



**School of Social Sciences**

**MASTER'S DEGREE PROGRAMME IN SUPPLY CHAIN  
MANAGEMENT**

**Lean Supply Chain: The Case of COVID-19**

**SCM07 Master Thesis**

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## **Abstract**

The COVID-19 pandemic has profoundly disrupted global supply chains, exposing weaknesses, vulnerabilities and challenging established practices. This dissertation explores the connection of lean supply chain principles and the challenges presented by the pandemic. It aims to evaluate the impact of COVID-19 on lean supply chains and examine the evolution and adaptability of lean practices.

The research employs a mixed qualitative methodology, including a literature review and a case study from Toyota Motor Europe, a pioneer in lean supply chain management. The literature review provides a comprehensive analysis of lean principles, supply chain dynamics, and the pandemic's implications for global lean supply chain networks. The case study offers practical insights into Toyota's strategies for maximizing agility, minimizing waste, and fostering collaboration across its pan-European network during and after the crisis.

Findings reveal that while lean supply chains enhance efficiency and cost-effectiveness under stable conditions, their inherent limitations, such as reduced inventories and reliance on long-term supplier relationships, rendering them vulnerable to systemic disruptions. However, the research also highlights the potential for lean frameworks to evolve, incorporating elements of resilience, flexibility, and digital innovation to better withstand future uncertainties rendering lean a future proof supply chain strategy.

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## **List of Abbreviations**

**3PL:** Third-Party Logistics

**AI:** Artificial Intelligence

**ASCM:** Association for Supply Chain Management

**FMEA:** Failure Mode and Effects Analysis

**IoT:** Internet of Things

**JIT:** Just-In-Time

**LSC:** Lean Supply Chain

**LSCM:** Lean Supply Chain Management

**PDCA:** Plan-Do-Check-Act

**RFID:** Radio Frequency Identification

**SC:** Supply Chain

**SCM:** Supply Chain Management

**TPS:** Toyota Production System

**VSM:** Value Stream Mapping

**WHO:** World Health Organization

# Chapter 1-Introduction

## 1.1 Overview

A supply chain is a network of several parties, all involved either directly or indirectly in fulfilling customer requests. The supply chain encompasses and interacts with a wide group of stakeholders, hence it is not limited to just two parties, such as only suppliers and manufacturers. It also includes other entities such as transporters, retailers, and even customers. It comprises a set of activities aimed at satisfying customer demands. A supply chain is not static, on the contrary, it is dynamic and involves the continuous flow of information, products, and funds across the chain and through multiple stages (Chopra and Meindl, 2016). This dynamic organization plays a critical role in society and economy, and the success of business activities relies on the effective management of the supply chain. Reduction of lead times, improvement of financial performance, better supplier relationships, and many more can be achieved through a well-managed and orchestrated supply chain. However, the success depends on several other factors that influence the supply chain functions, such as environmental uncertainty, company culture, information technology, supply chain relationships, value-added processes, customer satisfaction, and supply chain management performance (Quesada et al., 2012).

In recent decades, supply chains have faced unprecedented challenges, impacted by numerous factors and incidents. It has become a norm to navigate an uncertain world with an unpredictable present and future. The latest years have been marked by constant change driven by various circumstances. Rapid and continuous technological, social, and economic transformations, combined with growing uncertainty and adversities in the organizational environment, have significantly influenced supply chains (Pettit et al., 2010; Trkman et al., 2016; Chowdhury et al., 2021). Unpredictable consumer demands, economic instability, and constant changes in supply chains are among the factors contributing to supply chain challenges and overall uncertainty. The business landscape and global supply chains have been impacted by several incidents, such as the earthquake in Japan in 2011, the SARS outbreak in China in 2003, and the tsunami in Indonesia in 2004. In all these cases, the recovery after the disasters occurred within a matter of weeks. In the more recent years, global supply chains faced an event entirely different from all previous incidents and disasters. This event was the COVID-19 pandemic, which was evidently different in terms of its geographical impact and duration (Cekerevac et al., 2022).

COVID-19 affected all nations, and in March 2020, the World Health organization (WHO) declared it a global pandemic (WHO, 2020). COVID-19 profoundly changed humanity, with lockdowns, confinements, and shutdowns of various economic activities, while costing millions of lives. The pandemic impacted almost every stage of global supply chains (Xu et al., 2020). It had a severe effect on both supply and demand, making the situation extremely complex (Kwon, 2020). Its nature and extended impact significantly influenced global supply chains and logistics systems. Therefore, it would be interesting to examine the pandemic's impact and how different

aspects of the global supply chain experienced the effects of it and evolved after this rapid change.

Elaborating on these different aspects of supply chain, in several industries and organizations, there are supply chain structures that operate uniquely compared to traditional supply chains due to the implementation of lean practices across their entire value chain, both upstream and downstream. It would therefore be interesting to explore these supply chains and assess the impact of the pandemic on them and how the pandemic affected and triggered them to evolve. Several supply chains have adapted their strategies by adopting lean practices and lean manufacturing principles, extending the application of lean from internal processes to the entire value chain (Hines et al., 2004; Berger et al., 2018). This approach, known as Lean Supply Chain, emphasizes the supply chain as a network of interconnected units working collaboratively to minimize waste and deliver the highest value to the customer (Vitasek et al, 2005; Tortorella et al., 2018). Lean supply chains aim to produce higher-quality products, reduce costs, and improve efficiency and productivity and is an approach applied by numerous industries and different companies across the world. It would be valuable to investigate how lean supply chains managed the challenges posed by the pandemic and whether, or how, they experienced the pandemic disruption. Additionally, it is essential to introduce key terms, theories, and practices by reviewing existing literature to gain insight into the interesting world of Lean Supply Chains and Lean Practices.

## 1.2 Structure

The structure of this thesis aims to ensure a logical flow of theories, practices and ideas, with key sections addressing the research objectives. The thesis begins with an overview, the structure of the research and the research methodology in **Chapter 1** combining a detailed literature review and a real-world case study. This approach provided both theoretical depth and practical insights. The methodology ensured a balanced approach, leveraging academic studies and industry-specific observations. **Chapter 2** introduces the fundamentals of supply chains, exploring their components, objectives, and the disruptions they face. This chapter highlights the importance of collaboration and process optimization in delivering customer value. It also lays the ground for understanding the vulnerability of supply chains in the face of global disruptions, particularly those optimized under lean principles. **Chapter 3** delves into the principles of lean supply chains, emphasizing waste elimination, value creation, and efficiency. Tools and methods such as Just-in-Time (JIT), Value Stream Mapping (VSM), and the identification of the 8 Lean Wastes will be explored in depth. These principles demonstrate how lean supply chains achieve remarkable efficiency in stable environments but may struggle under conditions of high variability and uncertainty. **Chapter 4** examines the disruptive effects of the COVID-19 pandemic on global supply chains. The pandemic created unprecedented challenges, exposing vulnerabilities in lean systems. These include supply shortages, logistics delays, and rapid demand shifts. The ripple effects of these disruptions cascaded across the



supply chain tiers, amplifying delays and inefficiencies. The chapter reveals that while lean principles prioritize waste reduction and efficiency, they often lack the resilience to absorb such disruptive events. The case study in **Chapter 5** emphasizes the evolution of lean and provides a practical case scenario to understand the challenges and the strategies adopted to mitigate them. The European lean supply chain program of Toyota highlighted the need for continuous improvement and digital technologies such as real-time tracking, to enhance visibility and agility. The chapter also illustrates the importance of aligning lean practices with resilience strategies, such as diversifying suppliers and synchronizing operations across the supply chain. **Chapter 6** synthesizes the research findings on how COVID-19 exposed vulnerabilities in lean supply chains while highlighting opportunities for resilience through hybrid models, technology, and sustainability. It provides actionable managerial strategies to balance efficiency and resilience, supported by digital transformation and expanded metrics. Finally, it identifies research limitations and proposes future studies on integrating Industry 4.0 technologies into lean practices across industries.

### 1.3 Research Methodology

In research, which method will be used depends on the nature of the research therefore its natural suitability depends on the area that is going to be explored. Due to the complexity of the topic and the convergence of different areas, a mixed qualitative research approach will be employed. The research will employ the following two research approaches:

- Review of the literature in the most relevant academic journals and books.
- Case study from a Lean company.

#### Literature Review

The first part of the research focuses on identifying the most relevant literature to shed light on various topics related to the thesis's focus area. For instance, keywords such as "lean," "supply chain management," "logistics," and "COVID-19" etc were used to extract key academic journals from academic databases. According to Snyder (2019), relevant literature is critical for all disciplines and research projects, serving as a foundation for knowledge development and future research. In this study, it provides the basis for understanding the topic and lay the groundwork for further investigation.

Moreover, a literature review is not merely a summary of existing knowledge, but it is a critical assessment of the researched topic to identify theories and reveal knowledge gaps (Hart, 2018). In addition to peer-reviewed academic journals, which are an essential source of information, other resources will also be utilized. Books, for example, can provide in-depth insights into the topic, while other materials such as company reports, and industry reports will be evaluated for their reliability before use (Saunders et al.2019).

## **Case Study**

The second research approach aims to provide a practical, real-world context to the researched area through a case study from a lean company, adding valuable insights to the research. According to Yin (1989), a case study is an empirical research method designed to examine a phenomenon within its real-life context. It also facilitates making assertions about specific situations (Yin, 2013). Furthermore, case studies enable the investigation of contextual realities, allowing for the analysis of what was planned` versus what occurred (Anderson, 2013).

### **1.4 Research Questions**

An essential part of a research is the formulation of research questions, as well-defined questions provide the foundation for initiating a study (Anderson, 1993). According to Janesick (2000), a research can begin with a question or at least a curiosity, if not a passion, for a particular topic. In this study, the researcher has a deep interest in lean supply chain operations and has firsthand experience of the pandemic's impact on one of the most advanced and complex lean supply chains in a professional context. Based on this interest, specific research questions have been formulated, aiming to provide clear and concise answers.

The first research question seeks to understand the immediate impact of the pandemic and address the following inquiry:

- What were the implications of the pandemic on supply chains and particularly on the Lean Supply Chain?

The second research question focuses on the evolution of lean and addresses the following:

- How does the future of lean supply chains look like after the pandemic?

This study will investigate the pandemic's impact as a disruptive event for Lean Supply Chains (LSC) and explore what, if any, changes have occurred and what adaption needs to be done. As a next step we will explore key fundamental supply chain concept.

## **Chapter 2- Supply Chain Essentials**

### **2.1. Introduction to Supply Chain**

Before delving into the specific area of Lean Supply Chain and its associated effects from COVID-19, it is essential to familiarize ourselves with fundamental terms and principles. To begin, the term "supply chain" will be defined. Numerous definitions of supply chain exist, as it has been explored by various academics and professional organizations (Chopra and Meindl, 2016). Plenert (2006) simplifies the concept by using a single word: "movement." This term describes the core function of a supply chain, moving things from one point to another. According to this definition, three key resources are mobilized to facilitate this movement: materials, information, and money. Furthermore, the professional organization Chartered Institute of Procurement and Supply (CIPS) defines supply chain as the set of essential activities required to deliver goods or services to consumers. These activities involve transforming raw materials into products or services and delivering them to customers.

Another notable approach defines supply chain as a network of organizations, resources, and activities that collaborate to source raw materials, transform them into usable products, and deliver these products to the end consumer (Ganeshan and Harrison, 1995). Over time, numerous definitions have emerged, all emphasizing the delivery of products and services to the customer. Since the final recipient is the customer, the value they receive depends on the value generated by the supply chain. Consequently, one of the primary objectives is to maximize the total value generated. The key focus of a supply chain, as it will be further analysed, is to maximize this supply chain added value, which is the difference between what a product is worth to the customer and the associated cost to fulfil the customer's request (Chopra and Meindl, 2016). Finally, the term "supply chain" has also been defined by industry professionals and companies operating within the field. Hence, in line with previous definitions, the consulting firm McKinsey describes the supply chain as the interconnected journey that raw materials, components, and goods undertake before their assembly and eventual sale to the customer. Continuing the analysis of basic supply chain terms and concepts, the next focus will be on highlighting the objectives of supply chains.

### **2.2. Supply Chain Objectives**

The term "supply chain" has been introduced, and a foundational understanding has been established. The next step is to explore the objectives of this network of organizations, resources, and activities that collaborate with a shared goal to create value. According to Siebert et al. (2020), the supply chain objectives can be categorized into two types: process-oriented and collaboration-oriented. Both are essential. On one hand, rigid processes are necessary to manage the supply chain effectively, while collaboration is central for its operation. The importance of

collaboration has been demonstrated during major disruptions over the past decades, and particularly during the COVID-19 pandemic. From a process perspective, the supply chain aims to enhance the flow of information, money, and goods. In terms of collaboration, objectives include maximizing commitment to supply chain partners, intensifying cooperation across the supply chain, and ensuring the fair distribution of profits among participants. Collaboration is an absolute prerequisite for the smooth functioning of supply chains, a topic that will further appear in subsequent chapters on lean supply chains.

Examining supply chain objectives from another perspective, the aim is to generate and maximize value. This involves two key components; the cost incurred by the supply chain to fulfil customer needs and the value perceived by the customer. By deducting the cost from the perceived value, the supply chain surplus is calculated, and this surplus is what should be maximized (Chopra and Meindl, 2016). Therefore, it is critical for supply chains to deliver the right value to customers and exceed their expectations. The customers demand the right product or service, delivered at the right place, on time, and of the highest quality. However, as the world has become increasingly complex, supply chains must be orchestrated in a way that continue to meeting and exceeding customer expectations (Guilherme, 2022).

### **2.3. Supply Chain Management**

Next to defining the term "supply chain" and its objectives, it is essential to explore the concept of supply chain management (SCM). The term "supply chain management" was first introduced by Keith Oliver in 1982 and has since undergone significant evolution. Initially perceived as a logistics function focused on the transportation and storage of goods, SCM has expanded into a multifaceted corporate function that integrates various business domains. This transformation reflects the growing complexity of global markets, technological advancements, and the increasing emphasis on creating value across the entire supply chain. SCM is now recognized as a strategic discipline that transcends operational boundaries, encompassing the management and coordination of end-to-end processes. These processes start with the conceptualization and design of products or services and extend through production, marketing, sales, consumption, and ultimately the disposal or recycling of products by the end customer. Importantly, SCM involves aligning the interests of multiple stakeholders, including suppliers, manufacturers, distributors, retailers, and customers, to achieve efficiency, responsiveness, and sustainability (Christopher, 2016).

