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Challenges in maintaining high delivery reliability in the food industry: A case study in a Finnish food company

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ABSTRACT:
Delivery reliability is considered a key competitive factor in business environment, as it strengthens customer satisfaction, builds brand image, and fosters long-term customer relationships. This study examines the challenges of the supply chain for perishable food products and their impact on maintaining delivery reliability. Key challenges include fluctuating demand, short shelf lives, changing consumer preferences, seasonality and environmental and hygiene requirements, all of which contribute to the complexity of the food supply chain.

This study has been conducted in collaboration with a case company, aiming to identify cost-effective ways to maintain high delivery reliability. The empirical part has been implemented as a quantitative study analysing production and workforce data from 2023-2024. The analysis particularly focused on the number of overtime hours, and a scenario analysis was conducted to assess how changes in overtime affected labour costs, delivery reliability, and production volumes. Furthermore, a current state analysis and a correlation matrix were developed to identify variables that may negatively impact delivery reliability. The literature review discusses the Theory of Constraints, lean manufacturing, and the principles of resilience and agility, which can be used to improve the performance and delivery reliability in the food supply chain.

The results show that the case company has successfully maintained a high and stable level of delivery reliability in 2024. Additionally, shortages of raw materials and surplus have decreased compared to the previous year. The growth in both demand and the number of delivered products indicates operational success. However, the amount of overtime doubled compared to 2023, and according to the scenario analysis, hiring additional workforce for the summer would have been a more cost-effective solution. The results from the correlation matrix showed no significant correlation between overtime and delivery reliability, whereas a negative correlation was identified between the number of ordered products and delivery reliability. Based on these findings, it is recommended that the company reassesses its long-term human resources strategy and further develop production line capacity and flow to reduce overtime hours and enhance overall cost-efficiency.

KEYWORDS: food industry, delivery reliability, overtime, perishable products, shelf life, cost-effective

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TIIVISTELMÄ:
Toimitusvarmuutta pidetään keskeisenä kilpailutekijänä yritysmaailmassa, sillä sen avulla vahvistetaan asiakastyytyväisyyttä, rakennetaan brändimielikuvaa ja luodaan pitkäaikaisia asiakassuhteita. Tässä tutkielmassa tarkastellaan helposti pilaantuvien elintarvikkeiden toimitusketjujen haasteita ja niiden vaikutusta toimitusvarmuuden ylläpitämiseen. Keskeiset haasteet ovat vaihteleva kysyntä, lyhyet säilyvyysajat, kuluttajien muuttuvat mieltymykset, kausiluonteisuus sekä ympäristö- ja hygieniavaatimukset, jotka yhdessä lisäävät elintarviketjun kompleksisuutta.

Tutkimus on toteutettu yhteistyössä case-yrityksen kanssa tavoitteena löytää kustannustehokkaita keinoja toimitusvarmuuden ylläpitämiseksi korkealla tasolla. Empiirinen osuus on toteutettu määrällisenä tutkimuksena, jossa on analysoitu vuoden 2023–2024 tuotanto- ja henkilöstödataa. Analyysissä on keskitytty erityisesti ylityötuntien määrään, ja skenaarioanalyysin avulla on arvioitu, miten ylityötuntien muutokset vaikuttavat henkilöstökustannuksiin, toimitusvarmuuteen ja tuotantomäärään. Lisäksi on laadittu nykytila-analyysi ja korrelaatiomatriisi, joiden perusteella on pyritty tunnistamaan tekijöitä, jotka heikentävät toimitusvarmuutta. Kirjallisuuskatsauksessa on esitelty Theory of Constraints -ajattelutapa, lean-ajattelu sekä joustavuuden ja ketteryyden periaatteita, joita voidaan hyödyntää elintarviketjun kehittämisessä ja toimitusvarmuuden parantamisessa.

Tutkimuksen tulokset osoittavat, että case-yrityksessä on onnistuttu ylläpitämään korkea ja vakaa toimitusvarmuus vuonna 2024. Lisäksi raaka-ainepuutteet ja ylijäämä ovat pienentyneet edelliseen vuoteen verrattuna. Kysyntä ja toimitettujen tuotteiden määrä on kasvanut, mikä viittaa toiminnan positiiviseen kehitykseen. Toisaalta ylityötuntien määrä on kaksinkertaistunut, ja skenaarioanalyysin perusteella kustannustehokkaampi ratkaisu olisi ollut lisähenkilöstön palkkaaminen kesäsesongin ajaksi. Korrelaatiomatriisin tulosten perusteella ylityötunneilla ja toimitusvarmuudella ei havaittu merkittävää yhteyttä, kun taas tilattujen tuotteiden ja toimitusvarmuuden välillä havaittiin negatiivinen korrelaatio. Tulosten perusteella suositellaan, että yrityksessä arvioidaan pitkän aikavälin henkilöstön resurssistrategiaa sekä kehitetään tuotantolinjan kapasiteettia ja virtausta ylityötuntien vähentämiseksi ja toiminnan kustannustehokkuuden parantamiseksi.

AVAINSANAT: food industry, delivery reliability, overtime, perishable products, shelf life, cost-effective

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1 Introduction

The food industry faces challenges when trying to maintain high delivery reliability in the most cost-effective way, especially when it comes to perishable food products. Food sector must carefully consider attributes such as shelf life and cooling requirements to meet consumer quality expectations and to minimize food waste. Stüve et al. (2022) highlighted the complexity of supply chain planning in the food industry, emphasizing that, unlike in other industries, product quality continually declines as goods progress through the supply chain, making supply chain planning a critical function for food companies.

Cold chain management throughout the supply chain plays an important role in maintaining high delivery reliability. According to Mercier et al. (2017) the most significant challenge of an efficient cold chain is to account for the varying shelf lives and required temperature ranges of perishable food products to maximize product shelf life and commercial potential. The efficient transfer and coordination of transportation takes time, and each delay has a negative impact when the goods being transported are perishable (Rodrigue et al., 2013).

When products have a short shelf life, preparing them for storage can be risky, potentially leading to wastage. Maintaining high delivery reliability without contributing to food waste in the food industry can increase higher production costs, for example overtime may be required. Overtime refers to hours worked in excess of a 40-hour working week and comes in two types: scheduled overtime, which involves continuous additional hours, and occasional overtime, which is sporadic and limited to specific situations (Chang & Woo, 2017).

Sarmiento et al. (2007) highlighted the trade-offs, noting that achieving punctuality may require overcapacity, overtime, or high stock levels, which can impact economic metrics such as return on sales. This highlights the importance of production planning and scheduling throughout the supply chain. The need for a skilled workforce and expertise is essential to maintain a high level of delivery reliability, especially when navigating demand fluctuations, product shelf life constraints, and raw material availability.

