable benchmarks into the conventional supply chain in a manner that enables organizations to pursue both supply chain goals and environmental goals. The supply chain operations aim to increase revenue while keeping the value chain at a high level with low risk (Abdussalam et al., 2021b). In this study, the green operations and its effects on the green performance was empirically investigated and the results concluded that implementing green operations in the supply chain can enhance the green performance. The findings indicate that green operations positively influence green performance and companies are suggested to implement green operations into their SCM.

Lastly, hypothesis H4 which stated that green operations positively mediate the effects of SSC on green performance was supported based on the results of the analysis. While both of the variables, SSC and green operations were shown to have their sole positive influence on green performance and SSC had positive effects on green operations based on the hypothesis H2, the green operations mediate the effects of SSC on green performance. Viewing green operations as a mediator, the configurational perspective recognizes the interdependence between SSC practices and environmentally sustainable practices. It acknowledges that the success of smart supply chain initiatives in increasing environmental performance relies not solely on advanced technology adoption but also on integrating eco-friendly practices across the supply chain. Thus, emphasizing the mediating role of green operations highlights the necessity of combining smart supply chain configuration and green operations strategies to attain comprehensive and sustainable enhancements in environmental performance.

Practical Implications

This study analyzed the impacts of smart supply chain configuration on green performance in steel manufacturing and petrochemical companies in Iran. Also, this study intended to analyze the mediation brought by green operations in the relationship between SSCM and green performance. The findings show that the configuration of SSCM can positively affect the green performance. Moreover, the positive effects of SSC on green operations were supported with the findings of H2 regression analysis. The results demonstrate that H3 which indicated that green operations positively affect green performance was supported as well. Also, the findings supported the proposed hypothesis H4, suggesting that green operations mediate the effects of SSC on green performance.

This study shows that the petrochemical and steel manufacturing companies need to acquire advanced technologies and aim to digitize their supply chain network in order to achieve higher levels of green performance. The results of the analysis in this thesis could help managers implement digital transformation strategies and acquire advanced technologies to enhance their green performance. The results of the thesis demonstrate how a thorough digitization of the supply chain can benefit the firm on environmental aspects. The results suggest that managers should consider the implementation of smart technologies in their SCM to increase their environmental performance and gain competitive advantages. Since, this study was focused on the petrochemical and steel manufacturing companies in Iran which are highly polluting and necessary for economic progress, the results can help managers to gain new perspective on improving their green performance and diminish their negative environmental footprint.

The results of this study on green operations show that while SSC can solely enhance green performance, adopting green operations in the supply chain can help enhance the achievement of better green performance. The findings show that the integrating the SSC configuration and green operations can enable companies to achieve higher levels of green performance. Managers should consider aligning the SSC configuration with green operations to enhance their green performance. The SSC and green operations should be aligned according to the company's goals in the way that enables the company to achieve their environmental goals.

Recommendations According to Findings

Based on the findings of this study, the following recommendations are proposed:

This study suggests that more research should be carried out regarding the SSC implementation in the petrochemical industry in order to investigate the problems in a deeper context.

Secondly, based on the results of the present study, the SSC configuration enhances the green performance with statistical significance.

Thirdly, green operations variable is shown to have positive effects on green performance based on the results of this research. Companies should consider implementation of green operations in their SC practices to increase their green performance.

Lastly, green operations mediate the effects of SSC on green performance based on the results obtained in this research. Companies should consider the integration of SSC and green operations to achieve better results in their green performance.

In summary, petrochemical and steel manufacturing companies are suggested to adapt to new advanced technologies withing their supply chain in order to achieve higher levels of green performance. These companies are known to having high negative impact on environment, however with the help of advanced technologies, they can enhance their processes and diminish their negative footprint on the environment.

CONCLUSION

It has been proven that the configuration of smart supply chain in the petrochemical and steel manufacturing companies can have significant effect on their green performance based on the research conducted in this study. The holistic configuration of smart supply chain which considers the integration of digital transformation strategies, base technologies and front-end technologies in the SCM however, haven't been studied extensively, particularly in sectors studied in this research. The data collected in this study demonstrated that companies are adopting the digital transformation strategy dimension of SSCM better than base technologies and front-end technologies.