A comprehensive definition states that SCM includes several interconnected activities, such as product design, procurement, demand forecasting, capacity planning, manufacturing, inventory management, distribution, fulfilment, and after-sales services. Each of these activities is essential for delivering value to customers while optimizing costs and mitigating risks (Lauren and Swaminathan, 2015). Moreover, in the context of modern supply chains, the integration of digital technologies like IoT, blockchain, and AI has further transformed SCM by enhancing visibility, real-time decision-making, and collaboration across the supply chain

networks (Ivanov et al., 2021). SCM's evolution also underscores the importance of adaptability and resilience, particularly in response to disruptions such as the COVID-19 pandemic, which highlighted several vulnerabilities of global supply chains. Organizations are increasingly adopting agile practices and leveraging predictive analytics to respond effectively to changing market dynamics, ensuring continuity and competitive advantage (Tang, 2006). These advancements underscore the role of SCM as a critical enabler of organizational success in a highly interconnected and volatile global economy.

## **2.4. Supply Chain Components**

Building on the multidimensional definitions of the supply chain and supply chain management (SCM), it is crucial to examine the key elements that constitute a supply chain and to decompose supply chain into further components as necessary. These components form the foundation of effective SCM and reflect the diverse activities required to deliver value to customers while optimizing efficiency and sustainability.

The Association for Supply Chain Management (ASCM), a leading professional organization in the United States, emphasizes the critical role of supply chains in driving the global economy. It identifies the following essential components of supply chain management:

### **Planning and Forecasting**

Planning and forecasting involve demand prediction, production planning, supply planning and resource allocation to meet future customer requirements. Accurate forecasting is vital for aligning production schedules, minimizing waste, and optimizing supply chain performance. Advanced tools like predictive analytics and AI have enhanced planning accuracy, enabling companies to respond dynamically to market fluctuations (Chopra and Meindl, 2016).

### **Sourcing and Procurement**

Sourcing and procurement focus on identifying, selecting, and contracting with suppliers to secure the required goods or services. This component emphasizes supplier evaluation, relationship management, and cost optimization. Ethical and sustainable sourcing practices have gained prominence in recent years, with organizations increasingly prioritizing transparency and compliance with environmental and social standards (Handfield and Nichols, 2018).

### **Operations Management**

Operations management focus on the transformation of raw materials into finished products. It encompasses process design, production scheduling, quality control, and efficiency improvement. Lean manufacturing principles, such as just-in-time (JIT) production, are often integrated to eliminate waste and enhance operational agility (Krajewski et al., 2019).

## **Inventory Management**

Inventory management involves maintaining optimal inventory levels to balance supply and demand while minimizing holding costs. Techniques like Economic Order Quantity (EOQ) and Material Requirements Planning (MRP) are commonly employed to streamline inventory operations and prevent stockouts or overstocking (Silver et al., 1998).

## **Warehousing**

Warehousing plays a pivotal role in storing goods and ensuring their timely availability for distribution. Modern warehouses are equipped with automated systems for tracking, picking, and shipping, improving efficiency and reducing errors. Strategic warehouse placement is also critical for minimizing lead times and logistics costs (Ballou, 2004).

## **Logistics**

Logistics, as defined by ASCM, involves the coordination of forward and reverse movement of goods, along with their handling and storage. This component includes transportation management, fleet optimization, and freight forwarding, ensuring the smooth flow of materials across the supply chain (ASCM).

## **Distribution**

Distribution focuses on the delivery of goods from suppliers to customers, bridging the gap between production and consumption. Effective distribution networks, supported by advanced routing and scheduling systems, are crucial for meeting customer expectations for speed and reliability (ASCM).

## **Risk management**

Risk management addresses the identification, assessment, and mitigation of risks that threaten supply chain continuity. In an era of heightened disruption due to geopolitical tensions, climate change, and global pandemics, organizations are adopting proactive strategies such as scenario planning and supply chain digitization to build resilience (Christopher, 2016).

As supply chains evolve, the concept of circular supply chains has gained traction. These systems prioritize sustainability by integrating recycling, remanufacturing, and reuse into supply chain processes. Circular supply chains align closely with lean principles, which emphasize waste reduction, resource efficiency, and value creation. Together, these approaches are reshaping traditional supply chains into more adaptive and sustainable systems, reflecting the demands of a modern global economy.

## **2.5. Circular Supply Chain**

In today's global supply chain context, organizations strive to gain a competitive edge by becoming more sustainable from economic, environmental, and social perspectives. The traditional linear economy generates significant waste, which conflicts with businesses' sustainability goals. A major example is the depletion of natural resources, which leads to resource scarcity and environmental pollution. This unfortunate reality drives businesses to focus their efforts on waste reduction (Lahane et al., 2020) and as it will be presented in later chapters, waste reduction is the core objective of lean practices. Consequently, there is an urgent need to transition toward more sustainable supply chains, a concept aligned with the principles of the circular economy (Homrich et al., 2018).

The integration of circular economy principles into supply chains has been termed circular supply chain (Nasir et al., 2017). According to Farooque et al. (2019), circular supply chain management involves embedding circular thinking into supply chain management and its surrounding industrial and natural ecosystems. It aims to systematically restore technical materials and regenerate biological materials, working toward a zero-waste vision through system-wide innovations in business models and supply chain functions. This spans the entire lifecycle, from product or service design to end-of-life and waste management, engaging all stakeholders, including parts and product manufacturers, service providers, consumers, and users. The circular supply chain targets minimizing waste while maximizing resource efficiency by incorporating circular economy principles. It adopts practices such as reuse, reduce, recycle, redesign, remanufacture, and repair. Products are designed with their entire lifecycle in mind, emphasizing circularity throughout the supply chain. Reverse logistics are fully utilized to manage returning, recycling, repairing, and disposing of products effectively. This closed-loop supply chain model is a foundational framework that eliminates waste and enhances efficiency. Additionally, circular supply chains foster advanced business collaboration (Lahane et al., 2020). However, due to its complexity, this model requires effective management to ensure success.

Batista et al. (2018) define circular supply chain management as the coordinated integration of upstream and downstream supply chains within a purposeful business ecosystem. This approach creates value from products, services, by-products, and useful waste flows by extending their lifecycles. It improves the economic, social, and environmental sustainability of organizations. The primary goal of this research is to explore the different perspectives of lean supply chain. Key concepts such as waste reduction and efficiency improvement, both central to lean practices, will be examined in the following chapters. As a next step, the focus will shift to supply chain disruptions, with a particular emphasis on COVID-19 as a major disruptor.

## **2.6. Supply Chain Disruptions**

The smooth flow of goods and function of supply chain has been interrupted in various instances by unexpected events. These occasions affected the normal

operation by delaying or impeding the function of supply chain. Supply Chain disruptions are events that have achieved to successfully expose the vulnerability of global supply chains. As a principal, supply chain disruptions are significant disturbances in the flow of goods or services, or information across the supply chain caused by external and internal factors. These are events which expose the vulnerability and fragility of supply chain. The internal factors include organizational inefficiencies of the companies, lack of talent, insufficient digital technologies and ineffective inventory management. On the other hand, the external factors are geopolitical changes, natural disasters, pandemics, trade wars, inflation and regulatory changes (Loseby, 2023).

The disruptions affect the supply chain by triggering uncertainty and causing inefficiency with effects on suppliers and customers. The disruptions lead to increased production and transportation cost, making companies to adjust pricing strategies to maintain profitability. They cause also demand shifts where the scarcity or the potential upcoming scarcity of products makes customers to purchase more at higher prices causing market imbalances. They can also change the behaviour of consumers increasing or slowing the market activity (Bateh, 2024). Other authors emphasize the term 'ripple effect' that is an effect that was created because of the disruptions. According to it, disruptions cause the "ripple effect," impacting multiple levels of the supply chain, leading to significant operational and financial consequences. It describes how localized disruptions in one part of the supply chain can spread and escalate, leading to significant operational and financial challenges across the network. This effect is distinct from the bullwhip effect, which relates to demand-side distortions; the ripple effect encompasses disruptions caused by supply, demand, or other systemic factors (Katsaliaki et al., 2022). The ripple effect refers to how external disruptions, like natural disasters or pandemics, spread across the supply chain. The bullwhip effect arises from internal inefficiencies, where small demand changes at the customer side amplify upstream, causing inventory and forecasting issues (Ivanov and Dolgui, 2019; Lee et al., 1997).

Supply chain disruptions arise from various root causes, leading to significant challenges and impact on supply chain and its dynamic. First, there are natural disasters like the earthquake in Japan in 2011 which disrupted the automotive and electronics industries at global level (Bateh, 2024, Loseby, 2023). Then, there are events like Brexit, trade wars and the Russia-Ukraine war that are events that created operational restrictions and regulatory changes disrupting the supply chain networks (Loseby, 2023; Katsaliaki et al, 2022). Also, technology can be a source of disruptions like obsolete IT system and cyberattacks cause operational interruptions and affect several sectors (Macdonald and Corsi, 2013; Katsaliaki, et al, 2022). Moreover, the human factors play their role, as for example labour anomalies like strikes and talent shortages, add complexity to the smooth operation of supply chain risking its continuity (Loseby, 2023; Katsaliaki et al. 2022). Additionally, the market dynamics with fluctuations in demand lead to supply and demand imbalances (Bateh, 2024; Loseby, 2023). One of the latest disruptions was caused by a pandemic that achieved to expose the weaknesses of the entire supply chain causing production shutdowns, logistics bottlenecks and unanticipated demand surges. COVID-19, the global



pandemic, caused one of the most severe disruptions in supply chain (Macdonald, Corsi, 2013; Katsaliaki et al, 2022). The pandemic plays an important role in this research as its impact on lean supply chain will be studied and identified.

There are different types of disruption with a varying impact. They can stop production, decrease production capacity and cause inventory shortages eg. medical supplies during the pandemic (Bateh, 2024, Loseby, 2023). Also, disruptions trigger price volatility as they can increase cost due to limited availability of products. An example is the oil prices increase due to geopolitical events (Bateh, 2024; Macdonald, Corsi, 2013). Moreover, the Suez Canal blockage caused operational difficulties and transportation issues leading to higher transit cost and delays in global transportation (Loseby, 2023; Katsaliaki, et al, 2022). Additionally, financial consequences, including lost sales and recovery cost, are enormous in industries like the automotive that has suffered due to shortages of electronic components and parts after the earthquake in Japan (Macdonald and Corsi, 2013; Katsaliaki, et al, 2022). Another type is the damage on reputation when companies cannot satisfy demand face risks regarding their reputation and are exposed to their customer. (Katsaliaki, et al, 2022). Finally, the already mentioned ripple effect comes to propagate across the supply chain even if something occurs at one point of the chain (Katsaliaki, et al, 2022).

COVID-19 as a global pandemic had an immense impact on the global economies and the subsequent supply chains. Covid-19 proved to be a unique and significant disruption to the global supply chain. The pandemic caused unprecedented challenges due to its long-term persistence, global propagation and high unpredictability. It disrupted both supply and demand dynamics simultaneously, unlikely other disruptions that impact mainly the one side of the supply chain. The pandemics had a dual effect affecting both the demand and supply side of the supply chain networks (Rinaldi and Bottani, 2023). During the pandemic the disruption on global supply chain had an impact also on lean supply chain and this is something that this research aims to discover. As a next step of this research the focus will be on the principles of lean and the lean practices in supply chain.

## Chapter 3-Lean Principles & Lean Supply Chain

### 3.1 Background

The root of Lean is traced back to Taylor's principles of scientific management in 1911 and Henry Ford's assembly line introduced in 1913. Ford's production system emphasized efficiency and consistency but lacked the flexibility to accommodate product variety. Observing Ford's factory operations, Toyota's pioneers developed the Toyota Production System (TPS), which emphasized the minimization of inventory, ensuring timely supply, pull production based on actual demand, improving quality, and eliminating errors (Čiarnienė and Vienažindienė, 2012). Lean principles, therefore, date back to the early 20th century and are closely associated with the Japanese automotive company Toyota. Visionaries Sakichi Toyoda and Eiji Toyoda, together with the prominent engineer Taiichi Ohno, created the Toyota Production System, widely known as TPS. As both a management system and philosophy, TPS aims to eliminate waste and improve efficiency. TPS is built on two foundational pillars:

- **Jidoka:** Automation with a human touch.
- **Just-in-Time (JIT):** Producing only what is needed, when it is needed.

(Dekier, 2012)

The Japanese term Jidoka is a concept that aims to create processes with autonomous, built-in quality controls. Essentially, Jidoka guarantees that machines and as well their operators can shut down a process when an anomaly is detected. Therefore, Jidoka ensures built-in quality by detecting and stopping processes when abnormalities occur, preventing defects from advancing. It also promotes efficiency and problem-solving by enabling root cause analysis and continuous improvement. Just-in-Time (JIT) is a core concept within manufacturing that focuses on minimizing waste and optimizing efficiency by producing and delivering goods only as they are needed, in the quantities required, and at the time they are required. It reduces waste by minimizing inventory and aligning production with actual demand. JIT enhances efficiency, lowers costs, and ensures a smoother flow across the supply chain. (Liker, 2021).

The term Lean was first coined by Krafcik (1988) in his attempt to emphasize the principles of limiting excess inventory and excess workers as opposed to automotives other than Toyota which preferred at that time to buffer inventories. Later on, the term Lean Manufacturing was coined by Womack et al.(1991) from MIT. Lean Manufacturing or Lean Production is multidimensional as it can be approached as a philosophy, or set of principles and practices (Dekier, L, 2012). According to Womack et al. (1996) Lean Production is a philosophy that aims by eliminating waste in the value stream of the products to achieve the decrease of the time between the placement of the order and the delivery of the product while others view it as a set of different principles (Dekier, L, 2012). Another viewpoint is the one that perceives it as a set of practices and tools to eliminate waste (Shah & Ward, 2007, Narasimhan et al., 2006). Additionally, as the lean practices are associated with quality management

there is a consensus that there are four areas in lean production. These are pull production/JIT, total preventive maintenance, total quality management and human resources management (Cua et al., 2001; Shah and Ward., 2007).

Lean has evolved into a multi-dimensional management approach incorporating practices like Just in Time, quality management, work teams, supplier coordination etc and while it is originated in manufacturing lean has adopted by several industries and functions. Its success depends on cultural change and employee participation and involvement with an optimum target to create a lean corporate culture (Čiarnienė and Vienazindienė, 2012). As a next step, moving to the lean principles a deeper understanding of the lean will be achieved.