The food industry covers a diverse range of products, each varying in perishability, production lead times, customer types, order volumes, and purchasing frequencies (Dora et al., 2012). Despite this diversity, factors such as inconsistent raw material quality, unpredictable supply chains, and fluctuating customer demands make food manufacturing uniquely challenging (Dora et al., 2012). Thus, production planning and scheduling are vital for the productivity of a company. Effective production planning ensures that supply meets demand on time and that production lines are not overloaded or underutilised.

Minimizing food waste is an important priority, alongside effective food chain management. Raak et al. (2017) state that reducing food waste is currently one of the most important goals in research. They noted that food waste leads to unnecessary consumption of water and energy, as well as greenhouse gas emissions from production and distribution activities. Minimizing food wastage is critically important due to its economic, social, ecological, and health-related impacts. Reducing food wastage has a positive effect on the economy, food security, the reduction of hunger, and the global ecological footprint (Lemaire and Limbourg, 2019).

According to Jülicher (2019), recent estimates suggest that around 19% of food waste produced in the EU comes from the processing sector. While in the United States, around 12% of food waste occurs during distribution, primarily due to improper cooling (Mercier et al., 2017). Priority should be given to tackling the problem at source by reducing the generation of surplus food at all stages of the supply chain, covering production, processing, distribution and consumption (Jülicher, 2019). When surplus does occur, efforts should be made to recover it and utilize it in the most valuable way. Key opportunities for preventing and reducing food waste in processing sector include enhancing processing methods, developing innovative packaging solutions, providing a range of portion sizes, increasing consumer awareness about date labelling, redistributing surplus food, and encouraging circular approaches using food, feed, and non-food products (Jülicher, 2019).

The globalization of the food industry has raised concerns about food security, environmental impact, and economic sustainability while widening the gap between suppliers and consumers (Ladha-Sabur et al., 2019). It has also introduced logistical challenges, requiring strategic supply chain decisions to ensure efficiency and sustainability (Stüve et al., 2022). According to Imen and Abdelkarim (2024) key factors in food supply chain to contributing wastage are inefficiencies in production, storage handling and transportation.

When considering how a perishable food company can maintain or achieve high delivery reliability in the most cost-effective way, it is important to take into account factors such as short shelf life, fluctuating demand, variations in raw material quality, production delays, potential spoilage, environmental impacts such as food waste, and additional costs due to overstocking. Each day of delay reduces the time remaining to sell the product, which adds to the challenges.

The purpose of this study is to investigate the challenges associated with maintaining a high level of delivery reliability in the food industry and to identify cost-effective strategies for sustaining it. The study examines the impact of overtime on delivery reliability, labour costs and the quantity of products delivered. Additionally, it explores how delivery reliability would be influenced under scenarios involving either the elimination of overtime or the addition of workforce during specific periods. The study is conducted in collaboration with a case company that has a high level of delivery reliability but regularly works overtime. Therefore, the study focuses in particular on the amount of overtime and its impact.

1.1 The structure of the study

The study is structured into five primary sections, each addressing a key aspect of the research. The first section serves as an introduction to the topic, providing the necessary context and outlining the research objectives. The second section presents a comprehensive literature review, which serves as the foundation for understanding existing research and theoretical concepts. The third section delves into the empirical part of the study, which involves data collection and analysis. The fourth section focuses on the interpretation and discussion of the results and key findings derived from the empirical analysis. The fifth section summarizes the main insights and offers recommendations for the case company, research limitations, and future research directions.

The literature review is further divided into six subchapters, each focusing on a specific area of relevance to the study. The first subchapter discusses the key challenges faced by the food industry and highlights the importance of ensuring delivery reliability. The second subchapter presents the theoretical background, which includes the Theory of Constraints, lean manufacturing, and the principles of resilience and agility in the food supply chain. These frameworks help to understand how efficiency, flexibility, and risk management are addressed in dynamic and demanding market environments. The third subchapter explores production planning and forecasting, highlighting the challenges and strategies involved in these processes. The fourth subchapter discusses demand and raw material forecasting, including external factors influencing demand fluctuations. Additionally, the benefits and drawbacks of overtime are examined. The fifth subchapter discusses inventory management, examining its role in achieving efficient operations and minimizing waste. The final subchapter summarizes the key insights and main findings from the literature.

The empirical part of the study is conducted in collaboration with a case company, providing a practical context for the study. This section includes a thorough analysis of the current state of the case company, focusing on its operations and performance.

Historical data is analysed to explore the relationship between delivery reliability, demand, total working hours, overtime, and surplus. The primary objective is to assess how delivery reliability is currently impacting the company's costs and identify areas for improvement. In the empirical part, a couple of scenarios are developed to help illustrate the cost implications of maintaining high delivery reliability for the company. By drawing on both the historical data and insights from the literature review, the empirical analysis aims to provide actionable recommendations to the case company. These recommendations will focus on achieving the highest level of delivery reliability in the most cost-effective manner, ultimately enhancing operational efficiency and reducing unnecessary expenses.

1.2 Objective and scope

The objective of this study is to analyse the challenges associated with maintaining high delivery reliability in the food industry, with a specific focus on the manufacturing of perishable foods. The scope of this study is confined to a detailed examination of the case company that specialises in the production of perishable foods. The primary aim is to examine the relationship between delivery reliability and overtime costs. To ensure the accuracy of the analysis, additional factors must also be considered. The factors include total working hours, the number of ordered products, the number of delivered products, raw material shortages, surplus, and labour costs. Demand forecasting plays a crucial role in raw material forecasting in the case company, as these raw materials are perishable and must be ordered well in advance before production.

The literature review will delve into broader theoretical concepts related to supply chain management, forecasting, and food industry practices. The empirical part of the study is specifically focused on the practices and data from the case company. This means the research does not extend to other industries beyond perishable food production, nor does it address wider supply chain management issues that might influence delivery reliability and associated costs outside of the production stage. This study aims to offer valuable insights into the specific challenges faced by perishable food producers in maintaining efficient operations, with an emphasis on the interplay between forecasting accuracy, operational efficiency, and minimizing waste. By understanding these dynamics within the case company, the findings will contribute to improving delivery reliability and cost-effectiveness within the food manufacturing sector.

1.3 Research questions and objectives

This study seeks to explore the following research questions, which have been collaboratively developed with the case company. These questions are both relevant and valid from their perspective, addressing their current challenges.

Research questions:
1. What are the costs involved in maintaining the current level of delivery reliability in the case company?
2. How can the case company maintain a high level of delivery reliability while optimizing cost efficiency?

By answering these questions, the study aims to meet the following objectives:
1. To identify and analyse the costs associated with maintaining the current level of delivery reliability in the case company.
2. To identify cost-effective strategies for maintaining a high level of delivery reliability in the case company.