In this study, the findings show that smart supply chain configuration has significant effect on green performance, demonstrating that implementing smart supply chain can enhance the companies' green performance. The hypothesis for this assumption was tested and from the results, it was illustrated that the hypothesis which states that smart supply chain configuration positively effects green performance was supported. The study also supports the hypothesis stating that smart supply chain configuration positively affects green operations. Moreover, the hypothesis stating that green operations positively affect green performance is supported as well. The mediating role of green operations in the relationship between SSCM and green performance is supported concluding that green operations partially mediate the effects of SSC on green performance.

The findings confirm that SSCs benefit petrochemical industries regarding green performance supporting hypothesis H1. AI, IoT, cloud computing, and blockchain implementations enhance supply chain visibility, real-time data processing, and automation; all these enable further improvement of energy efficiency and reduction of generated wastes, thus increasing sustainability performance metrics (Bechtsis et al. 2022). The application of those technologies enables the firm to rationalize its production process to reduce the loss of materials and energy consumption, achieving an enhanced degree of environmental performance.

This dissertation establishes that SSC adoption strengthens green operations by empowering process automation, predictive maintenance, and efficient waste management, supporting the second hypothesis, H2. In the petrochemical industry, where production processes are highly resource-intensive, real-time monitoring systems, AI-driven predictive analytics, and smart logistics solutions become very significant in terms of reducing inefficiencies while enhancing sustainability.

The findings also highlight that petrochemical firms need to embed green operations across the supply chain workflow to realize maximum benefits from digital transformation. Technologies such as digital twins, automated tracking, and production planning with energy efficiency are generating substantial benefits in improving green operations and lessening environmental impact. Moreover, the findings have revealed that such integration is not sufficient; companies have to apply digital technologies strategically to a specific field of supply chain operation in order for sustainability to materialize.

A strong relationship is established between green operations and green performance, confirming that environmentally optimized operational strategies significantly enhance sustainability in petrochemical industries. Companies that adopted AI-driven process optimization, energy-saving technologies, and waste minimization strategies performed better in resource efficiency and lower carbon emissions.

The study further identifies that green operations act as a bridge between technological advancements and green performance. Overall environmental performance can be improved with sustained operational efficiency by incorporating energy-efficient processes, optimizing production scheduling, and reducing the consumption of superfluous resources.

One of the critical findings in this study is that green operations mediate the relationship between SSC and green performance in petrochemical industries, supporting hypothesis H4. It underlines that digital transformation alone does not directly contribute to environmental performance, but its benefits are realized with structured green operational strategies. This should correspond to integrating smart supply chain solutions from a sustainability perspective with operational changes. Since the petrochemical industry is one of the highly energy and emission intensive industrial sectors, tending to produce much waste, companies must ensure that technology-driven efficiencies match pragmatic green performance improvement through optimized resource management and sustainable production practices.

This study also validates that SSC adoption combined with structured green operations can significantly improve green performance in the petrochemical industry. It would mean enhancing operational efficiencies and resources, but smart technology cannot be deemed useful unless operational strategies are carried out. It implies that a good integration of SSC technologies and sustainability-driven operational changes in energy consumption minimization, waste management, and increasing production efficiency would eventually drive green performance. The findings clearly point out how petrochemical companies must develop their supply chains through digital transformation and improve sustainability performance concurrently.

Considering the highly vital and polluting role of the steel manufacturing and petrochemical industries, configuring smart supply chain shows promise to enhance their green performance. While this study was limited to Iran, it provides insightful information on the smart supply chain configuration and its effects on green performance. For instance, the use of blockchain technologies can enhance transparency and the use of AI and robotics can enable firms to enhance their resilience and diminish their negative impacts on environment. The study also provides information on the mediating role of green operations in the model.

In conclusion, this research emphasizes the fundamental role of smart supply chain configuration and the relating green operations in achieving higher green performance goals. This study investigated the role of green operations as a mediator and the findings support that green operations works as a partial mediator in the research model. Hence, companies could relate to these findings in order to implement necessary strategies to achieve their environmental goals.