### **3.2 Lean Principles**

Waste elimination and value creation are two central concepts in Lean thinking (Čiarnienė and Vienazindienė, 2001). These aspects lie at the heart of Lean philosophy, driven by the logic that every business seeks to generate value while simultaneously eliminating waste. Several researchers have identified five principles that underpin Lean manufacturing. According to Womack and Jones (1996), Spear (2004), Murman et al. (2002), and Hopp and Spearman (2004), these principles are:

#### **Define Value**

The value of a product or service must be defined and specified from the end customer's perspective. This approach enables companies to identify non-value-adding activities and take appropriate actions to eliminate them (Čiarnienė and Vienazindienė, 2012). A thorough understanding of customer needs and preferences is essential for defining value accurately. Companies must engage in customer feedback mechanisms and market research to ensure that their definitions align with expectations and deliver superior satisfaction.

#### **Map the Value Stream**

The second principle emphasizes the importance of mapping every step of the process to create a value stream map. This visual process mapping identifies the flow of activities across the supply chain, integrating suppliers, manufacturers, and distributors (Rother and Shook, 2003; Rawabdeh, 2005). Mapping the value stream provides a clear understanding of where waste occurs, such as overproduction, excessive transportation, or unnecessary waiting times. By addressing these inefficiencies, companies can optimize resource allocation and streamline operations to deliver maximum value.

#### **Create Flow**

Creating a smooth flow involves eliminating waste identified through value stream mapping. This ensures an uninterrupted flow of materials and information to the customer (Čiarnienė and Vienazindienė, 2012). The concept of waste is integral to Lean with several types of waste identified that must be assessed and minimized

(Rawabdeh, 2005). The focus is on customer-valued activities, eliminating interruptions, delays, and inefficiencies. Achieving a seamless flow requires cross-functional collaboration and the implementation of tools such as standardized work processes to align production rates with customer demand.

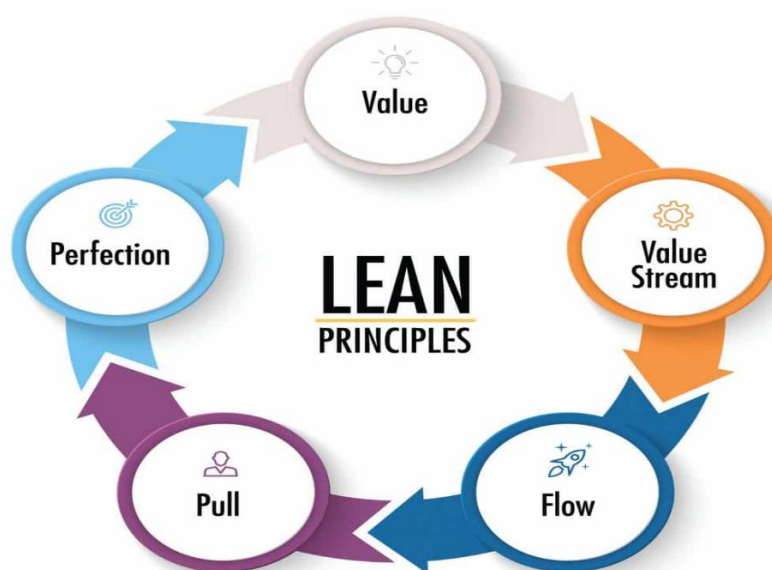
### Use Pull Systems

This principle advocates that production should be triggered by customer demand rather than pushing products to customers. A pull system ensures that materials are released, and activities are performed only when needed. Mechanisms such as kanbans are used to synchronize production processes with customer needs (Ciarniene and Vienazindiene, 2012; Womack and Jones, 1996; Emiliani, 1998). By implementing pull systems, companies can reduce inventory costs, avoid overproduction, and enhance responsiveness to market fluctuations. This approach fosters agility and enables businesses to adapt quickly to changing customer preferences.

### Pursue Perfection

The final principle emphasizes continuous improvement. The value stream must be regularly reviewed, analysed, and improved to eliminate defects and reduce waste. This process is essential for achieving operational excellence and zero defects (Dekier, 2012; Murman et al., 2002; Womack and Jones, 1996). Continuous improvement, often referred with the Japanese term Kaizen, encourages employees at all levels to participate in identifying areas for enhancement. Tools such as PDCA (Plan-Do-Check-Act) cycles, are instrumental in driving ongoing improvements and fostering a culture of excellence.

**Figure 1: Lean Principles**



Source: Fourie and Umeh (2017)

These principles highlight the systematic approach that Lean adopts to enhance efficiency and customer value while minimizing waste. Continuous improvement serves as the cornerstone of Lean thinking, requiring ongoing optimization of processes to meet and exceed customer expectations. Organizations that embrace Lean principles are better equipped to remain competitive in dynamic markets, as they can deliver high-quality products and services while maintaining cost-effectiveness and operational performance.

### **3.3 Introduction to Lean Supply Chain**

The Lean practices and principles started becoming popular in the 1990s, and a few years later, their application in supply chain management attracted significant interest (Ugochukwu et al., 2012). The application of Lean in Supply Chain began with the book "Lean Thinking" by Womack and Jones (1996). As Lean thinking was adopted by all the participants of the supply chain, it marked the emergence of a new paradigm known as Lean Supply Chain (El-Tawy and Galleary, 2011). Lamming (1996) defines the Lean Supply Chain as an arrangement designed to provide a flow of goods, services, and technology from supplier to customer, including the bidirectional flow of information and communication, without waste. This definition underscores the importance of a smooth, waste-free flow. Furthermore, according to Vitasek et al. (2005), the Lean Supply Chain is a network of organizations directly linked to upstream and downstream flows of products, services, information, and funds. These organizations collectively aim to reduce costs and waste while pulling only what is needed to meet customer demands and deliver added value. The practical application of Lean Supply Chain principles and practices aims to achieve superior performance. Evidence suggest that Lean Supply Chain Management drives transformative changes, leading to continual improvements in supply chain performance across various activities. Lean Supply Chains enhance competitiveness by improving efficiency and flexibility at every stage. Beyond waste elimination and cost reduction, they also seek to elevate quality. However, while Lean Supply Chains hold immense promise, they are challenging to implement as they require seamless collaboration and active engagement from all stakeholders across the supply chain (Cvetic et al., 2021).

This challenge has been acknowledged by large companies, which recognize that improving performance within their organizational boundaries alone is insufficient. Instead, Lean Supply Chain practices advocate for the integration of all parts and activities within the extended end-to-end supply chain. Applying Lean principles across the entire supply chain creates what is referred to as a Lean Supply Chain (Ugochukwu et al., 2012). This approach adheres to the five core Lean principles: Value, Value Stream, Flow, Pull, and Perfection. It also incorporates Lean practices such as waste elimination, which will be analysed in more details later. The role of the Lean Supply Chain has become increasingly significant in addressing challenges such as technological uncertainty, disruptions, COVID-19, and geopolitical events. It is regarded as a strategic tool for enhancing organizational performance (Garcia-

Buendia et al., 2022). The challenges have pushed organizations to reassess their supply chain strategies and invest in Lean practices that foster resilience and adaptability. Technological advancements, such as automation and digitalization, have further enhanced the capacity of Lean Supply Chains to respond to disruptions and maintain operational continuity. Additionally, the Lean Supply Chain model aligns with sustainability goals by reducing waste and promoting resource efficiency. Companies adopting Lean practices are better positioned to meet environmental regulations and customer expectations for greener operations. The integration of sustainability into Lean Supply Chains reflects a broader trend where businesses seek to balance economic performance with environmental responsibility.

This research will explore the impact of the COVID-19 pandemic on Lean Supply Chains, examining both its multidimensional effect. Furthermore, it will investigate the potential evolution of Lean principles and practices to adapt to future requirements and navigate an environment of continual uncertainty. This exploration will highlight the critical role of innovation and other factors in achieving long-term success and resilience in Lean Supply Chain management.

### **3.4 Lean Supply Chain vs Traditional Supply Chain**

Every supply chain comprises several participants including suppliers, manufacturers, retailers, wholesalers and other parts consisting of a broad structure. Each of the constituting parts is involved in the flow and process of goods, services, information, funds and knowledge within the end-to-end supply chain structure. Based on this structure, in the traditional supply chain each part of the chain in a non-collaborative way aims to maximize their profit. This is where the bullwhip effect comes when there is no collaboration and visibility across the supply chain nodes. The supply chain relies on and operates with independent forecasts each generated by incomplete data. Each supply chain actors predicts demand based on the data received from the next downstream part of the chain. This causes a demand variability that is amplified when moving up to the supply chain causing a lot of inefficiencies (Cvetić et al, 2021).

On the contrary, the lean supply chain is characterised by collaboration. The supply chain members work together with the needs of the end-customer in mind while maximizing the profitability of the entire supply chain that is the difference between the revenue generated from the sale of products to the end customer and the overall supply chain cost (Chopra and Meindl, 2004). Therefore, the lean supply chain underlines the importance of the overall supply chain cost reduction by eliminating wastes.

There are several differences between the Lean Supply and the Traditional Supply Chain all based on specific characteristics. According to Cvetić (2021) the following are the main differences based on the characteristics of the traditional supply chain and lean supply chain:

**Table 1: Traditional SC vs Lean SC Characteristics**

<b>Characteristics</b>	<b>Traditional SC</b>	<b>Lean SC</b>
Aim	Each participant cares of their own profit maximization	Focus on the overall supply chain profitability maximization, waste elimination and cost reduction
Cooperation	Siloed supply chain. Each participant strives to achieve their own goals	Supply chain collaboration, trust, responsibility and commitment to achieve common goals
Relationships time horizon	Short term	Long term
Processes	Non-integrated and standardised processes. Key processes not determined.	Built on end-customer needs, determined and standardised. Visual controls are used and application of fail-safe processes
Customers	The immediate, next level customer is only considered	All customers levels are considered, and segmentation is done.
Demand forecasting	Siloed forecasts at supply chain participant level	Demand prediction with the end-customer needs in mind, data is shared to the key supply chain participants
Suppliers	Large number without supplier segmentation	Limited suppliers with segmentation and higher forms of cooperation with key customers
Suppliers' selection	Mostly on price criteria	Multiple criteria are applied eg. quality, delivery time, distances, service level etc
Product delivery frequency	Not frequent product delivery	Frequent deliveries
Product quality control	Not strict	Strict and standardised quality control activities
Human resources	No attention to low level employees	Appreciation and involvement of all employees from different levels
Performance	Participants measure their own performance	Financial and non-financial measurement of the overall supply chain performance

Process improvement	Focus on participants own processes	Continuous improvement of the overall supply chain process
New product development	Siloed at participant level	Participation of more participants in the development of new products

Source: Cvetic (2021)

Therefore, within the lean supply chain there is a more collaborative way of working or must be established between the participants with a common goal to satisfy the needs of the end-customer and add value. In such structures information sharing and knowledge transfer is not uncommon but on the contrary is the role of the participants working together to improve the overall supply chain condition and mitigate the impact of wastes and eliminate them. In lean supply chain the elimination of waste has a prominent role as everybody strives to eliminate waste. As an example, in the traditional model a supply chain might involve several intermediaries/participants and each participant optimizes their own operation without integrating with the others leading to inefficiencies in demand, transportation, inventory etc. In the lean model there is a collaboration with the suppliers adhering defined quality standards, ensuring just in time deliveries and minimizing waste.

Lean supply chain is designed to maximize value for the customers while minimizing waste. They extend much beyond individual organizations and encompass entire supply chain networks. A hallmark of the lean supply chain is the integration of all members fostering collaboration and alignment across the network ensuring value delivery to the customer. Transparency and information sharing is vital to enable the entire lean supply chain to achieve its targets. Pull systems with productions driven by customer demand and continuous efforts for improvement enable the entire system to eliminate inefficiencies and adapt to changing conditions. Low inventory levels focusing on what is needed and customer centric mentality with constant focus on value delivery set the landscape of lean supply chain (Ugochukwu et al, 2012).

### **3.5 8 Lean Wastes & SC**

Lean aims to eliminate waste thus it becomes pivotal to identify the wastes and their sources in an organization. Waste is an activity that will not bring any cost improvement or will not improve the value of the product and potentially the customer will not want to pay for that. In Japan Taichi Ohno identified seven types of waste known in Japanese as Muda. There is an acronym that applies to them known as TIMWOOD. In the 90s the western industries added the eighth waste that was the unused worker talent or skills. The 8 wastes are referred usually with the acronym TIMWOODS (Sharma, Khatri, 2021).

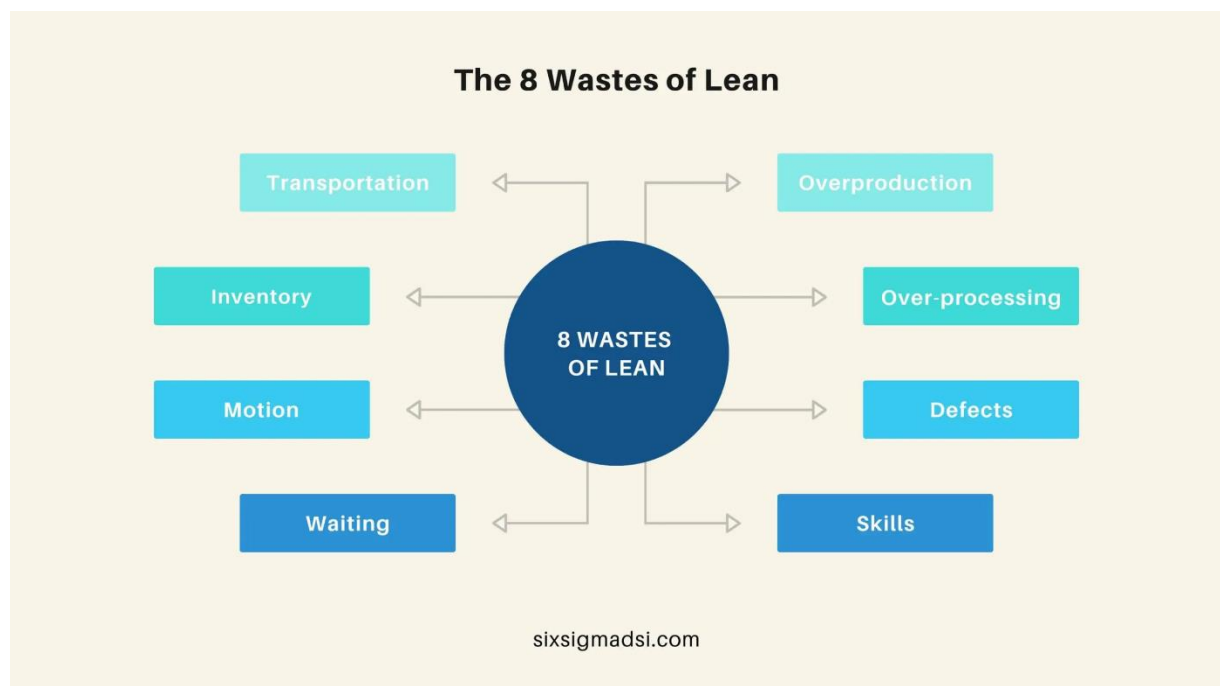


The eight wastes of lean manufacturing are the following:

1. **Transport**
2. **Inventory**
3. **Motion**
4. **Waiting**
5. **Over-production**
6. **Over-processing**
7. **Defects /Rework**
8. **Skills**

(Sharma, Khatri, 2021).