The literature review provides a solid framework and background for these questions. However, the empirical part plays a more significant role to find answers for the questions.

1.4 Case company overview

This study is done in collaboration with a case company. The case company operates in the food sector and produces perishable products. In this study the name of the case company has not been mentioned for their request. The company is known for its focus on high-quality and locally sourced products. They prioritize ethical production practices and sustainable operations. Their products are aimed at meeting the needs of modern consumers, emphasizing freshness, traceability, environmental responsibility and the promotion of regional food.

The company's current competitive advantage is that they are able to offer their customers products on fresh shelf life and have a high level of delivery reliability. The raw materials are sourced from locations geographically close to the factory, resulting in short transport distances. This is a crucial factor in food supply chain, as shorter transport distances help to reduce lead times and maintain the freshness and quality of the products.

On the other hand, from an economic point of view, the company faces the challenge of having to rely on overtime to maintain high delivery reliability and to meet tight delivery deadlines. The aim of the study is to gain a clearer understanding of whether maintaining a high level of delivery reliability through overtime is justified, or if adjustments are necessary to improve the current situation.

1.4.1 Current production planning process

This section details the case company's current production planning process. A successful process relies heavily on demand forecasting. Demand forecasting is driven by sales, which aligns long-term forecasts with the budget. Forecasts are influenced by the product range chosen by customers, which is reviewed three times a year. In the middle of the period, the range of product categories cannot change. This means that customers decide three times a year the product range they will select for their own sales. However, this does not mean that they have to order an x number of products, but that customers order according to consumer needs. In addition, the forecast is also influenced by historical data, which is used to help forecast the demand.

Once the long-term forecast has been made for sales, the production planning team starts to make a weekly plan. Exact order quantities from customers are normally received the day before and the delivery is made from the factory the following day. In special situations, such as campaigns, customers are asked to make orders earlier. The factory must place a binding raw material order from its own suppliers well in advance, so that the raw material can be delivered from the supplier on time. This is a critical point for the operation of the company, as the amount of raw material ordered in advance cannot be changed.

Based on the information mentioned above, it can be concluded that the production planning is based extensively on demand forecasting and its accuracy. In addition, it is not possible to make sudden big changes to the supply after ordering the raw materials. However, through short-term planning, it is possible to determine product-specific quantities, with the goal of meeting customer demand effectively.

2 Literature review

The literature review plays an important role in forming theoretical foundation of the research, providing important insight for the empirical part. It is essential that the literature review addresses topics relevant to the study, thereby supporting and strengthening the research results. This literature review will begin with an introduction to delivery reliability, with a focus on critical capabilities, costs, and delivery performance. Key challenges within the food industry will also be presented at the beginning of the thesis to provide a comprehensive overview of the subject matter. After this the theoretical background the study is presented, focusing on the Theory of Constraints, lean manufacturing, and resilience and agility in food supply chains. These concepts provide a foundation for understanding how companies can optimise their processes by identifying bottlenecks, minimising inefficiencies, and leveraging core competencies to gain a competitive advantage.

Following this, the discussion will extend to production planning and forecasting, both of which are essential elements for ensuring smooth operations and meeting demand fluctuations. Production scheduling and demand forecasting strategies will be analysed to highlight their impact on operational efficiency and delivery reliability. Furthermore, advanced scheduling techniques will be discussed to emphasize their role in optimizing production timelines, improving resource allocation, and enhancing overall supply chain efficiency. Furthermore, the benefits and limitations of overtime will also be examined.

At the end of the literature review, inventory management is presented as a critical aspect of supply chain optimization for perishable products. Inventory management techniques and models, including, First-In-First-Out (FIFO), First-Expired-First-Out (FEFO) and safety stock will be discussed to demonstrate their importance in maintaining optimal stock levels, minimizing spoilage, and preventing supply chain disruptions. Lastly, summary of key insights and gaps in the future research are discussed.

2.1 Challenges in the food Industry and the importance of delivery reliability

On-time delivery is vital in today's dynamic business environment. Delivery reliability refers to the ability to meet promised delivery dates and quantities (Sarmiento et al., 2007). Ensuring high delivery reliability is essential for maintaining customer satisfaction, strengthening trust, and sustaining long-term relationships, all of which contribute to competitive positioning (Sarmiento et al., 2007). According to Schäfer et al. (2016), delivery reliability is a key competitive factor for a company. If a company cannot deliver on time, it must resort to costly express deliveries or face customer dissatisfaction. Speed of delivery plays a critical role in meeting customer expectations, especially in fast-paced and highly competitive markets where quick turnaround times are highly valued (Sansone et al., 2017).

Delivery reliability has been consistently ranked as one of the top competitive priorities, often second only to quality, and is basic and minimum requirement for business (Sarmiento et al., 2007). Customers highly value delivery reliability due to its impact on their own performance, driving companies to prioritize it. It is notable that delivery reliability should be achieved without losing other characteristics such as quality (Sansone et al., 2017).

Accorging to Sansone et al. (2017), delivery reliability faces challenges when balancing costs, flexibility, and resource allocation. Additionally, it is suggested that empirical studies indicate delivery reliability is compatible with several manufacturing capabilities, particularly internal quality and inventory management. For example high internal quality reduces uncertainty, facilitating on-time delivery by improving process outcomes. Similarly, they mentioned that managing inventory effectively helps companies meet delivery commitments without relying on costly measures such as safety stock or overtime. However, Sarmiento et al. (2007) note that ensuring punctuality may sometimes require overcapacity, overtime, or high stock levels, which can negatively impact financial metrics like return on sales. To balance punctuality with cost efficiency, it is essential to focus on quality consistency and product flow speed, but in some cases, adding capacity can improve cycle times, reduce inventories, and enhance flexibility (Sarmiento et al., 2007).

The cost performance reflects a firm’s ability to minimize production and distribution expenses while maintaining competitive pricing and enabling firms to offer lower-priced products without sacrificing profitability (Sansone et al., 2017). This is crucial in industries with intense price competition, where the cost efficiency can drive competitive advantage.

Sansone et al. (2017) highlighted key aspects of the cost performance, including total cost and productivity. Total production costs include expenses related to energy, inventory, distribution, and materials, all of which form the foundation for pricing strategies and directly influence a firm's profit margins (Sansone et al., 2017). Productivity, another critical aspect of cost efficiency, refers to optimizing resource utilization to maximize output (Sansone et al., 2017). According to them, improving productivity and capacity utilization is essential to maintain a competitive cost structure. By improving cost capabilities, firms can remain competitive in price-driven markets without compromising product quality. Chen and Voigt (2020) mentioned that low-profit margins in most of the food sectors drive industries to improve the production efficiency, and to reduce energy consumption and adopt updated production management systems.