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APPENDICES

Appendix 1.

Participants Information Sheet

Participant Information Sheet and Informed Consent Form

Dear Participant,

You are asked to participate in a research study that we are carrying out in order to assess the impacts of technological advances and transformations in supply chains on companies' sustainability performance. The data collected through this scale will be used to understand how technological advancements affect supply chains and also, how they affect the sustainability performance. The data will help to understand different aspects of smartness and sustainability in a supply chain including (transforming to smart supply chain, base technologies for SC and sustainable performance.). By filling in the following scale, you agree to participate in this study. If you agree to participate, we will send out questionnaires for (4) weeks. The observations will be recorded by the researchers via online google forms. All questionnaires will be recorded via email and kept by the research team for 2 years after the completion of the study, after which they will be deleted from all of our databases.

Please note that your participation in the study is voluntary and whether you agree to participate or not will have no impact on your work. The data collected during the course of this study will be used for academic research purposes only and may be presented at national/international academic meetings and/or publications. Your identity will not be revealed in any case to third parties and pseudonyms will be used in all observational and interview data. You may quit participating in this study at any time by contacting us. If you opt out of the study, your data will be deleted from our database and will not be included in any further steps of the study. In case you have any questions or concerns, please contact us using the information below.

Dr. Ayşe Hyusein (Supervisor)
Business Administration Department,

Near East University

E-mail: ayse.hyusein@neu.edu.tr

NAME OF THE STUDENT: RAMIN SHAYANRAD
Department of Business Administration
Near East University
Email: 20226311@std.neu.edu.tr

Appendix 2.

Survey Questionnaire

The impact of smart supply chain on businesses' green performance

Dear participant,

This study aims to measure how digital transformation in supply chain affects sustainability performance of a company. The study is being conducted as part of my MSc dissertation.

Please note that your participation is voluntary and your identity will not be recorded and revealed to third parties. The study is for academic purposes only and your response will be treated with utmost confidentiality.

Your kind assistance on the completion of the questionnaire is needed which will directly affect the outcome of my thesis.

Thank you for your time.

Yours faithfully,

NAME OF THE STUDENT: RAMIN SHAYANRAD

Department of Business Administration

Near East University

Email: 20226311@std.neu.edu.tr

Section A:

Demographic Questions:

1. Age

☐21-29

☐ 30-39

☐ 40-49

☐ 50-above

2. Gender

☐ Male

☐ Female

3. Level of education

☐ Undergraduate

☐ Graduate

☐ Post-graduate

4.Experience with supply chain processes:

☐ 1-2 years

☐ 2-5 years

☐ 5-10 years

☐ More than 10 years

Tick as you see appropriate (√).

Digital Transformation

Please use the rating scale below to respond to the following statements related to **Digital Transformation in Supply Chain...** (Lerman, et al. 2022). It is important that you respond to each statement.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

	QUESTIONS	1	2	3	4	5
1	We aim to transform everything possible to smart supply chain.					
2	We aim to collect large amounts of data from different sources in the supply chain.					
3	We aim to achieve a better communication network between different sectors of the supply chain with smart technologies.					
4	We aim to exchange information in the supply chain with smart technologies.					
5	We aim to improve the interface with customers with the help of smart technologies.					

Front-End Technologies

Please use the rating scale below to respond to the following statements **related to Front-End technologies in Supply Chain…** (Lerman, et al. 2022). It is important that you respond to each statement.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

	QUESTIONS	1	2	3	4	5
1	We use collaborative robotics in our company processes and in the supply chain.					
2	We use computer simulation in supply chain processes.					
3	We use augmented reality in supply chain processes.					
4	We use 3D printing in supply chain processes.					

Base Technologies

Please use the rating scale below to respond to the following statements **related to <u>Base Technologies in Supply Chain…</u>** (Lerman, et al. 2022). It is important that you respond to each statement.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

	QUESTIONS	1	2	3	4	5
1	We use Internet of Things in our supply chain processes.					
2	We use cloud computing in our supply chain processes.					
3	We use Big Data Analysis in our supply chain processes.					
4	We use Artificial Intelligence in our supply chain processes.					
5	We use blockchain in supply chain processes.					