**Figure 2: 8 Wastes of Lean**



Source: SixSigmaDSI

They all have direct impact on Supply Chain. **Transportation** waste is the unnecessary movement of materials, products, or information between processes. This adds no value to the product and increases lead times, often caused by poor layout or unoptimized supply chain flows. Excess **Inventory** represents a significant waste as it ties up capital and resources without providing immediate value. It increases the risk of items becoming obsolete or damaged while incurring storage costs. Lean emphasizes producing only what is needed when it is needed to avoid these inefficiencies. **Motion** concerns extra movement of employees or equipment that does not add value to the process. A warehouse layout that is not well designed

can cause extra motion. **Waiting** waste happens when time is lost due to idle equipment, workers, or delays in the workflow. This could be caused by unbalanced workloads, bottlenecks, or dependency on other processes to finish before moving forward. **Overproduction** occurs when a product or service is created earlier, faster, or in larger quantities than required. It leads to waste by tying up resources in unnecessary inventory or production, which could otherwise be utilized elsewhere. When producing more parts than needed can result in excess stock, storage costs, and potential obsolescence. **Overprocessing** occurs when more work or features are added to a product than what the customer requires or values. This can be caused by unclear requirements, redundant steps, or non-standardized processes, leading to wasted effort and resources. Rework, or correcting **Defects** in products, is another form of waste. This happens when errors in a process necessitate additional effort to bring the product up to standard. While quality checks may identify defects, frequent rework increases cycle times and costs, consuming labour and materials unnecessarily (The Council for Six Sigma Certification, 2018, Sharma and Khatri, 2021). **Skills** waste refer to the eighth waste that introduced. This waste to the underutilized talents, creativity and skills. It happens when management fails to recognize or leverage employees' full potential, relegating them to merely following instructions instead of contributing their knowledge and insights to improve processes (Sharma and Khatri, 2021).

In the business world, in supply chain operations sometimes we witness unnecessary movement of goods between distribution centres due to wrong routing. This is an example of transportation waste which add cost instead of value to the customer. Excessive stock in warehouses increase the inventory carrying costs and the risk of obsolescence. Also, wrongly defined and configured warehouse layouts increase the walking distances affecting the productivity of a warehouse facility. Trucks waiting due to delays in loading, wrong scheduling, or other delays cause the waiting waste. Production and replenishment based on forecast and not based on actual demand increase inventory levels and holding cost. Errors, defects eg. in shipping labels result into incorrect deliveries. Logistics workers are not involved in process improvement discussions or are assigned tasks below their skill level, such as experienced personnel only handling basic manual tasks instead of optimizing routes. The lean supply chain involves the identification of all types of waste across the end-to-end supply chain and taking the appropriate action of eliminating them while reducing delivery times. It should enable the total flow and processes to be across the entire supply chain network from the supplier, through manufacturer, distributor and final customer to function without waste. The members of the chain should take the right actions to continuously make improvements erasing activities that do not add value focusing on meeting the needs of the customers. (Rother and Shook, 2005, Abdulmalek, Rajgopal, 2007, Goldsby et al, 2011, Wee and Wu, 2009)

### 3.6 The Lean Toolkit in SC

When implementing Lean in an organizational context, it is important to use Lean management approaches, tools, and techniques. The use of Lean tools plays an important role in cost reduction, elimination of non-value-added activities, and supply chain optimization. Lean manufacturing had a pioneering role in the development of tools that enable Lean practitioners to eliminate waste and find solutions to different problems in their organizations (Arif-Uz-Zaman and Ahsan, 2013). In a Lean supply chain organization, the underlying supply chain processes are designed according to the needs of the end customers. Several industries have adopted Lean in their supply chains. The most common tools and techniques are the following:

#### 5S Methodology

5S is considered the most common Lean method. It is a popular methodology that aims to create a safe and well-organized workplace. The method involves five steps as described below:

**Sort:** Aims to sort everything in a workstation and identify and remove every item that is not necessary.

**Set in Order:** Aims to organize everything in designated areas reachable by the employees.

**Shine:** Ensures that the physical working space is clean, and everything is in proper working order.

**Standardize:** Aims to establish repeatable and reliable processes to maintain the results of the first steps.

**Sustain:** Aims to make the previous steps a habit for the employees to use and continually improve the process

(Tiwari and Singh, 2019).

The application of 5S is not only limited to manufacturing workstations but the entire supply chain, and each part of the supply chain can benefit from its application. For example, in a warehouse, the unnecessary items should be removed (Sort). Each item should be allocated to a specific location with correct labelling and barcoding to be found and reached easily by the warehouse operatives (Set in Order). The areas and storage systems should be clean (Shine). Each warehouse must have a defined cleaning schedule and inventory count process (Standardize). The total process needs to be sustained and continuously improved (Sustain).

#### Kaizen

According to Liker (2021), Kaizen is a Japanese term meaning "Change for the Better" or "Continuous Improvement." It is both a philosophy and a systematic approach aimed at achieving excellence through incremental improvements. Kaizen involves the engagement of the entire organization and often utilizes tools such as the PDCA (Plan-Do-Check-Act) cycle, which will be analyzed later. Kaizen encourages a culture of collaboration and continuous development.

## **Standardised Work**

Process standardization is fundamental in lean. Standardization of processes ensures consistency, reduces variability, and facilitates continuous improvement. It helps in maintaining quality and efficiency across supply chain activities. Standardised work is the foundation for Kaizen/Continuous Improvement (Dennis, 2007). By documenting a current process and the way of performing tasks, standardised work forms the baseline for improvement initiatives. When the standard is improved then the improved process becomes the baseline for future improvement (Liker, 2021)

## **Just-in-Time (JIT)**

A popular approach previously discussed is Just-in-Time(JIT), which is one of the pillars of the famous Toyota Production System. According to Liker(2021), It is a system of continuous flow that brings all the required materials, goods, or information only when they are needed. It is a way to avoid waste due to overproduction by creating an efficient flow that surfaces abnormalities, motivating people to take actions to improve quality, delivery time, and responsiveness to changes in customer demands.

## **Jidoka**

Jidoka, the second pillar of the Toyota Production System (TPS), also plays an important role in Lean. It refers to a machine that has the capacity to stop itself whenever a problem occurs, freeing up the operator for value-added work and problem-solving (Liker, 2021). For example, an Automated Guided Vehicle (AGV) in a warehouse is equipped with sensors to detect obstacles. Upon encountering an obstruction, the AGV automatically stops, triggering an alarm to notify operators. This allows for immediate intervention, preventing delays and potential damage.

## **Toyota 3Ms**

Lean methodology emphasizes waste reduction. Toyota addresses three key types of waste that are a high-level representation of wastes compared to the detailed breakdown of 8 lean wastes:

**Muda:** Non-value-adding activities that consume resources without contributing to the final product or service. It refers any activity or process that consumes resources but does not add value to the final product or service from the customer's perspective. Muda is one of the three inefficiencies targeted in the Toyota Production System (TPS), alongside Mura (inconsistency) and Muri (overburden).

**Muri:** Overburdened tasks or processes that place excessive strain on workers or equipment, leading to inefficiency and potential breakdowns. Muri refers to overburden or the imposition of unreasonable demands on people, equipment, or processes. It occurs when resources are pushed beyond their natural limits, leading to inefficiency, fatigue, and potential breakdowns.

**Mura:** Variability or inconsistencies in operations that disrupt workflows and create inefficiencies. Mura refers to inconsistency, unevenness, or irregularities in processes, workflows, or demand.

(Jamwal, 2019; Sharma and Khatri, 2021, Liker, 2021).

**Figure 4: Toyota 3Ms**



Source: Theleansuite

For example, a company struggling with poor forecasting may experience excessive inventory levels, reflecting Muda. At the same time, warehouse staff might be overworking due to unrealistic operational demands, highlighting Muri. Additionally, frequent and unpredictable fluctuations in customer demand could cause variability in logistics operations, representing Mura. By identifying and addressing these forms of waste, Lean ensures smoother workflows, higher efficiency, and better overall performance.

### **Kanban**

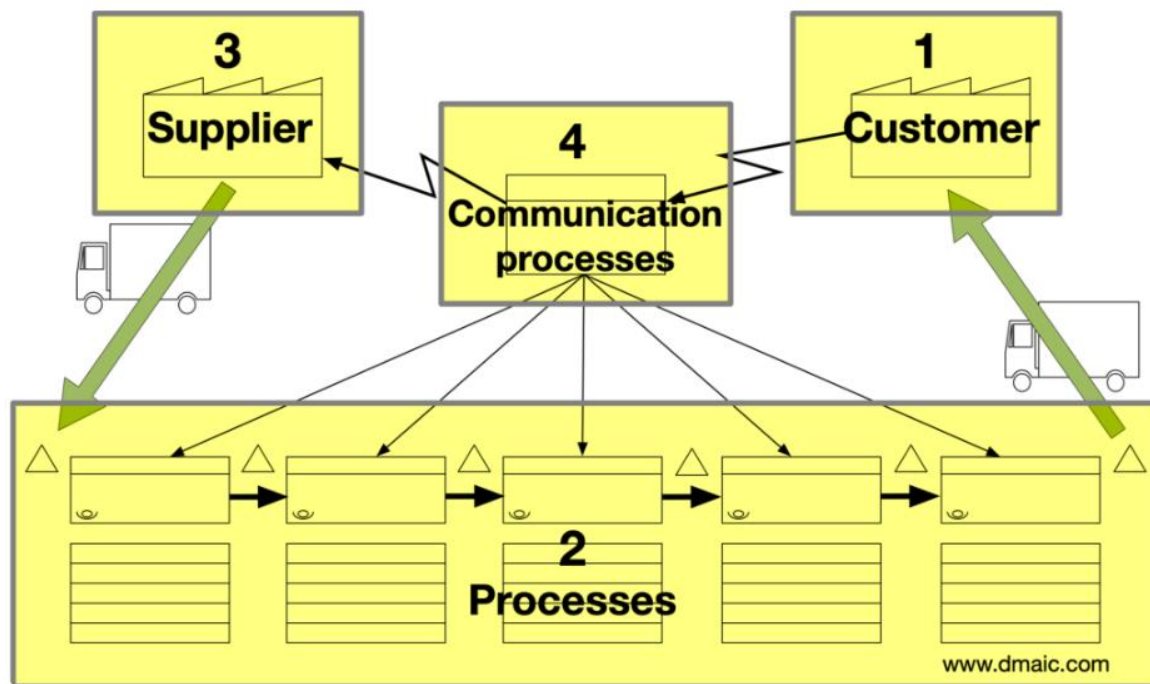
According to Liker (2021), Kanban is a scheduling system used in Just-In-Time (JIT) production that enables customers to control the flow of materials and information directly based on demand. This pull-based approach ensures that resources are replenished only when needed, preventing overproduction and minimizing waste. Kanban can be implemented throughout the supply chain, e.g. including managing inventory levels in warehouses, retail locations, and other storage areas. By improving inventory visibility and streamlining workflows, Kanban enhances efficiency and reduces excess stock, aligning with Lean principles of waste elimination.

### **Value Stream Mapping (VSM)**

Value Stream Mapping (VSM) is an advanced Lean technique used to analyze and define the flow of materials and information across interconnected processes (Sharma and Khatri, 2021). According to Liker (2021), VSM is a critical tool for visualizing these flows and identifying inefficiencies or waste within the value stream. By providing a comprehensive view of the entire process, VSM enables organizations to optimize workflows and create more efficient, value-driven systems. In supply chains, VSM can

be applied to map the entire network, identifying sources of waste and evaluating flow efficiency. A current state map captures the existing operational conditions, highlighting areas for improvement, while a future state map outlines the desired optimized process. Together, these tools serve as a strategic framework for achieving operational excellence and aligning business processes with customer value.

**Figure 5: Value Stream Mapping (VSM)**



Source: Dmaic.com

### PDCA Cycle

The PDCA (Plan-Do-Check-Act) cycle is a systematic quality improvement method used to plan actions, implement them, monitor results, and address deviations from expected outcomes (Sharma and Khatri, 2022). Also known as the Deming Cycle, this methodology provides a structured approach to problem-solving and continuous improvement. It consists of four iterative steps:

**Plan:** Identify a problem, analyze it, and develop a solution or strategy.

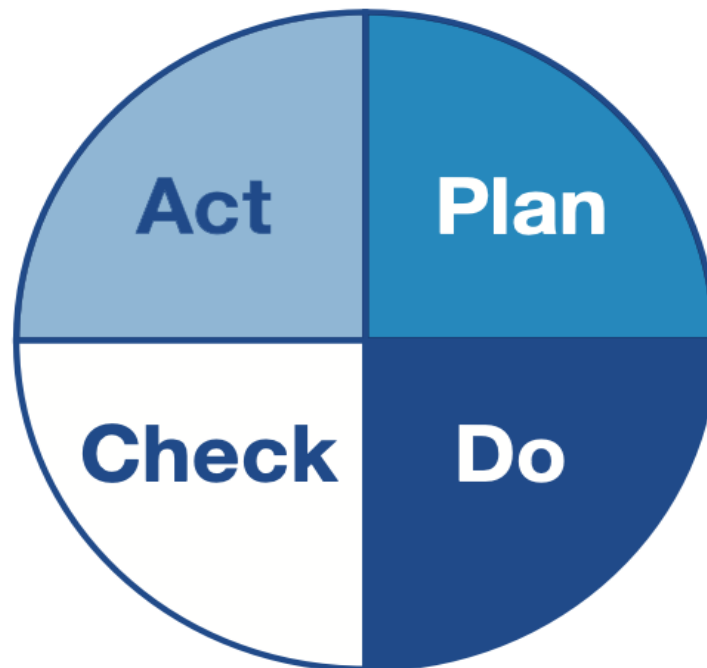
**Do:** Implement the changes to test its effectiveness.

**Check:** Monitor and evaluate the results against expected outcomes.

**Act:** Standardize successful solutions or begin the cycle again.

(Liker, 2021, Lean.org, 2024)

**Figure 6: Plan-Do-Check-Act (PDCA)**



Source: Lean.org

By following this iterative process, organizations can systematically address challenges and achieve incremental improvements in their operations.