2.1.1 The key challenges of the food industry

The key challenges of the food industry include managing relationships, aligning supply and demand, managing processes, maintaining quality and safety, utilising technology, and managing responsibly (Mena & Stevens, 2010). Product diversification has increased in recent years benefiting consumers but creating challenges for supply chain management. New products are difficult to forecast leading to overstocking and understocking which can lead to complicate warehousing and distribution operations (Mena & Stevens, 2010).

Supply chain research initially focused on industries that produce complex assembled products, such as automotive and electronics (Mena & Stevens, 2010). However, food supply chains operate differently from these industries. Applying the same concepts and tools without recognising these differences can be problematic. According to Mena and Stevens (2010) the main differences are seasonality, health, nutrition and safety, short shelf life and volatile demand, and impact on the environmental.

Various trends impact food supply chains. According to Mena and Stevens (2010) these include globalization, economic shifts, changing power structures, product diversification, sustainability, and corporate social responsibility. For example large companies, particularly retailers, have gained significant influence over suppliers and market dynamics (Mena & Stevens, 2010). The growing influence of retailers in food chains may grant them greater control over prices and delivery times, creating challenges for food manufacturers and primary production.

2.1.2 Seasonality

According to Mena and Stevens (2010), various industries experience seasonality, but food chains face seasonality in both demand and supply. As a result, organizations must design their supply chains to align with these cyclical patterns. Managing seasonal demand requires precise inventory control, while seasonal supply requires for sourcing from multiple locations, often in different regions (Mena & Stevens, 2010).

Effective management of seasonal supply and demand in the food industry requires annual sales and operations planning, with accurate forecasting being crucial for success (Mena & Stevens, 2010). Agile production cycles are required, as manufacturing operations must frequently adjust setup processes in response to product seasonality

(Verna et al., 2025). In addition, strong collaboration between departments, such as marketing, production, and logistics, is essential to ensure alignment and responsiveness to market fluctuations.

2.1.3 Health, nutrition and safety

Food directly affects consumers' health, making factors such as quality, traceability, safety, and risk management essential for success (Mena & Stevens, 2010). Particularly perishable food requires careful handling because of their perishability. According to Chen and Voigt (2020), food industry requires stringent regulations to ensure product quality and safety throughout the supply chain and product lifecycle. Products must be traceable and provide details like attributes, origin, and genetic modifications, and contamination should be identifiable in response to consumer complaints (Chen & Voigt, 2020).

Traceability is a crucial component for ensuring food safety and quality (Verna et al., 2025). Traceability enables documentation of all stages of the product life cycle, which helps to meet food safety and transparency requirements and also helps optimize production processes (Verna et al., 2025). EU has reinforced traceability as a legal requirement to enhance food safety and hygiene (Verna et al., 2025). The adoption of technological innovations, such as the Internet of Things (IoT), Radio Frequency Identification (RFID), and blockchain technology, has greatly enhanced traceability systems in the food processing industry (Verna et al., 2025).

Enhancing traceability contributes to strengthening consumer trust. Understanding consumer confidence in food safety and its regulation is crucial to effectively implement risk management and communication strategies aimed at restoring confidence in food systems (Mena & Stevens, 2010). Improperly storing perishable food outside the recommended temperature range due to inadequate refrigeration can promote the growth of harmful pathogens and spoilage microorganisms, making the product unsafe to consume (Mercier et al., 2017). Furthermore, growing consumer demand for ethical, healthy, and eco-friendly products has heightened the focus on sustainability and corporate responsibility (Mena & Stevens, 2010).

2.1.4 Short shelf life and volatile demand

In food industires products typically have a short shelf life, and demand can be influenced by various factors like weather changes, promotions, special events and rapidly changing customer preferences (Mena & Stevens, 2010). Since maintaining stock to accommodate unforeseen demand is not feasible, agility and quick response are crucial (Mena & Stevens, 2010). The demand for food products is influenced by economic factors such as the credit crisis, a decline in consumer confidence, and the overall economic downturn (Mena & Stevens, 2010). However, the food industry is less sensitive to income fluctuations than other sectors, which is why the share of food in total consumption tends to increase during economic downturns, although consumers may still choose cheaper alternatives (Mena & Stevens, 2010).

Food manufacturers must determine a shelf life for their products. This ensures that the food meets microbiological, chemical, and sensory requirements until the end of the sales period (Ruokavirasto, n.d.) This requirement applies to both products with a 'use by' date and products with a 'best before' date. Temperature is the most important factor influencing the perishability of a food product, but carbon dioxide production, respiratory behavior, ethylene production, and sensitivity are also significant factors (Mercier et al., 2017).

Food products have different temperature requirements and shelf lives, which vary depending on the type and characteristics of the product. Ndraha et al. (2018) classify foods stored in cold storage into four categories: frozen (-18°C), chilled (0-1°C), medium chilled (5°C), and exotic chilled (10°C- 15°C). According to Mercier et al. (2017), challenges arise in managing the cold chain for perishable foods due to the varying shelf lives and temperature requirements of different products. Packaging plays a crucial role in the shelf life of perishable foods. It facilitates storage and transport, improves product shelf life and allows the development of different product variations (Li et al., 2017)

Trattner et al. (2019) emphasize the importance of understanding how product complexity impacts operational performance, particularly in terms of time, costs, quality, and delivery. In the food industry, this complexity is heightened by the perishable nature of products, strict regulations, and the critical role of temperature management, making efficient operations even more challenging. Additionally, product diversification complicates forecasting, inventory management, and logistics (Mena & Stevens, 2010).

2.1.5 Impact on the environment

Every industry affects the environment, but the food industry has a particularly significant impact due to its heavy reliance on resources like water, energy, and land, as well as the unintended byproducts such as carbon dioxide (CO2) emissions, pollution, and waste (Mena & Stevens, 2010). The food industry is among the world's largest energy consumers, utilizing around 30% of global energy (Corigliano & Algieri, 2024). Energy is crucial across the food production chain, powering processes like heating, cooling, drying, refrigeration, processing, packaging, and transportation, all of which are vital to maintaining efficiency, quality, and safety (Corigliano & Algieri, 2024).

The food industry is a vital and constantly evolving sector that plays a key role in ensuring global food security and contributing to economic growth (Corigliano & Algieri, 2024). Looking to the future, the industry's dedication to sustainable development and ethical practices will be crucial in building a more resilient and environmentally friendly future. Sustainability in food manufacturing and processing demands collaborative efforts across various areas. Enhancing energy efficiency throughout production is essential, including optimizing heating and cooling systems, integrating energy-efficient technologies, and incorporating renewable energy sources (Corigliano & Algieri, 2024).