Green Operations

Please use the rating scale below to respond to the following statements **related to <u>Green Operations within Supply Chain Activities…</u>** (Lerman, et al. 2022). It is important that you respond to each statement.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

	QUESTIONS	1	2	3	4	5
1	Our company assesses the environmental impact to develop/improve products					
2	Our company develops products with recyclable raw material.					
3	Our company develops products with lowest consumption of resources					
4	Our company develops products with low impact on the environment.					
5	Our company develops products with a high life span.					

Sustainability Performance

Please use the rating scale below to respond to the following statements **related to Sustainability Performance in Supply Chain…** (Lerman, et al. 2022). It is important that you respond to each statement.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

	QUESTIONS	1	2	3	4	5
1	Our company has increased material recycling over the past three years.					
2	Our company has reduced emissions over the past three years.					
3	Our company has reduced use/waste of resources over the past three years.					
4	Our company has decreased its use of hazardous and harmful materials in the last three years.					

Thank you for your time…

Appendix 3.

Ethical Committee Report

NEAR EAST UNIVERSITY

SCIENTIFIC RESEARCH ETHICS COMMITTEE

07.05.2024

Dear Ayse Hussein, Ramin Shayanrad

Your application titled **"The impact of smart supply chain on businesses' green performance"** with the application number NEU/SS/2024/1790 has been evaluated by the Scientific Research Ethics Committee and granted approval. You can start your research on the condition that you will abide by the information provided in your application form.

Prof. Dr. Aşkın KİRAZ

The Coordinator of the Scientific Research Ethics Committee

Appendix 4.

Similarity Report

The impact of smart supply chain on businesses green performance (20226311)

ORİJİNALLİK RAPORU

%15	%9	%12	%2
BENZERLİK ENDEKSİ	İNTERNET KAYNAKLARI	YAYINLAR	ÖĞRENCİ ÖDEVLERİ

BİRİNCİL KAYNAKLAR

1	www.emerald.com İnternet Kaynağı	%2
2	Laura V. Lerman, Guilherme Brittes Benitez, Julian M. Müller, Paulo Renato de Sousa, Alejandro Germán Frank. "Smart green supply chain management: a configurational approach to enhance green performance through digital transformation", Supply Chain Management: An International Journal, 2022 Yayın	%1
3	Aleksandr M. Kitsis, Injazz J. Chen. "Does environmental proactivity make a difference? The critical roles of green operations and collaboration in GSCM", Supply Chain Management: An International Journal, 2021 Yayın	%1
4	Laura V. Lerman, Guilherme B. Benitez, Julian M. Müller, Paulo Renato de Sousa, Alejandro Germán Frank. "When digital transformation meets supply chain needs in emerging	%1

CV

Ramin Shayanrad

raminshayanrad@gmail.com   +905338797385

Education

Zand Institute of Higher Education — 05/2018
Bachelors of Industrial Engineering — Shiraz, Iran

Isfahan University of Technology — 02/2022
Masters degree in Industrial Engineering — Isfahan, Iran
- Project scheduling and management
- C# and Python programming for system optimization

Near East University — 2023 – 01/2025
Masters degree in Business Administration (MBA) — Nicosia, Cyprus
- Data Analysis of Smart Supply Chain Configurations

Skills

- Python
- MATLAB
- C#
- Excel
- SPSS25
- Microsoft Office
- Machine Learning
- Project Scheduling and Management
- Optimization
- Gams
- Task Automation

Professional Experience

Ubar — 03/2022 – 01/2023
Junior Programmer — Tehran, Iran
- Assisted in building APIs
- Assisted in developing task automation services

Zand institute of higher education — 2016 – 2017
Teacher Assistant — Shiraz, Iran
- Teacher assistant for MATLAB for two semesters.

Afra Modern Systems — Shiraz, Iran
Internship
- Cooperated in balancing production line.
- Assisted in HR planning.

Profile

I have programming experience in C# and Python programming languages. I also have experience in project management and scheduling optimization problems.