### **Pull System**

According to Liker (2021) pull system methods applied to avoid overproduction by initiating work only when there is demand. For example, a retail supply chain can leverage real-time sales data to trigger replenishment orders. With a pull system, a retailer restocks products based on actual customer purchases rather than demand forecasts. For instance, when items are scanned at checkout, this process triggers a replenishment order to the supplier to replace only what was sold. This approach minimizes overstocking, reduces waste, and ensures inventory levels align with actual demand. Another simple example is when a product is purchased in a supermarket, a vacant spot is made on the shelf. Then a stock controller checks the stock levels at regular intervals and replenish only the required quantities.

### **Heijunka/Levelling**

Levelling of scheduling to balance demand over time and create smooth flow, reducing variability (Zaki et al., 2015). For instance, a distribution centre might schedule trucks to leave every two hours with mixed loads, rather than sending all orders out in the morning. This approach reduces warehouse congestion, ensures timely delivery, and balances workload for staff and drivers.

## **Genchi Genbutsu/Actual Place**

The practice of going to the actual place of work to investigate problems firsthand (Liker, 2021). This is a common practice in Lean organizations for addressing supply chain issues. For example, in logistics is when a manager visits a distribution centre to observe bottlenecks causing delayed shipments. Instead of relying solely on reports, they directly investigate issues like loading dock inefficiencies or incorrect inventory placement. By witnessing operations firsthand, they gain deeper insights and implement solutions to improve flow and efficiency.

## **Poka-Yoke/Mistake Proofing**

Poka-Yoke is a mistake-proofing technique designed to prevent and detect errors in processes, ensuring quality and reliability (Salonitis and Tsinopoulos, 2016). For example, a company may use RFID tags on pallets to prevent shipping errors. These tags enable automatic scanning, and if an incorrect pallet is about to be loaded onto a truck, the system triggers an alert. This ensures that only the correct products are shipped to their intended destinations, reducing errors, minimizing returns, and lowering operational costs. By integrating such preventive measures, companies enhance operational accuracy and customer satisfaction while reducing waste and inefficiencies.

## **5 Whys**

The 5 Whys is a problem-solving tool used to uncover the root cause of a problem by repeatedly asking "Why?" until the fundamental issue is identified (Salonitis and Tsinopoulos, 2016). It is particularly effective for addressing recurring issues in supply chains, such as inventory inaccuracies or shipping errors. For example, if a shipment is delayed, the process might go as follows:

Why was the shipment delayed? → Because the truck departed late.

Why did the truck depart late? → Because the loading process took longer than planned.

Why did the loading process take longer? → Because some items were missing from the staging area.

Why were the items missing? → Because the warehouse pickers did not prepare the right orders.

Why did they not prepare the right orders? → Because wrong priorities were given by the warehouse management system or their supervisor.

By identifying the root cause, the organization can implement corrective measures to prevent future delays. This systematic approach ensures that solutions address the underlying problem rather than treating symptoms, leading to lasting improvements in operational efficiency.



## **Hoshin Kanri/Policy Deployment**

According to Liker (2021), Hoshin Kanri is a strategic planning and execution methodology used to align an organization's long-term objectives with its daily operations. The process begins with defining corporate strategy and long-term goals, which are then cascaded vertically through hierarchical levels and horizontally across departments to ensure alignment at all levels of the organization. This methodology ensures that individual and departmental efforts are focused not on isolated productivity improvements but on achieving the organization's overarching goals. By aligning daily tasks with strategic priorities, Hoshin Kanri fosters a unified direction and drives collective success.

For example, a company seeking to reduce shipment errors by 20% might establish this as a strategic objective to add value to their customers. Senior management identifies key initiatives, such as improving warehouse and distribution accuracy. These initiatives are translated into measurable goals for each department, such as training warehouse staff and distribution drivers or companies or integrating/improving the Warehouse Management System/Transportation Management System. Regular reviews and feedback loops ensure progress is monitored, obstacles are addressed, and goals remain aligned across all levels.

## **Failure Mode and Effects Analysis (FMEA)**

Failure Mode and Effects Analysis (FMEA) is a proactive tool used to identify potential process failures, evaluate their effects, and prioritize risks based on a calculated risk rating scale, which considers severity, likelihood of occurrence, and detection capability (Fourie and Umeh, 2017). By focusing on critical issues, FMEA allows organizations to implement corrective actions before failures occur.

For example, in warehouse management, FMEA can be applied to an inventory system to mitigate risks such as stock misplacement, inaccurate inventory counts, or delays in order fulfilment. A typical process might involve:

Identifying potential failure modes, such as barcode scanning errors or software errors in the warehouse management system (WMS).

Evaluating the impact of these failures on operations, such as delays in order processing or shipment errors.

Prioritizing risks, such as focusing on scanning errors with a high likelihood and significant operational impact.

Implementing mitigation measures, such as upgrading scanning technology or providing additional staff training.

By addressing high-priority risks, FMEA helps ensure smoother warehouse operations, reduces errors, and improves overall efficiency.

## **Visual Management**

According to Liker (2021), visual management is an effective approach for visually presenting the current status of a process, procedure, or project, highlighting its

alignment with set standards. It enables quick identification of gaps or deviations, which then become the focus for improvement. Toyota integrates visual management as part of its Lean philosophy, recognizing that it complements human capabilities, as humans are naturally inclined to process information visually, tactilely, and audibly. Tools such as visual boards and dashboards, provide real-time insights, making operations more transparent and facilitating prompt corrective actions.

For example, in a distribution centre, visual boards are used to display real-time updates on key performance indicators (KPIs) such as order picking rates, packing accuracy, and shipping timelines. For example, a large digital screen on the warehouse floor shows the number of orders picked per hour compared to the target, with colour coding to highlight performance. This allows warehouse staff and supervisors to quickly identify bottlenecks, such as delays in packing or loading, and take immediate corrective action, ensuring smoother operations and improved efficiency.

### **3.7 Constraints and Success Factors**

The strategic importance of lean has been widely recognized by companies, yet its adoption and sustainability present significant challenges. Lean transformation is often justified by the need to eliminate waste and enhance effectiveness by minimizing variability at the supplier, customer, or internal levels (Kapaj, 2022). However, each organization is unique, and the degree of adoption and success rates varies. Critical success factors must be identified and understood, as the mere application of lean tools and techniques may not be enough (Costa et al., 2018). Successful lean adoptions have been observed across industries, including automotive, food supply chains, healthcare, and electronics. However, lean implementation requires direct involvement and cooperation from companies, customers, and suppliers (Cvetic et al., 2021), but the success of any management practice depends on organizational characteristics, which differ across companies and significantly influence lean transformations. Thus, understanding the context and tailoring tools and practices to each specific setting is crucial (Tortorella et al., 2017).

Perez et al. (2010) identified four primary constraints in lean supply chain implementation; current trading strategies, difficulty in forming value stream teams, senior management commitment, and power-based relationships with customers and suppliers. Additionally, Elkhairi et al. (2019), highlighted barriers such as lack of expertise, inadequate planning, resistance to change, and a lack of strategic perspective. Similarly, Maware et al. (2022) emphasised obstacles, including the absence of a management succession plan, insufficient management support, poor eight-step problem-solving competencies, lack of standardization, ineffective data collection methods, and difficulty in fostering a sustainable culture. Poor commitment to a systems approach and limited leadership-driven cultural transformation also impedes lean initiatives.

In supply chain practices, rigid trading strategies, such as inflexible supplier contracts dictating fixed prices and quantities, often hinder the adaptability essential for lean operations. Lean relies on just-in-time and demand-driven supply chains, which require seamless collaboration across organizational silos and political structures, amplifying the challenges. Leadership teams must demonstrate commitment and provide clear direction to overcome these hurdles. Resistance to information sharing among supply chain members further exacerbates the problem, as collaboration is critical for realizing the benefits of lean practices. Additionally, the absence of necessary skills, strategic planning, and a focus on short-term gains limit lean's effectiveness. Implementing lean in industries, such as healthcare or service-based sectors, introduces complexities due to the complex nature of these systems. Despite these challenges, addressing the critical success factors can positively influence the performance of lean initiatives (Houti et al., 2019). Netland (2015) identified several success factors for lean transitions, including management commitment, employee training, cultural change management, and alignment with strategic goals. Sustained success requires structured approaches, cross-functional integration, continuous improvement, and effective communication. Leadership involvement is fundamental for aligning supply chain strategies with organizational goals and fostering a culture that favours lean. Leaders must actively participate in strategic alignment, resource allocation, and culture-building activities. Clear communication of the benefits of lean and motivational messaging are essential to encourage employee buy-in (Kapaj, 2022). Furthermore, organizations must empower employees to identify and eliminate waste, thereby enhancing efficiency and reducing costs. Establishing a culture of continuous improvement supported by leadership and reward systems is critical (Womack & Jones, 1996).

To succeed, organizations must evaluate their unique characteristics, constraints, and critical success factors before embarking on a lean transition. As a next step we are going to examine the benefits associated with lean in supply chain. By aligning supply chain strategies with long-term objectives and fostering an organizational culture that prioritizes continuous improvement, businesses can maximize the advantages of lean while mitigating its challenges.

### **3.8 Lean SC Benefits**

The application of lean in supply chain to eliminate waste has already been underlined several times, therefore the main advantage has been identified. The implementation of lean in supply chain can effectively improve the overall performance of the supply chain and its participants. The companies can realize several potential improvements from lean supply chain. Apart from waste reduction its impact can be positive on cost, quality, delivery, efficiency, lead time, inventories and in general provides solutions that enable supply chain to become more effective, efficient and adaptable (Cvetic, 2021).

According to Ugochukwu et al. (2012) the widely acknowledged benefits of lean supply chain are the following:

- Low level of inventories
- Increased customer satisfaction
- Streamlined efficiency
- High quality
- Cost reduction
- Improved delivery concerning time, quantity and quality specifications
- High flexibility

In practice, when a company uses Just-in-Time and Kanban systems can improve the inventory levels. In the automotive industry a car manufacturer produces spare parts for cars only when they are needed keeping the inventories low. Also, with a kanban system a warehouse replenishes the storage locations when it is required avoiding the excessive inventory. Also, by reducing waste in the process, the final product or service is delivered to the customer with value leading to increased customer satisfaction (Čiarnienė and Vienažindienė, 2012). For example, when a supply chain has implemented lean to minimize the waiting time for the customers then the realised effect on the customer is increased customer satisfaction. When waste is minimized, processes become more efficient, cost-effective, and responsive, thereby enhancing the quality of the product or service. This results in higher customer satisfaction, as customers receive better quality, lower cost, and faster delivery. Additionally, the companies can benefit from elevated efficiency and productivity. For example, a warehouse which has identified and eliminated through value stream mapping the non-value-added activities can realize reduced cycle times. In the same way, by implementing 5S in warehouse facility a more organised workplace can be created improving efficiency, errors and productivity. The productivity is increased because of this focused improvement that aim to eliminate waste.

Substantial can be also the improvement of quality through the application of lean in supply chain as the process improvement initiatives generate a better overall quality. For example, in a collaborative supply chain environment, the suppliers are involved in the design process of the product defining quality standards and specifications. Also, suppliers' audits are common to verify adherence to quality standards, quality KPIs are applied, and collaborative continuous improvement initiatives are essential. On this way, also the impact on delivery is important, as the time factor is affected using pull systems and visual management. A pull system request products from suppliers only when they are needed, and a visual management tool helps to identify progress and potential delays in the delivery process. According Čiarnienė, R. (2012) lean benefit is also the change of attitude as implementing lean requires a significant shift in the overall organizational attitude, especially when an organization is not familiar with the change process. In the business environment a crucial aspect of lean supply chain is the change in mindset and attitude of everybody involved. This concerns all the organizational levels, from blue-collar workers to the leadership team and the overall culture of an organization. It is a change of culture and mindset that is a transformational process and aims to ensure the sustainability of the lean practices in the supply chain environment. This is related to the element of flexibility as a lean supply chain advantage. A flexible supply chain can quickly adapt to changes in

customers demand and market conditions improving responsiveness and reducing lead times (Manzoor et al., 2022).

### **3.9 Lean SC and Competitive Advantage**

Lean helps the businesses to achieve a competitive advantage by streamlining business processes and identifying key strategic areas for improvement. This is crucial as all the industries and businesses need to be competitive to survive and thrive. According to Elias(n.d.) from Lean Competency System and Cardiff University lean can help an organization to gain a competitive advantage and this can be done through exceptional customer service, value to customers, high quality employees, business growth and positive environmental impact. Eliminating ineffective processes like waiting time and focus on aspects that add value affects the overall customer experience and bring added value to the customers. Lean can increase the reputation of an organization and attract high quality employees and increase employee's engagement and motivation. Lean enables organizations to review continuously their business processes helping the business to grow. Also, the environmental impact of lean can help an organization to become more environmentally friendly by eliminating natural waste. The application of lean management practices helps an organization to achieve a competitive advantage and has positive effect and leads to a subsequent performance improvements (Tupamahu et al, 2019).

According to Porter (1985) competitive advantage refers to the factors that allow a company to produce goods or services better and cheaper than its rivals. There are various internal and external factors in lean supply chain management that have direct impact on competitive advantage. There are classified into internal and external factors. The internal factors include customer focus, flexibility, cost reduction, time-to-market, quality, information management, collaboration, innovation, strategic planning, supply chain integration, lean principles, and organizational culture. The external factors included parameters like technology, human capital, sustainability, risk management, logistics management, and supplier management. The application of lean in supply chain has a significant impact on competitive advantage through the forementioned factors (Khawka et al, 2024).

Focusing on the key principles of lean we understand that by reducing waste and increasing efficiency an organization or the entire supply chain can become more competitive. Continuous improvement and lean practices enhance the overall operational performance delivering value that is a critical component of getting a competitive edge.

### 3.10 Lean SC Criticism and Limitations

After discovering and analysing the positive aspects of lean and investigating its impact on competitive advantage, it is important for this research to reveal the potential negative aspects and criticisms of lean. Even though the Lean Supply Chain offers many advantages, it also has limitations when applying its principles to various organizations. While lean principles can have a positive impact, they do not work for all companies, and the negative points must be highlighted.

First, lean requires skilled staff, which involves significant investment, making it costly to implement at every level of an organization. Additionally, lean relies heavily on outsourcing, which introduces additional costs, such as profit margins for logistics providers or redundancy costs during the transition to outsourcing. Outsourcing also exposes organizations to the risk of costly product recalls when faults occur, as evidenced by automotive's multiple recalls. Moreover, its customer-centric approach has been criticized for emphasizing cost minimization, which limits the ability to meet modern consumer demands for product variety. Lean is less suited to markets where customer preferences frequently change or require high customization. Furthermore, the lean supply chain has been criticized for inflexibility and resistance to change. For some, lean thinking is not dynamic or adaptable to rapidly evolving market conditions. It struggles to embrace innovations driven by customer needs, leading to insensitivity to changing market demands. This rigidity makes lean less suitable for environments that require frequent and unpredictable changes. Additionally, strict adherence to lean principles can result in insensitivity to consumer preferences and evolving trends, making organizations less competitive in contemporary markets (UKEssays, 2018).