2.2 Theoretical background

2.2.1 The Theory of Constraints

The Theory of Constraints is a management philosophy that focuses on identifying and addressing bottlenecks that limit overall system performance (Şimşit et al., 2014). The Theory of Constraints can be applied across various domains, particularly in production, where it aids in detecting bottlenecks and optimizing resource allocation (Şimşit et al., 2014). The fundamental principle of the Theory of Constraints is that every system has at least one constraint that prevents it from reaching its maximum potential. By systematically managing and mitigating these constraints, companies can establish a framework for continuous improvement, ultimately enhancing profitability and operational efficiency (Şimşit et al., 2014).

According to Urban and Rogowska (2020) the Theory of Constraints identifies three main types of constraints; resource constraints, material constraints and policy constraints. According to them resource constraints include for example limited workforce, machine time or changing demand which can disrupt the efficiency of production. Material constraints occur when there is a shortage of raw materials or components which will disrupt the production. Material constraints require usually improved inventory management, stronger supplier relationships and alternative sourcing strategies. Policy constrains includes internal rules and management practices both of which can affect negatively to efficiency.

The Theory of Constraints could be applied in the food industry, as Stüve et al. (2022) note that fluctuations in consumer demand complicate supply chain management, with factors such as seasonal changes, weather conditions, and shifting consumer preferences contributing to this unpredictability. For example, a sudden heatwave can cause a spike in demand for perishable items such as fresh product, requiring rapid adjustments in production and distribution. These fluctuations emphasize the need for effective planning tools to align supply with varying demand. The Theory of Constraints could assist in identifying resource constraints caused from unpredictable changes in demand.

2.2.2 Lean Manufacturing

Lean manufacturing, a management approach focused on meeting customer demands quickly while ensuring high quality and minimizing costs, has proven to be effective in enhancing organizational performance over the long term (Negrão et al., 2016). Lean aims to optimize process flow by minimizing waste and reducing variability (Costa et al., 2018). Companies using lean manufacturing experience reduced cycle times, improved resource utilization, and increased competitiveness (Cusiatado Palomino et al., 2024).

Dora et al. (2012) investigated the implementation of lean manufacturing in small and medium-sized food companies. They found that the specificities of the food industry prevent the direct application of lean manufacturing principles to food production. In particular, the low shelf life of food and the variability of supply and demand have been barriers to the adoption of lean manufacturing in the food industry. Cusiatado Palomino et al. (2024) also highlighted that many food companies, especially small and medium-sized, struggle with outdated systems and lack of awareness about lean manufacturing benefits.

However, according to the study by Dora et al. (2012) the implementation of lean manufacturing has improved the situation in the food industry sectors studied, with shorter downtimes and improved delivery performance. Their study found that the commitment of top management is one of the most crucial factors in the adoption of lean, while a lack of skilled labour had a negative impact on the adoption of lean. According to Cusiatado Palomino et al. (2024) effective lean tools in food industry are for example 5S, Kaizen, Value Stream Mapping, Just-in-time, Kanban and Total productive maintenance. Just-in-Time and Kanban could help reduce inventory costs by ensuring that production aligns closely with actual demand, minimizing excess stock and waste.

2.2.3 Resilience and agility in food supply chains

Supply chain resilience and agility are critical for managing modern food supply chains. These qualities enable firms to navigate challenges such as globalization, rapid change, shorter product life cycles, evolving customer demands, and increasing demand uncertainty (Gligor et al., 2019). A fundamental principle of supply chain agility is the ability of all members to quickly coordinate their capabilities and adapt to fluctuations in supply and demand (Gligor et al., 2019). In contrast, resilience refers to the capacity to recover from disruptions (Gligor et al., 2019). Disruptions like political changes, accidents, natural disasters, and supplier failures can affect the entire supply chain's revenues and costs (Gružauskas et al., 2019).

According to Gligor et al. (2019), agility is characterized by the ability to quickly change direction, accelerate operations, scan the environment and anticipate changes, empower customers through customization, adjust tactics and operations, and integrate processes across firms. Meanwhile, resilience encompasses the ability to withstand and survive disruptions, prevent shocks entirely, recover and return to the original state after a disruption, accelerate operations, adjust tactics and operations, and continuously monitor and anticipate environmental changes (Gligor et al., 2019). Resilience requires flexibility and adaptability, ensuring that food supply chains remain operational despite market and environmental disruptions (Manning & Soon, 2016). While agility focuses on managing change, enhancing customer responsiveness, and navigating market volatility, resilience ensures long-term stability and recovery (Gligor et al., 2019).

2.3 Production scheduling and Forecasting

For manufacturing facilities capable of producing multiple products, it is crucial to determine the optimal production sequence, assign tasks to specific equipment, and set precise operation times. Production scheduling addresses these aspects with the goal of maximising profitability and ensuring that demand is met within the specified timeframe (Baldea & Harjunkoski, 2014). Improving production flow has a direct effect to profitability (Stephens, 2019).

Mehrotra et al. (2011) highlighted that one of the most significant challenges for manufacturers in the processed food industry is meeting stringent food safety standards and regulations, along with addressing additional challenges related to allergens, as it is common to produce multiple variants of the same basic product, such as gluten-free or dairy-free alternatives. As noted by Mehrotra et al. (2011), these variations introduce strict sequencing constraints within the production line. Effective sequencing is therefore of critical operational importance in the food industry, as these challenges can negatively impact production flow. For instance, the need for thorough cleaning and equipment setup changes between product variants leads to downtime, reducing overall efficiency.

Sales and Operations Planning plays a crucial role in the food supply chain in order to maintain balance between supply and demand (Mena & Stevens, 2010). It serves as a connection between strategic and operational planning. Sales and Operations Planning requires ongoing updates, with both operational and strategic plans needing frequent reviews and adjustments (Mena & Stevens, 2010). Essentially, the purpose of Sales and Operations Planning is to align strategic business planning with the more detailed operational planning processes (Mena & Stevens, 2010).

2.3.1 Production planning and flow optimization in the food industry

According to Stüve et al. (2022) the food industry faces challenges in production planning due to mass customisation, as growing consumer preferences and the demand for personalised options drive an increase in product variety. Products often have different setup times, and, as mentioned earlier by Mehrotra et al. (2011), equipment may require thorough cleaning between production runs to comply with stringent hygiene standards. These factors increase production complexity and demand greater agility in planning systems (Stüve et al., 2022). As previously discussed, the Theory of Constraints can be applied to identify resource bottlenecks, such as limited machine time, and optimise production efficiency.