Reviewing other studies reveals that lean supply chains are designed for efficiency and cost reduction but lack resilience during disruptions. The reduction of inventory levels and tight coupling between supply chain nodes make them highly vulnerable to disruptions, such as those experienced during COVID-19. Countermeasures like increasing inventory and diversifying suppliers, which were essential during the pandemic, contradict core lean principles, such as inventory minimization and long-term supplier relationships. While lean practices reduce waste and cost under predictable conditions, they can lead to operational paralysis when unexpected disruptions occur. The lack of spare resources can amplify the negative effects of such disruptions. Moreover, there is criticism of the lean supply chain's capability to fully address the demands of prolonged global crises, such as the COVID-19 pandemic. Finally, doubts have been raised about the adaptability of lean supply chains. During the pandemic, lean supply chains had to adopt to practices inconsistent with their principles, such as higher inventories and a focus on short-term adaptability (Tortorella et al., 2022).

This chapter laid the groundwork for exploring the profound impact of the COVID-19 pandemic on global supply chains, particularly those that have implemented lean practices. The pandemic will be examined as a disruption, and this research will attempt to gain insights into how such an event challenged the principles and practices of lean. The next chapter will delve into the nature of COVID-19 and its cascading effects on the dynamics of supply chains and lean practices.

## Chapter 4-COVID-19 & Lean Supply Chain

### 4.1. Introduction to Pandemics

A pandemic is defined as an epidemic occurring worldwide or over a very wide area, crossing international boundaries, and usually affecting a large number of people. Pandemics have occurred throughout human history and seem to be increasing due to the rising emergence of zoonotic diseases that are viral infections transmitted from animals to humans. The impacts of pandemics extend beyond health, influencing economic, social, gender, and political dimensions. Addressing these global challenges requires extensive preparedness and coordination. Therefore, a pandemic come into contrast with an epidemic as it spreads across countries or continents and affects a substantial number of people while an epidemic can be geographically contained and affects specific population for shorter period (Taylor and Moji, 2021).

Pandemics have been a recurrent part of human history, with significant outbreaks causing widespread mortality and social disruption. Notable pandemics include smallpox, cholera, plague, dengue, AIDS, tuberculosis, and various forms of influenza. Other significant diseases like severe acute respiratory syndrome (SARS) and West Nile virus have also emerged in modern times, illustrating the persistent global threat posed by infectious diseases. Influenza pandemics are particularly notable for their unpredictability and recurrence. Since the 1500s, influenza pandemics have occurred approximately every 10–50 years. In the 20th century much before the outbreak of COVID-19 the humanity experienced the Spanish Flu, the Asian Flu and the Hong Kong Flu. The pandemics had severe consequences on the human life and the global development (Qiu et al., 2017, WHO, 2011). Apart from the aforementioned events some more outbreaks have been seen the recent years such as the hantavirus pulmonary syndrome, severe acute respiratory syndrome, H5N1 influenza, H1N1 influenza, Middle East respiratory syndrome, and Ebola virus disease epidemic (Gostin et al., 2016).

According to Qiu et al. (2017) there are particular features that define pandemics and distinguish them from the large-scale epidemics:

- **Wide Geographic Extension:** Pandemics typically affect large geographic areas, crossing international borders and involving many countries, as seen during the H1N1 outbreak in 2009.
- **Disease Movement:** The spread of pandemics involves rapid and widespread transmission, often through person-to-person contact.
- **Novelty:** Pandemics usually involve new or novel variants of organisms, such as the emergence of SARS in the 21st century.
- **Severity:** They are associated with severe or fatal diseases, with high disease and mortality rates.

- **High Attack Rates and Explosiveness:** Pandemics exhibit rapid spread and high infection rates, though diseases with slow transmission are not typically classified as pandemics.
- **Minimal Population Immunity:** A lack of immunity in the population makes pandemics more impactful, as seen with new strains like H7N9.
- **Infectiousness and Contagiousness:** Pandemic diseases are transmissible, either directly (person-to-person) or indirectly (via vectors)

The pandemics have proved to have a multidimensional impact on the human societies. According to Taylor (2021) the following impact categories have been identified:

- **Health Impact:** Pandemics result in high mortality and morbidity rates. Indirect health impacts include overwhelmed healthcare systems and resource shortages.
- **Economic Impact:** Pandemics often cause recessions due to reduced workforce participation, diminished tax revenues, and disrupted supply chains.
- **Gender, social and political impacts:** Women, vulnerable groups and ethnic minorities disproportionately bear the impact of economic and social disruptions. Pandemics also exacerbate social tensions and stigmatization of vulnerable populations. Moreover, public trust in governments can gradually deteriorate due to leadership challenges.

While historical pandemics like the aforementioned had significant impact on global health and economies, the Covid-19 pandemic possesses a special position. As a next step COVID-19 with its impact will be investigated.

## 4.2. COVID-19

The COVID-19 pandemic has been recognized as one of the most significant global threats since World War II and the greatest health disaster of the century. The outbreak originated in Wuhan, China, where cases of a novel pneumonia were reported on December 31, 2019. Initially linked to the Wholesale Seafood Market famous for trading exotic animals, the infection quickly spread, leading to the identification of the virus as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The World Health Organization (WHO) declared it a global health emergency on January 30, 2020, as nations worldwide faced immense health, economic, and social challenges. The pandemic's implications extend far beyond health concerns, severely disrupting international trade, global supply chains, and financial markets. Lockdowns implemented to control the virus's spread, paused the global economic activity, causing widespread job losses, business closures, and reduced operations across multiple sectors, including manufacturing, tourism, education, entertainment etc. As a result, the global economy experienced sizable downturns, with many industries struggling to recover. The economic collapse caused by COVID-19 underscores its far-reaching impact, which in some cases continues to pose challenges for countries worldwide (Naseer et Al, 2023).



The COVID-19 pandemic has significantly affected the global economy and how our globalised world functions in multiple ways. The pandemic disrupted global travels and trade, evident in a 30% reduction in airline stock prices and a sharp decline in sea trade volumes. Lockdowns led to event cancellations, workforce reductions, and supply chain disruptions, causing economic challenges, including a 6% average global recession in 2020. The healthcare systems, particularly in low- and middle-income countries, struggled due to limited capacity, exposing vulnerabilities and inequalities globally (Shrestha et al., 2020).

Moreover, according to Shrestha et al. (2020) the virus affected our life in several ways. Air travel experienced a significant decline, dropping from 4.5 billion passengers in 2019 to 2.2 billion during the pandemic, with major airlines facing a 30% reduction in stock prices due to international travel bans. Similarly, trade volumes at seaports, such as Los Angeles, decreased by over 22%, highlighting the pandemic's strain on global trade. Economically, the world faced a shrinkage of 3%, with advanced economies projected to shrink by 6.1% in 2020. The informal workforce, representing 62% of global employment, was heavily impacted, with 1.6 billion workers significantly affected by lockdowns. Healthcare systems worldwide struggled under the burden of the pandemic, with low- and middle-income countries facing greater challenges due to limited infrastructure and resources. The Pandemic Vulnerability Index revealed that countries like the U.S., Brazil, and India were highly vulnerable due to population density and healthcare limitations. The food and agriculture industry also suffered, with disruptions exacerbating food insecurity, particularly in countries dependent on imports, such as Bangladesh. Academic institutions encountered major challenges, including financial losses from reduced international student enrolment, estimated to cost U.S. universities \$3 billion, and logistical issues in transitioning to online education. These impacts collectively highlight the vulnerabilities of interconnected global systems and underscore the urgent need for improved disaster preparedness and stronger healthcare infrastructure (Shrestha et al., 2020).

Therefore, we can realize the magnitude of COVID-19 and its impact in the economic activity. Several aspects of our life significantly impacted like mobility and travel, economy and employment, healthcare, food and agriculture, education and academic institutions. The impact of COVID-19 on global economy is obvious that has affected substantially the smooth operation of supply chains. The next step of this research will investigate the impact of the pandemic on the smooth operation of supply chain.

### **4.3. SC Challenges & Risks**

The COVID-19 pandemic is not the first disruption to supply chains. Events like the 2011 Japan earthquake, the 2003 SARS outbreak in China, and the 2004 Indonesia tsunami also caused significant shortages and challenges. However, these disruptions typically saw recovery within weeks, unlike COVID-19, whose unprecedented scope and magnitude had far-reaching effects. While past disruptions were often limited geographically and short-term, COVID-19 rapidly spread worldwide, forcing people into lockdown and shutting down major economic sectors. Its unpredictability and

potential for resurgence further destabilized supply chains globally. COVID-19 disrupted supply chains across all stages, exposing the vulnerabilities of interconnected networks. The irregular behaviour of downstream actors, particularly large companies, led to severe demand volatility. This bullwhip effect was especially damaging to upstream actors, including small and medium-sized enterprises, which struggled to manage sharp demand fluctuations and supply interruptions (Xu et al,2020).

Therefore COVID-19 pandemic significantly disrupted global supply chains, exposing vulnerabilities across industries and creating severe risks, including supply and demand imbalances, financial instability, and reduced profits. It highlighted the vulnerability of supply chains and the limited resilience of enterprises to disruptions. Markets faced critical shortages in essential goods and services, prompting governments to adopt measures such as tax reductions, regulatory flexibility, and direct assistance to support businesses (Younis et al, 2023). On the other hand, several industries saw Covid-19 as an opportunity. While the pandemic had a negative effect, still also created opportunities within a certain context especially for those operating in the pharmaceutical and the ecommerce retail sector (Amalia et al. 2020; Acioli et al. 2021; Frederico et al. 2021a). In the same way, there was a substantial surge in the express delivery sectors as it was experienced a significant increase in the diversity and extend of service-related transport to commercial and residential locations during and post pandemic (Yang et al. 2021). The COVID-19 pandemic led to significant disruptions across global supply chains, affecting various dimensions of demand, supply, and logistics. According to the research of Younis et al (2023) the pandemic impacted the supply chain in several ways:

- The pandemic led to significant shortages in critical supplies, raw materials, and finished goods, disrupting the flow of goods through the supply chain.
- Restrictions, lockdowns, and reduced workforce availability caused delays in production and transportation.
- Global shipping disruptions were exacerbated by port closures, container shortages, and increased customs procedures.
- Businesses experienced lower revenues due to decreased consumer demand and interrupted operations.
- Organizations unable to adapt quickly to the disruptions faced significant competitive disadvantages.
- Sudden changes in consumer behaviour, such as stockpiling, created unpredictable demand patterns.
- Supplier shutdowns and dependency on single-source suppliers caused interruptions in production schedules.
- The pandemic caused financial strain on organizations, leading to workforce reductions and salary cuts.
- The health risks posed by COVID-19 impacted the availability of labour and the overall well-being of employees.
- Heavy reliance on global supply chains exposed businesses to ripple effects from disruptions in any part of the world.

- The outbreak in China revealed vulnerabilities in supply chains heavily reliant on Chinese manufacturing.
- The pandemic created bottlenecks in logistics systems, especially in last-mile delivery and container shipping.
- Adjustments to mitigate risks, such as alternative transportation modes, increased operational costs.

In the same direction Van Hoek (2020) has identified risks and challenges classifying them in three categories Supply, Demand and Control risks:

### **Supply Risks**

The pandemic highlighted significant supply risks, including factory closures that caused delivery delays and disruptions. Heavy reliance on single or limited suppliers increased vulnerabilities, while logistical bottlenecks, such as reduced transportation capacity, compounded the challenges.

### **Demand Risks**

Panic buying caused demand spikes for essentials, while industries like apparel and automotive faced sharp declines. The rapid shift to e-commerce and home delivery added further strain to supply chains.

### **Control Risks**

Control risks arose as companies struggled to manage supplier relationships while extending payment terms and renegotiating contracts. The lack of preparedness and inadequate contingency plans further hindered effective responses to the crisis.

Hence, COVID-19 disrupted supply chains by causing delays, shortages, and uncertainty. Factories closed, shipping was delayed, and companies couldn't get the materials they needed. Some products were not available while others didn't sell at all. Many businesses lost money, and workers faced layoffs or health risks. It showed how fragile supply chains are but also pushed companies to find new ways to adapt and improve. Despite the significant challenges and disruptions caused by the COVID-19 pandemic, it also opened the door to unexpected opportunities. Many businesses found ways to adapt and innovate, turning obstacles into chances for growth. The pandemic pushed companies to rethink their strategies, embrace new technologies, and respond to shifting consumer demands. In the next section, we'll explore the emerged opportunities and the change they brought in the supply chains.

## **4.4. Opportunity for Change**

The pandemic has profoundly transformed the global supply chain, exposing vulnerabilities and risk while on the other hand triggered change in how businesses approach supply chain. First, supply chains have become a central focus for corporate leadership, with chief supply chain officers gaining prominence. Secondly, while cost reduction and productivity were the primary drivers of supply chain investments,

businesses are now prioritizing continuity, resilience, and flexibility. Moreover, the collaboration between buyers and suppliers has been emphasized and while relationships often emphasized cost and efficiency over collaboration now strategic alliances and co-development between OEMs (Original Equipment Manufacturers) and suppliers, such as Ford and GM's partnerships with chipmakers, have become more common. Furthermore, now companies explore new supply chain solutions driving innovation and disruptions risk mitigation with unconventional solutions, including chartering their own vessels, creating storage space, and using alternative ports. Additionally, it is crucial that the supply chain have identified vulnerabilities in supply chain models like Just-in-Time e.g. automakers such as Toyota and Tesla stockpiled critical components. Retailers like Nordstrom and Gap over-ordered and adopted "pack-and-hold" strategies to avoid shortages (Sultan, 2022).

Also, the pandemic became a reason to accelerate digital transformation and e-commerce as the customer behaviours adapted to the pandemic and the physical purchases become online accelerating the development of e-commerce business models (Zwanka and Buff, 2021). The pandemic accelerated improvements in digital transformation, data sharing and increased investments in Industry 4.0 with big data and artificial intelligence and other technologies. Also, the focus shifted to resilience and collaboration in supply chain (Taghipour and Merimi, 2021). The companies started considering alternative suppliers to reduce dependencies and focused on domestic suppliers because of limitations in transportation. Also, given the interconnectedness and interrelationship of supply chains, companies started considering all aspects from the upstream to the downstream to make better decisions (Khodoomi et al, 2024). COVID-19 accelerated the adoption of circular economy practices in supply chain with the reuse, recycling, recovery and remanufacturing for achieving a reduction of waste (Liu et al., 2022). The pandemic encouraged companies to rethink their waste management and embrace circularity to conserve resources and minimize environmental impact (Ellen MacArthur Foundation, 2021).