In manufacturing, efficient scheduling ensures that resources are aligned with customer demand by emphasising just-in-time production, minimizing setup times, reducing work-in-process inventory, and optimizing facility utilization (Heizer et al., 2024). Effective scheduling has both internal and external impacts. Internally, it accelerates the movement of goods and services, maximizes asset utilization, increases capacity relative to invested resources, and reduces costs, while externally enhancing throughput, providing greater flexibility, ensuring reliable delivery, and improving overall customer service, all of which contribute to its overall effectiveness (Heizer et al., 2024). Scheduling criteria include minimizing completion time, maximizing utilization, minimizing the work-in-process and reducing customer waiting time (Heizer et al., 2024).

2.3.2 Advanced scheduling techniques

Advanced scheduling techniques play a key role in optimizing resource allocation and improving system performance across different sectors. Through technologies such as artificial intelligence and digital twins, Industry 4.0 will enable the optimization of production processes. These technologies offer potential improvements in food quality determination, traceability and customized food design (Henrichs et al., 2021).

The food industry faces many challenges, such as the need to feed a growing population, the increasing amount of food waste and inefficient production systems. Digital twins, which create a digital representation of physical entities by integrating real-time and real-world data, appear to be a promising approach to address these challenges (Henrichs et al., 2021). A digital twin, a virtual model of a product or process created using sensor data, enables simulations and real-time analysis of production status, offering significant advantages in food processing (Henrichs et al., 2021).

According to Henrichs (2021), the main challenges in integrating digital twins into food supply chain systems stem from the difficulties in collecting high-quality physicochemical data and integrating digital twins into existing supply chain structures. Food processes often have poorly described properties and variables that are difficult to predict or calculate, making data collection and processing challenging (Henrichs et al., 2021).

Modern production environments are affected by many factors that influence the production process, such as machine variations, order fluctuations and unpredictable job inputs (Del Gallo et al., 2023). To stay competitive and meet consumer demand on time, it's essential to be adaptable and respond quickly to changes in production planning. In the food industry, demand fluctuates constantly, so quick responsiveness is essential to maintain effectiveness and customer satisfaction. Artificial intelligence plays a crucial role in manufacturing systems by enabling rapid responses and predicting potential discrepancies in the production plan. It serves as a valuable tool to support the decision-making process (Del Gallo et al., 2023).

2.4 Demand and raw material forecasting

According to Krajewski et al. (2019) balancing supply and demand start with creating accurate forecasts and aligning them across the supply chain. Forecast is a prediction of future events used for planning process, and it is needed to coordinate with suppliers and customers. Krajewski, et al. (2019) highlight that forecasts are essential for shaping business strategies, annual plans, and budgets. Additionally, they mentioned that the finance team relies on them to estimate cash flow and capital needs, while human resources use them to plan for recruitment and training. Marketing contributes valuable insights for sales forecasts, given its close connection to external markets. Operations and supply chain managers depend on forecasts to organise production levels, procure services and materials, schedule workforce and output, manage inventories, and plan for long-term capabilities.

Effectively managing a supply chain involves more than simply creating accurate demand forecasts or determining optimal order quantities and timings. Companies need to establish strategies to ensure the availability of materials, inventory, financial resources, and production capacity to meet demand efficiently (Krajewski et al., 2019). According to (Goel et al., 2024) demand forecasting in supply chains can be classified into three types: short-term, long-term, and time series forecasting. Short-term forecasting, typically covering less than 12 months, focuses on daily operational decisions, using statistical models to manage inventory, workforce planning, and short-term adjustments (Goel et al., 2024). Long-term forecasting spans over a year or more, supporting strategic planning through trend analysis, market research, and scenario planning to anticipate shifts in customer behaviour and market dynamics (Goel et al., 2024). Time series forecasting, a specialized method, uses historical data collected over time to predict future trends, helping businesses optimize inventory management and pricing strategies (Goel et al., 2024).

Eksoz et al. (2014) discussed in their article about the importance of collaborative forecasting between different factors between supply chain. With collaborative forecasting internally and externally information has been brought together and provide more accurate forecast into whole supply chain. Collaborative Planning, Forecasting and Replenishment is business concept recommended by Eksoz et al. (2014) for food supply chain. With Collaborative Planning, Forecasting and Replenishment business partners can manage supply chain operations collaboratively, for example, by comparing sales and order forecast and make timely decisions. However, Eksoz et al. (2014) mentioned that collaborative forecasting might face challenge in the food supply chain because of the dominance of retailers in collaborations, lack of information sharing or retailer’s poor forecasting process. Nevertheless, according to them lack of trust between partners is because of poor collaborative forecasting.

2.4.1 The influence of external factors on demand fluctuations.

According to Chaudhary et al. (2018) the demand for perishable products can be either deterministic, meaning it is predetermined, or stochastics, meaning it is random. There are different types of demand which are standardized demand, time-based demand, inventory-dependent demand, price-dependent demand, randomly distibuted demand and non-stationary stothictics demand (Chaudhary et al., 2018).

Demand forecasting in the food industry faces several challenges due to various external and internal factors. Eksoz et al. (2014) mentioned that different campaigns make it challenging to predict the demand for products, as the duration of the campaigns and different prices cause sales to vary. Additionally, the introduction of new products further complicates demand forecasting, as there is no available historical data to rely on, and customer preferences are constantly changing (Eksoz et al., 2014). This unpredictability makes accurate demand forecasting even more difficult for manufacturers.

Consumer income levels also play a critical role in shaping demand, as explored by Wu (2023). According to Wu, the effect of income on demand varies depending on whether the product is classified as a normal or inferior good, with demand for normal goods increasing as incomes rise, and demand for inferior goods typically rising as incomes fall. This relationship between demand, income, and the global economic situation further complicates forecasting, as economic fluctuations can significantly affect consumer purchasing behaviour.

Inflation also has an impact on fluctuations in demand. Inflation refers to the rate at which prices rise over a given period, typically one year. High inflation occurs when most prices increase rapidly, reducing the purchasing power of money and impacting consumers' cost of living, unlike price increases in individual goods, which only change relative prices (Dekimpe & Van Heerde, 2023). When prices rise faster than income, consumers' purchasing power decreases, leading them to adjust their spending by opting for cheaper alternatives, prioritizing necessities, or shifting shopping habits (Dekimpe & Van Heerde, 2023). Changing shopping habits may lead to more people eating at home rather than dining out, which could shift demand from restaurants to grocery stores. Depending on the food, consumers may switch to cheaper alternatives, such as opting for cheaper foreign food instead of domestic products, which could negatively affect demand for domestic food manufacturers.

Seasonality is a key characteristic of the food industry, where a demand for certain products fluctuates significantly throughout the year. For example, demand for products such as ice cream and barbecues typically increase during the summer months, while it declines in winter. According to Rajagopal (2008) seasonal market demand also drives new product launches.