As a result, it is obvious that the pandemic has prompted changes in supply chain, moving away from traditional models focused on efficiency toward more resilient and adaptive systems. While many of these changes were a reaction to the problem encountered, they have set the stage for a more intelligent, collaborative, and flexible global supply chain ecosystem. After exploring the challenges, risks and changes that COVID-19 brought on supply chain, it will be important for this research to examine the effect of lean supply chains.

#### **4.5. Covid-19 impact on LSC**

The global economy and supply chains underwent unprecedented disruptions due to the COVID-19 pandemic, compelling organizations to challenge foundational theories and principles. Lean supply chains, with their focus on efficiency through practices like Just-In-Time (JIT), were particularly vulnerable to these disruptions. Designed to minimize waste, reduce inventory levels, and cut costs, JIT systems excel in stable and predictable conditions. However, the pandemic exposed their limitations, as

disruptions to transportation and logistics interrupted the smooth operations the lean systems depend upon (Tortorella et al., 2022). Consequently, many companies faced production delays and struggled to meet customer demands. To address these challenges, organizations were forced to adapt by increasing inventory levels, diversifying suppliers, and adopting short-term solutions; actions that deviated from lean principles like minimizing inventory and fostering close customer-supplier relationships. For instance, Honda's lean supply chain, heavily reliant on JIT, experienced significant setbacks when the supply of critical components was disrupted, resulting in production inefficiencies (Supply Chain Digital, 2021c). Similarly, Apple faced production slowdowns due to shortages of key components caused by factory closures and logistics delays, highlighting the rigidity of JIT systems in the face of global disruptions (Supply Chain Digital, 2021d). These examples underscore the need for a balance between efficiency and resilience in supply chain management. The pandemic also brought attention to the risks of offshoring and single-supplier reliance. Many companies in Europe and North America faced production pauses when critical parts from China became unavailable. Disruptions in China's manufacturing sector, for instance, led to a 13% drop in global car production, affecting companies like Fiat Chrysler Automobiles and Hyundai (Gong, 2024). This highlighted the importance of diversifying supplier networks and reducing dependency on single regions to manage future disruptions effectively. The transition to "just-in-case" strategies became an essential response to ensure business continuity. By holding additional stock and preparing for unexpected disruptions, companies prioritized resilience over efficiency. Zhang and Doan (2022) emphasized that firms heavily reliant on imported inputs and minimal inventories were unable to maintain operations during the pandemic, prompting a re-evaluation of traditional JIT practices.

The lessons from the pandemic extend beyond short-term crisis management. Companies have begun to reconsider the overall design of their supply chain strategies to ensure they can adapt to future challenges. This has led to a paradigm shift, where lean principles are being integrated with elements of agile and resilient supply chain strategies. For example, organizations are increasingly leveraging digital technologies such as artificial intelligence (AI), blockchain, and advanced analytics to enhance visibility and responsiveness across their supply chains. AI-powered predictive analytics can help forecast demand fluctuations and identify potential disruptions, enabling companies to take proactive measures. Blockchain technology, on the other hand, offers enhanced traceability and transparency, which are critical for managing complex global supply chains. Moreover, fostering closer collaboration with suppliers and stakeholders has emerged as a critical approach to building more resilient supply chains. Companies are investing in long-term partnerships and joint risk management initiatives to ensure a steady supply of critical components. For instance, Toyota's approach to cultivating strategic partnerships with suppliers has been instrumental in maintaining operational continuity during disruptions (Supply Chain Digital, 2021a). Similarly, localizing supply chains by sourcing materials and components closer to production facilities has gained traction as a strategy to mitigate risks associated with global transportation and geopolitical uncertainties.

Looking forward, the COVID-19 crisis revealed that while lean supply chains perform well under predictable conditions, they require adaptation to withstand uncertainties. The integration of lean principles with strategies that enhance flexibility and resilience becomes vital. Leveraging technology, strengthening supplier networks, and building contingency plans can help balance efficiency with robustness. Additionally, companies are likely to emphasize sustainability and circular economy practices as part of their broader resilience strategies. By adopting such measures, supply chains cannot only withstand future disruptions but also contribute to long-term environmental and economic goals. The research will explore innovative approaches to align lean supply chain practices with the demands of an increasingly unpredictable global environment.

## **Chapter 5-The Evolution of Lean Supply Chain**

### **5.1. LSC Shift**

As we so far analysed, the COVID-19 pandemic immensely disrupted the global supply chain, exposing the vulnerabilities of lean practices and prompting organizations to adapt and evolve their supply chain practices. The supply chains and particularly the lean supply chains had to adapt triggering an overall shift in the lean organizations as their supply chains were struggling to survive under abnormal circumstances due to the challenges of the pandemic and in order to become more resilient in a business environment where disruptions and challenges have been constant. There are areas that underwent or have been undergoing a transition process to adjust to the new realities.

#### **Hybrid Lean Supply Chain Models**

Before the pandemic, lean supply chains were heavily reliant on Just-In-Time (JIT) principles aimed at minimizing inventory and cost. However, COVID-19 revealed the fragility of this approach, as disruptions led to severe supply shortages, particularly in industries like automotive and electronics (Supply Chain Dive, 2021b). For example, companies like Ford faced production stoppages due to semiconductor shortages, highlighting the risks of minimal inventory buffers. With the outbreak of the pandemic, many organizations have adopted hybrid models that combine JIT with Just-In-Case (JIC) strategies. These approaches include maintaining safety stocks of critical items to enhance resilience while preserving cost efficiency (Chang and Huang, 2022). This shift has been further supported by frameworks such as leagility, which integrates lean and agile principles to achieve a balance between efficiency and responsiveness (Rashad and Nedelko, 2020).

#### **Supply Chain Resilience**

The COVID-19 pandemic revealed the need for resilience in supply chains, supplementing traditional goals of efficiency and cost minimization. Resilience refers to a supply chain's ability to anticipate, prepare for, respond to, and recover from disruptions while maintaining operations (Rossini et al., 2024). Geographic concentration in supply chains, particularly in Asia, caused severe disruptions when factories and ports shut down during the pandemic. In response, companies have diversified their supplier bases, adopting nearshoring and reshoring strategies to reduce dependency on single regions and mitigate risks (Kenan Institute, 2021). For instance, European manufacturers increasingly source within the EU to enhance supply chain resilience and reduce lead times (Rossini et al., 2024). While lean principles traditionally emphasize minimizing inventory, the pandemic highlighted the importance of maintaining buffer stocks for critical components. Strategic stockpiling mitigates the risks of shortages during disruptions, as illustrated by Ford's experience with semiconductor supply constraints (Supply Chain Dive, 2021b). Furthermore, organizations are increasingly investing in risk management tools and scenario planning. By conducting thorough risk audits, companies identify vulnerabilities in their

supply chains and develop contingency plans, such as alternative supplier networks and backup logistics strategies (Musella, 2023). Building resilience into supply chains has become a priority, reflecting a transition toward more strategic and proactive approaches that balance efficiency with adaptability and long-term stability.

### **Agility and Flexibility**

Agility and flexibility have increasingly prioritized in lean supply chains to manage uncertainty and rapid market changes. Techniques like multi-echelon inventory control, dynamic production systems, and modular manufacturing allow businesses to respond swiftly to demand fluctuations (Supply Chain Dive, 2020). The COVID-19 pandemic emphasized the necessity of adopting agile strategies to complement traditional lean approaches in supply chains. Agile supply chain strategies prioritize speed and flexibility, enabling organizations to respond quickly to uncertainties and disruptions. In comparison to lean strategies, which focus on cost reduction and waste minimization, agile strategies ensure faster lead times and improved responsiveness by enabling dynamic operations. For instance, agile supply chains demonstrated their effectiveness during the vaccine distribution process, where responsiveness to demand changes and rapid rollout were critical to minimizing infections and deaths. These strategies are particularly suitable for managing inventory efficiently, collaborating with suppliers, and addressing sudden shifts in customer needs. By incorporating agility, supply chains can maintain a balance between operational efficiency and adaptability to disruption scenarios (Gomes et al., 2023). Agility and flexibility have become essential components of lean supply chains, enabling businesses to effectively manage uncertainty and rapid market changes.

### **Collaboration and Transparency**

Collaboration and transparency proved essential in facing the disruptions caused by COVID-19 in lean supply chains. Transparent communication and collaborative decision-making processes facilitated rapid information sharing and increased predictability among stakeholders. The emphasis on collaboration has enabled companies to adapt to disruptions by fostering trust and alignment across the supply chain. During the pandemic, some companies reinforced supplier relationships by engaging them in decision-making and demonstrating commitment to long-term partnerships. When digital information systems lacked precision, firms relied on direct communication methods such as emails and phone calls to ensure real-time updates. These practices highlight the importance of transparent and collaborative approaches in navigating external complexities while maintaining performance during severe disruptions (Tortorella et al., 2022).

Therefore, collaboration across supply chains has emerged as a critical factor for resilience. Vendor-Managed Inventory (VMI) systems, collaborative forecasting tools, and integrated digital platforms foster trust and alignment among stakeholders. This enhances information sharing, joint decision-making, and supply chain adaptability (McKinsey, 2021; Rashad and Nedelko, 2020). Collaboration and transparency have proven vital for enhancing resilience in lean supply chains, particularly during the disruptions caused by COVID-19.



## **Performance Metrics**

The pandemic necessitated a re-evaluation of supply chain performance metrics. Traditional lean metrics focused on cost and efficiency are now supplemented by resilience, sustainability, and risk management. Organizations are balancing short-term profitability with long-term adaptability and environmental responsibility (Hyder, 2021; Musella, 2023). The pandemic highlighted the importance of aligning supply chain performance metrics with the specific demands of lean strategies, emphasizing financial and efficiency aspects of performance while also integrating resilience and adaptability. Lean supply chain metrics, such as cost control, productivity, inventory turnover, and lead time, have traditionally focused on waste elimination and resource optimization. However, the disruptions caused by COVID-19 have expanded these metrics to include customer service and flexibility, recognizing the importance of agility in responding to market volatility. Additionally, sustainability considerations, such as reducing environmental impacts and enhancing social outcomes, have been incorporated into performance frameworks, highlighting the critical need for a balanced and dynamic approach to performance evaluation (Dahinine et al., 2024).

The pandemic has driven a significant shift in supply chain performance metrics, evolving them from being focused on cost and efficiency to a more balanced framework that incorporates resilience, adaptability, and sustainability. By integrating customer service, flexibility, and environmental considerations, organizations are now better equipped to navigate market volatility and align operational goals with broader societal responsibilities, ensuring both short-term efficiency and long-term sustainability.

## **Sustainability and Environment**

The pandemic accelerated the integration of sustainability into lean supply chains. Companies are aligning their operations with the United Nations Sustainable Development Goals, adopting the 4Rs framework (Reduce, Reuse, Recycle, Replace) to minimize waste and promote environmentally friendly practices (Chang and Huang, 2022). Digital tools also support sustainability by optimizing resource utilization and reducing carbon footprints. For instance, modular production systems ensure efficient use of materials and energy, contributing to both lean and sustainability goals (Rossini et al., 2024). Additionally, green logistics practices, such as the use of renewable energy and eco-friendly transportation, are being widely adopted (Rashad and Nedelko, 2020).

Also, the adoption of lean and green processes enhances the sustainability of supply chains by leveraging their complementary strengths. Lean supply chain management focuses on waste elimination and continuous improvement, while green supply chain management integrates environmental considerations into supply chain operations. Together, these approaches drive sustainable performance across environmental, social, and economic dimensions. For example, lean processes on the customer side, such as reducing overproduction and involving customers in continuous improvement, are particularly effective in improving environmental and social outcomes. Also, green processes on the supplier side promote eco-friendly raw materials and safer working environments, reducing environmental risks and enhancing occupational health and

safety. The integration of lean and green processes fosters innovation and creates unique capabilities that help firms achieve sustainable performance with greater efficiency (Huo et al., 2019).

The pandemic has acted as a trigger for the evolution of lean supply chains by embedding sustainability at their core. This shift aligns operations more effectively with sustainable development goals, while addressing environmental, social, and economic challenges to become more resilient and sustainable.

### **Digital Transformation and Industry 4.0**

Technology plays an important role in modern supply chains by enhancing visibility, decision-making, and operational efficiency. Industry 4.0 technologies, such as IoT, AI, blockchain, and big data analytics, have become integral components of lean supply chain practices (Rossini et al., 2024). IoT enables real-time tracking of goods and inventory, facilitating proactive decision-making (Rossini et al., 2024). AI contributes to improved demand forecasting and production planning, allowing businesses to quickly adapt to changing conditions (Hyder, 2021). Blockchain strengthens transparency and traceability, mitigating fraud and fostering collaboration across supply chain networks (Rossini et al., 2024). Furthermore, these technologies address inefficiencies like the bullwhip effect, which arises when minor demand variations at the consumer level lead to amplified fluctuations further upstream (Rashad and Nedelko, 2020).

Also, the integration of digital twins into lean supply chain management illustrates the evolution of lean practices in the digital era. Digital twins, which provide virtual replicas of physical processes or systems, enable real-time monitoring, optimization, and synchronization between digital and physical supply chains, enhancing their connectivity and resilience. This technology is applied extensively within the end-to-end supply chain, contributing to waste elimination, improved logistics management, and just-in-time (JIT) flows. Additionally, digital twins foster supply chain integration, coordination, and adaptability, which are increasingly vital in addressing disruptions like COVID-19 and geopolitical uncertainties. They also strengthen performance metrics, such as reliability, responsiveness, agility, cost efficiency, and asset utilization. By enabling predictive analytics and intelligent decision-making, digital twins not only support traditional lean principles but also drive the development of resilient and adaptive supply chain strategies for dynamic and uncertain environments (Guo and Mantravadi, 2024). Technology has significantly advanced lean practices by enabling real-time decision-making, enhanced flexibility, and synchronized operations. These technologies allow for the seamless integration of physical and virtual supply chains, transforming traditional practices into dynamic, adaptable frameworks. By leveraging real-time analytics, predictive and prescriptive insights facilitate the reduction of lead times, optimization of logistics, and enhanced customer service. Moreover, digital platforms enable improved collaboration among supply chain partners, addressing inefficiencies such as information asymmetry and fostering a more responsive and integrated ecosystem (Cifone et al., 2021).

Additionally, the growing complexity of modern supply chains and the increasing demand for visibility underscore the importance of leveraging advanced technologies

such as supply chain control towers platforms. These centralized, cloud-based platforms enable real-time visibility and coordination across the end-to-end supply chain, fostering operational efficiency and sustainability. Control towers enhance decision-making by integrating data from multiple sources, offering predictive analytics to anticipate disruptions and optimize resources. Moreover, they play a pivotal role in aligning supply chain activities with sustainability objectives, such as reducing carbon footprints, improving resource utilization, and promoting transparency across operations. By providing a single source of truth, they empower organizations to transition from reactive to proactive supply chain management, ensuring resilience and adaptability in dynamic environments (Salah et al., 2023). The integration of digital tools and Industry 4.0 technologies has significantly transformed lean supply chain management, enabling real-time decision-making, enhanced collaboration, and operational resilience. Innovations such as IoT, AI, blockchain, and digital twins not only strengthen traditional lean principles but also address modern challenges, including global disruptions. Furthermore, advancements like supply chain control towers provide organizations with real-time visibility and predictive capabilities, ensuring adaptability to the challenges. These technological evolutions make lean supply chains more agile, efficient, and sustainable for navigating today's complex and dynamic business environment.

The changes brought to lean supply chains due to COVID-19 reflect a shift toward balancing efficiency with resilience and adaptability. Businesses have adjusted their strategies to better handle disruptions, focusing on collaboration, sustainability, and the use of technology to strengthen their operations. These changes show how lean supply chains can evolve to meet the challenges of a constantly changing global landscape.

## **5.2. Case Study**

In this research, the case study examines the pan-European supply chain operations of Toyota, the largest automotive company in the world, with its global headquarters in Japan and its European head office in Brussels, Belgium. This company is widely regarded as the pioneer of Lean Management and has significantly contributed to the development of expertise and practices in this field. The case study focuses on lean projects and operations at the European distribution centre in Belgium, which is responsible for the European logistics operations. This includes the coordination of a network of 17 regional and national warehouses, managing distribution operations across Europe, and facilitating also transportation from Europe to other regions. The case study specifically addresses a program that is part of the company's Lean strategic roadmap. This program aims to reduce waste, enhance visibility, improve internal and customer satisfaction, foster synergies across the supply chain, and achieve a competitive advantage, resilience and agility contributing to the establishment of a future proof-supply chain. The knowledge for developing the case study derives from the following sources:

- **Personal experience:** The researcher has worked as a manager in supply chain functions at the company. This experience provides an observational perspective that enables the researcher to extract and utilize information not accessible through other research methods. It also offers insights for a deeper understanding of the research topic (Noor, 2008).

- **Interviews:** Semi-structured interviews were conducted with employees of the company. This method allows for flexibility in approaching different respondents while ensuring the extraction of sufficient and relevant information (Noor, 2008).

Therefore, relevant information for the compilation of the case study was acquired through open discussion, existing knowledge of the researcher as former manager of the company. For confidentiality purposes, the names of the interviewees, and other sensitive information will not be disclosed. Additionally, corporate details, such as financial data, details of strategic roadmaps and the future vision will not be presented.

Toyota has long been recognized as a leader in lean supply chain management. However, the challenges of recent years, such as the COVID-19 pandemic, have shown the need for some of its processes to adapt to new realities. This case study looks at how Toyota Motor Europe (TME) updated its supply chain approach, keeping lean principles at the core while adding resilience, agility, and sustainability to stay competitive and yet remain the largest automotive manufacturer. Lean supply chains, as defined by the Toyota Production System (TPS), focus on efficiency, reducing waste, and continuous improvement. However, the COVID-19 pandemic exposed the risks of relying on minimal inventory and operating in global supply chains. Companies like Toyota needed to rethink their approach to maintain efficiency while becoming more flexible and prepared for disruptions.

In 2019, TME launched a programme to improve its warehousing, packaging, and transportation operations across Europe and contribute to the overall operational sustainability. The programme's goals were to:

- Maintain lean efficiency focusing on the key metrics of Toyota; Safety, Quality, Delivery, Cost, Environment and Employees Morale.
- Improve resilience and flexibility.
- Support environmental sustainability.

Although the project was planned to take three years, the pandemic accelerated its completion to just over 14 months. This rapid implementation demonstrated Toyota's ability to innovate and adapt its lean principles to address emerging challenges. The programme solved several issues that had been limiting Toyota's supply chain performance:

- Inefficient packaging, not aligned to current requirements, led to low truck loading density and higher transportation costs.
- Lack of supply chain visibility on the flows of its transportation assets.
- Current transportation packaging capacity versus Increasing sales volumes based on the corporate strategy.
- environmental goals required better processes.

Toyota supply chain programme aimed to:

- Improve packaging efficiency.
- Reduce costs and CO2 emissions to comply with the defined environmental targets.
- Increase flexibility to handle disruptions.
- Meet internal and external customer expectations.

Toyota's programme followed lean principles but adapted them to fit contemporary needs. The whole programme consisted of the following continuous improvement initiatives/projects:

- **Technology for Efficiency**

An RFID and IoT tracking systems gave Toyota insights into the packaging assets inventory levels and particularly on transportation assets, improving track and trace, visibility, operational efficiency, accuracy, collaboration across the network and decision-making. The system reduced manual tracking errors and streamlined inventory replenishment processes, which were critical during pandemic and the issues that caused. Paired with business intelligence tools implementing Microsoft PowerBi, the RFID system ensured data visualization and data-driven decisions across the supply chain network of Toyota.

- **Sustainable Transportation Packaging Solutions**

Reusable metal pallet crates reduced waste and improved truck loading efficiency. These durable crates addressed multiple issues. They reduced damage to parts during transportation, increased truck density by standardizing dimensions. The use of standardised reusable solutions instead of limited life or single use packaging, improved warehouse picking process improving overall performance and supported Toyota's goal of meeting the EU environmental regulations.

- **Logistics Outsourcing**

By outsourcing assets storage and replenishment processes to a 3PL provider, Toyota improved inventory management while focusing on its core logistics operations that is the management of the spare parts and vehicle logistics business. This partnership used advanced logistics systems to streamline processes, including electronic Kanban (e-Kanban) systems that maintained lean inventory levels and ensured timely replenishments.

The programme used several core lean tools:

**Just-in-Time (JIT):** Ensured smooth material flows without excess inventory, minimizing waste while maintaining operational efficiency.

**Kanban and Pull Systems:** Managed inventory replenishment efficiently by signalling demand-driven restocking processes.

**Value Stream Mapping:** Identified and eliminated waste in processes, focusing on improving end-to-end supply chain visibility. Supply Chain flows were analysed and

improvements were implemented erasing useless operations in transportation and warehouses.

**Kaizen:** Constant continuous improvement initiative accelerated the progress of the project and improved the outcome.

Toyota's programme delivered significant benefits:

**Financial Improvements:** The project ROI realised within three years through cost savings from reduced packaging cost, optimized transportation, and improved inventory management. Lower operational costs allowed Toyota to reinvest in further innovations, strengthening its competitive edge in the market.

**Greater Flexibility:** Real-time inventory tracking and improved packaging allowed Toyota to quickly adjust to the operational disruptions due to the pandemic and Brexit. This agility ensured uninterrupted service to customers even during global supply chain challenges.

**Environmental Benefits:** Reusable packaging and optimized logistics cut CO2 emissions and aligned with Toyota's sustainability goals. Metrics such as *% reduction in disposable materials* and *emissions per kilometre* highlighted the programme's success in minimizing environmental impact.

**Enhanced Customer Satisfaction:** Reliable, efficient operations improved customer experiences by reducing delays and increasing service flexibility. Toyota's ability to meet demand swiftly and sustainably strengthened its reputation as a dependable partner.

Toyota's experience shows how lean principles can evolve to meet new challenges. Strategic assets stock, built resilience as adding reusable crates and leveraging 3PL partnerships provided flexibility without undermining efficiency. These strategic buffers allowed Toyota to maintain lean operations while preparing for unexpected disruptions. Technology enhanced lean practices as tools like IoT/RFID and advanced analytics improved decision-making, enhanced visibility, and supported lean goals. These technologies ensured that lean principles remain relevant in the digital age. Sustainability complemented Lean as reducing waste and emissions aligns with lean's focus on eliminating inefficiencies while meeting modern environmental standards. Toyota's sustainability efforts demonstrate that lean and environmental protection practices can coexist effectively. Collaboration was key as partnerships with 3PL providers and cross-functional teams ensured smooth implementation and better outcomes. Collaboration fostered innovation and streamlined complex processes, enhancing overall supply chain performance. Agility was critical as in a volatile environment, flexibility in operations is essential. Toyota's quick adjustments during the pandemic highlight the importance of agile supply chain systems supported by lean practices.

Toyota Motor Europe's supply chain programme shows how lean principles can be adapted for resilience, sustainability, and agility. By combining traditional tools like Kanban with modern technologies and collaborative approaches, Toyota created a supply chain model fit for today's challenges. This case study highlights the

importance of innovation, flexibility, and long-term vision in maintaining lean efficiency while addressing the demands of a dynamic business environment. Toyota's success serves as a benchmark for companies striving to balance lean efficiency with the need for resilience and sustainability in an increasingly uncertain global landscape.

# Chapter 6-Conclusion

## 6.1. Discussion

This thesis aimed at answering two key questions regarding the lean supply chain within the context of the COVID-19 pandemic:

- What were the implications of the pandemic on supply chain and particularly the lean supply chain?

and

- How does the future of lean supply chains look like?

Regarding the first research question the thesis concluded to several key finding concerning the implications of the pandemic:

- **Inventory shortages** as lean systems, which rely on minimal inventory, faced critical shortages when suppliers halted production.
- **Disrupted logistics** as transportation bottlenecks, including shipping delays and port closures, created inefficiencies in supply chain operations.
- **Demand volatility** as lean systems struggled to respond to rapid demand shifts, as they lacked the buffers needed to adapt quickly.
- **Ripple effects** as the interconnected nature of lean supply chains amplified disruptions, causing eg. delays across multiple tiers.
- **Increased operational costs** as adjustments, such as expedited transportation or alternative sourcing, raised costs and challenged lean efficiency.

These effects emphasized the vulnerabilities of lean systems when experiencing large-scale, prolonged disruptions like the COVID-19 pandemic.

Regarding the second research question the thesis outlined how the lean supply chain has evolved to be able to withstand disruptions and encounter COVID-19. The key findings of the research are the following:

**Hybrid Approaches:** Transition from purely Just-In-Time (JIT) systems to hybrid models incorporating Just-In-Case (JIC) strategies for greater resilience.

**Focus on Resilience:** Increased diversification of suppliers, nearshoring, reshoring, and maintaining buffer stocks to mitigate disruptions and reduce dependency on single sources.

**Agility and Flexibility:** Adoption of modular manufacturing, dynamic inventory control, and faster response systems to manage demand fluctuations and uncertainties.

**Enhanced Collaboration:** Stronger partnerships with suppliers, Vendor-Managed Inventory (VMI), and integrated planning tools to ensure synchronized operations and transparency.



**Sustainability Integration:** Alignment with environmental goals through the 4Rs framework (Reduce, Reuse, Recycle, Replace) and adoption of green logistics practices.

**Technology Adoption:** Integration of Industry 4.0 technologies such as IoT, AI, blockchain, and digital twins to improve visibility, decision-making, and adaptability.

**Broader Performance Metrics:** Expansion of metrics to include resilience, adaptability, and sustainability alongside cost and efficiency.

The findings of this thesis demonstrate that while lean supply chains excel in stable conditions, their long-term success depends on their ability to adapt to disruption. The pandemic exposed critical weaknesses, including over-reliance on tightly linked systems and low inventories. However, the research also highlighted opportunities for improvement, particularly through the integration of resilience strategies and digital tools. The case study reinforced these insights, showcasing practical ways lean systems can evolve to meet modern challenges.

## 6.2. Managerial Implications

The evolution of lean supply chains highlights the need for a strategic balance between efficiency and resilience. Managers must consider hybrid supply chain models that combine traditional Just-In-Time (JIT) principles and alternative strategies, such as maintaining safety stocks for critical components to mitigate disruptions. Building resilience requires diversifying suppliers, embracing nearshoring or reshoring strategies, and conducting risk audits to identify vulnerabilities and implement contingency plans. Collaboration and transparency have become essential, necessitating the use of integrated digital platforms to synchronize operations and strengthen supplier relationships. Digital transformation is another critical area, with technologies like IoT, AI, and blockchain enabling real-time decision-making, improved visibility, and predictive capabilities. Additionally, sustainability must be integrated into supply chain practices by aligning operations with environmental goals and adopting the Reduce, Reuse, Recycle and Replace strategies to minimize waste. Managers should also expand performance metrics beyond efficiency to include adaptability, resilience, and sustainability while fostering a culture of continuous improvement (Kaizen) to drive innovation and align teams with strategic objectives. These shifts will ensure that lean supply chains remain robust and competitive in an increasingly uncertain and dynamic global environment.

## 6.3. Research Limitations

This research, while offering valuable insights into the evolution and challenges of lean supply chains during the COVID-19 pandemic, has certain limitations. The research is based on a mixed-method approach that combines a literature review and a case study on specific company, which may limit the generalization of the findings

and may not fully represent the entire lean supply chain practices across diverse industries or regions although this specific company is famous for its lean mentality and is the paradigm for the lean industry. Additionally, the rapidly changing nature of the global supply chain landscape means that some conclusions might become outdated as new technologies, strategies, or disruptions emerge. Of course, these limitations provide opportunities for future research to build on this study by incorporating broader industry analyses, contemporary data, and exploration of additional case scenarios.

## **6.4. Future Direction**

Future research on lean supply chains should focus on the role of new technologies and Industry 4.0 in shaping the next generation of lean practices. Technologies like blockchain, digital twins, artificial intelligence (AI), and the Internet of Things (IoT) have the potential to further transform lean supply chains by improving visibility, enhancing decision-making, and building resilience. Exploring how these tools can be integrated into lean systems, without compromising their core principles but on the contrary enhancing them, such as waste reduction and efficiency, would be a valuable area of study. Research could also investigate how the philosophy of Kaizen, or continuous improvement, can evolve in a world increasingly driven by new technologies. This could include examining how companies use digital tools to support collaboration, real-time problem-solving, and ongoing innovation, while adhering to the fundamental values of Kaizen. Finally, future studies might focus on how these advancements apply in specific industries, such as manufacturing, healthcare, and logistics, to better understand the practical application of technology and continuous improvement in diverse contexts. Such research would provide insights into how lean supply chains can remain effective and adaptable in the constantly changing environment.

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