However, Mehrotra et al. (2011) mentioned that the demand for processed foods is less sensitive to economic fluctuations compared to other industries. Since food is considered a basic need, its demand remains relatively stable even during times of economic downturns. Nevertheless, this resilience in demand for processed foods does not eliminate the challenges of forecasting, as factors such as promotional campaigns, new product introductions, and changing consumer preferences still play a significant role in shaping demand patterns.

2.4.2 Overtime

According to Chang and Woo (2017) there are two types of overtime; scheduled overtime and occasional overtime. Scheduled overtime is defined as work that is more than 40 hours per week in a continuous period, while occasional overtime consists of random overtime worked by a limited number of employees (Chang & Woo, 2017). Overtime is frequently favoured as it allows for faster progress, avoiding the coordination challenges typical of shift work and the overcrowding issues linked to excessive staffing (Chang & Woo, 2017).

According to Dall'Ora et al. (2016) overtime work is linked to reduced job performance, including increased errors, lower cognitive function, and poorer quality of care. Chang and Woo (2017) have also investigated in their research how overtime effects productivity in construction field. According to them, overtime reduces efficiency not only during the overtime hours themselves, but throughout the working week. Overall, productivity fell by around 1% for every hour worked over 40.

Overtime is utilized to respond to fluctuating demand, enabling the organization to meet customer needs effectively. According to Chang and Woo (2017) industries operating in highly competitive and volatile markets face significant challenges, where staying on schedule is critical for project success. To ensure timely completion, working overtime is a common response to accelerate project schedules. As previously noted, overtime can lead to a decrease in productivity, making it essential to weigh this factor when deciding whether to implement it. Additionally, overtime incurs higher costs than regular working hours, so it is crucial to carefully assess the most cost-effective approach.

2.4.3 Raw material forecasting

Raw material management is a critical part of supply chain and operations management, which has a significant impact on the cost structure, quality and overall efficiency of manufacturing and production processes (Zamani Dadaneh et al., 2023). The efficiency of a manufacturing organisation depends significantly on the availability of raw materials in the right quality and quantity, as they directly affect the availability, quality and quantity of the final product (S Akindipe, 2014). Material management plays a vital role in manufacturing by coordinating procurement, transportation, stocking, and utilization to ensure efficiency and uninterrupted production (S Akindipe, 2014).

In the food industry, raw materials are typically sourced from farms; for example, the poultry supply chain involves key stages such as hatcheries, grow-out farms, and slaughterhouses (Solano-Blanco et al., 2023). When a slaughterhouse is integrated with farm operations, production planning must align with the forecasted demand for broiler meat products, the facility's processing capacity, and inventory policies, while resource allocation considers farm conditions, slaughterhouse capacity, and wholesale demand (Solano-Blanco et al., 2023). Coordinating the flow of materials and information across the entire poultry supply chain makes production planning even more challenging

The Collaborative Planning, Forecasting, and Replenishment model could improve demand forecasting, helping to avoid overcapacity and underproduction. This would benefit all parties and reduce environmental waste. Solano-Blanco et al. (2023) emphasize that production planning must balance economic viability with environmental sustainability. When manufacturing perishable products, the production should not exceed demand to avoid excess stock, which can lead to spoilage and food waste (Polon et al., 2018). Additionally, inadequate information-sharing infrastructure causes delays between consumer demand and farmers' responses, making efficient production planning difficult (Siddh et al., 2015).

Improving the forecasting of raw material purchase is an important opportunity to prevent and reduce food waste in the food industry. Food manufactures need to promote the adoption of digital tools that can enhance the organization's ability to effectively manage raw material procurement, ensuring better alignment between demand forecasts and supply needs (Jülicher, 2019). Digital tools play a crucial role in improving raw material procurement and aligning demand forecasts with supply needs in the food industry. Artificial intelligence and machine learning enhance forecasting accuracy and inventory management by analysing vast datasets from multiple sources (Gružauskas et al., 2019).

2.5 Inventory management and optimization of perishable goods inventory

Effective inventory management of perishable products is crucial, as it directly affects sales, pricing, stock levels, costs of inventory, spoilage, deterioration, logistics, and product availability, all of which impact overall profitability (Chaudhary et al., 2018). There are several factors to consider when looking at inventory problems for perishable products. According to Chaudhary et al. (2018) these factors include product characteristics, the level of competition, internal and external constraints, the impact of price on demand, product availability, and the nature of demand. The goal of the effective inventory management of perishable goods is to receive optimal returns and the correct inventory management model should be chosen taking into account internal and external factors and product characteristics (Chaudhary et al., 2018).

According to Bubber et al. (2023), effective inventory management positively influences both operational and business productivity. Key aspects of inventory management include minimizing stock handling costs, as maintaining optimal inventory levels and reducing handling and transportation costs can enhance operational efficiency (Bubber et al., 2023). Excessive storage leads to storage costs, product spoilage and margin costs, while too little storage leads to lost in demand (Chaudhary et al., 2018). The previously mentioned strict quality, shelf life, and other criteria in the food industry also require efficient inventory management to ensure the delivery of high-quality products. For example, Sansone et al. (2017) mentioned that in the meat market, consumers prioritize freshness and minimal storage time. In addition, excessive storage takes up valuable physical space that could be used for other activities (Bubber et al., 2023). Analysing the management of perishable product stocks using the Economic Order Quantity (EOQ) model is crucial in various sectors, as this mathematical model helps determine the optimal quantity to minimize total costs associated with perishable stocks (Imen & Abdelkarim, 2024).

Effective inventory management also plays a critical role in strengthening a firm’s competitive edge by enabling the timely delivery of customer orders (Bubber et al., 2023), which is one of the key competitiveness prioritise for companies. It is crucial to balance inventory levels with demand to guarantee customer satisfaction. Solano-Blanco et al. (2023) stated that efficient coordination between farm and slaughterhouse operations often results in lower inventory levels and cost reductions since organised information flow help to react quickly to fluctuations of demand and therefore avoid both shortages and excess stock. To illustrates, slaughterhouses store chicken meat products in sectioned cold rooms, where operations are guided by inventory levels and safety stock requirements, maintaining inventory close to safety stock levels to help ensure product freshness while reducing storage costs (Solano-Blanco et al., 2023).

According to Ng (2007), an effective method for managing large inventories is to classify items into distinct groups. ABC analysis, a widely recognized and practical classification technique based on the Pareto principle, is commonly used for this purpose (Ng, 2007). In this approach, group A items generate approximately 70% of a company’s revenue but account for only 10% of the inventory, making them critical to operations. Group B items contribute about 20% of the business and represent 20% of the inventory. Lastly, group C items, though responsible for just 10% of the business, comprise 70% of the inventory.

In perishable inventory management, product shelf life and customer demand are crucial factors. Inventory models for perishable products can generally be categorised based on these two factors (Chaudhary et al., 2018). The product´s shelf life and physical condition play a pivotal role in determining inventory management strategies. Shelf life can either be fixed or random, with spoilage occurring on factors such time, storage quantity or the age of the product. Chaudhary et al. (2018) point out that certain products, such as some food items with a fixed shelf life, have a predetermined expiry date. On the other hand, they also mentioned that the shelf-life of some products, like vegetables and fruits is random, and it it difficult to determine their exact shelf life in advance. Additionally, they note that some products spoil more quickly when stored in larger quantities, indicating that perishability can be influenced by storage volume.

In inventory models for perishable products, it is important to combine other factors in addition to demand and the level of perishability to get a more realistic picture. Such factors may include price account, inflation, and time value of money (Chaudhary et al., 2018). In the food industry, the constraints of seasonality and short shelf life make stock maintenance challenging, necessitating highly precise forecasting (Barbosa et al., 2015).

2.5.1 FEFO and FIFO -inventory management

Common strategies in inventory management and supply chains for efficient product handling include the FIFO (First In, First Out) and FEFO (First Expired, First Out) methods (Hertog et al., 2014). FIFO is widely used for its simple and effective approach to asset rotation, ensuring that products are shipped in the order they arrive at each distribution centre. This method prioritizes the dispatch of items that have been stored the longest, regardless of their remaining shelf life or final destination (Hertog et al., 2014). In contrast, the FEFO method takes product shelf life into account. This strategy prioritizes shipping goods based on their expiration dates in relation to their intended destinations, ensuring that only high-quality products are delivered and minimizing losses during transportation (Hertog et al., 2014).

Adopting the FEFO approach requires robust information-sharing systems across supply chain partners, enabling a data-driven network (Hertog et al., 2014). In the context of inventory management in the food processing industry, the FIFO method could be more beneficial, as it ensures that the first-produced items, which typically have a shorter shelf life, are used first. Additionally, the FIFO method requires less information sharing compared to FEFO. However, it is still essential to ensure that raw materials are used in the order they arrive at the facility to maximize the shelf life of products.

2.5.2 Safety stock

In supply chain inventory management, safety stocks are commonly regarded as an effective strategy to handle supply and demand fluctuations and avoid stock-outs (Gonçalves et al., 2020). While higher safety stock levels lead to better service levels, they must be carefully optimized to avoid increasing the overall costs of the supply chain (Barros et al., 2021). Safety stocks are useful to prevent stock outs and manage supply chain risks and uncertainties. According to Barros et al. (2021), there are various uncertainties and risks associated with the procurement process, and the use of safety stock can help mitigate these risks in the supply chain. These risks include factors such as uncertain lead times, demand fluctuations, price variations, uncertain yield, supplier delays, and order crossover.

As previously mentioned, the short shelf lives and the need for quality assurance make maintaining safety stock challenging for perishable products. Moreover, when finished products are produced in advance and stored, their time to market is shortened, which may influence consumer purchasing decisions. Similarly, ordering perishable raw materials ahead of time reduces their shelf life over time, ultimately impacting the shelf life of the final product.

2.6 Summary of key insights and gaps in the future

The food industry faces a variety of complex challenges that require adaptive strategies and efficient management techniques to ensure operational success, sustainability, and cost-efficiency. One of the primary challenges is the short shelf life of perishable products. This, combined with the need to manage demand fluctuations, product diversification, seasonality, and stringent hygiene and safety regulations, complicates production processes. Product diversification, including catering to different allergens and creating variations of products, increases the complexity of the production line. This requires more frequent changes in production setups and cleaning processes, which can disrupt production flow and reduce overall efficiency.

Demand in the food industry is highly volatile and subject to fluctuations due to various external factors, such as weather changes, special promotions, seasonal events, and shifting consumer preferences. These demand fluctuations make it difficult for companies to forecast accurately and balance supply with demand, creating constant challenges for maintaining optimal production levels. To manage this volatility, food manufacturers must be agile in responding to changing conditions while also managing production schedules and inventory efficiently.

In addition to the challenges posed by demand volatility, the food industry must also address its environmental impact. Food processing is one of the largest energy-consuming industries, and sustainability practices are becoming increasingly important. Reducing energy consumption and minimizing food waste are key areas that require attention. The industry must adopt environmentally conscious practices while also maintaining the productivity and cost-effectiveness of their operations. The food industry also plays an essential role in ensuring global food security and contributes significantly to economic growth. Its capacity to meet growing demands for food, while maintaining quality and efficiency, has a profound impact on both local and global economies.

Delivery reliability is emerging as one of the top competitive priorities. A reliable delivery system is vital for customer satisfaction and for maintaining a competitive edge in the market. However, achieving high delivery reliability must not come at the expense of other critical factors, such as product quality. The challenge lies in balancing costs, flexibility, and available resources, as well as ensuring that reliability does not undermine product quality. In some cases, overtime is used to ensure timely deliveries, but its long-term impact on labour productivity and costs needs to be carefully considered.

Advanced forecasting and production scheduling, along with new technologies like digital twins and AI, can significantly improve supply chain efficiency. Collaborative forecasting is valuable but challenging due to the dominance of large retailers. Effective inventory management, particularly for perishable goods, is crucial to avoid stockouts and excess storage costs, while strategies like FIFO help maintain product freshness.

In conclusion, the food industry faces numerous challenges, including managing demand volatility, production efficiency, and environmental impact, which complicate maintaining a high level of delivery reliability. Embracing advanced technologies such as AI, digital twins, and adapting lean manufacturing can help optimize production processes and improve supply chain performance. The industry must continue to evolve and adopt strategies that address the unique challenges of perishable product management, while also striving to achieve greater cost efficiency and sustainability. Future research should focus on developing more effective forecasting methods, enhancing collaboration in the supply chain, and exploring new techniques for balancing inventory levels in the face of perishable product constraints.

3 Methodology

This part of the study presents the research methodology, data collection methods, data analysis techniques, reliability of the study and limitations of the methodology. The objective of the empirical section of this study is to examine the costs associated with maintaining a high level of delivery reliability, with particular emphasis on overtime costs. The analysis, based on the company's historical data, aims to identify cost-efficient ways to maintain high delivery reliability at or close to current level. By analysing historical data this research aims to get an understanding of how different factors correlate between each other.

3.1 Research method

This study employs quantitative research methods, combining correlation analysis with scenario analysis. Quantitative research utilizes numerical data and hypotheses to analyse variables and establish relationships (Ghanad, 2023). One type of quantitative research, correlational research, examines the relationships between two or more variables without manipulation (Ghanad, 2023). Ghanad also emphasises the importance of well-defined problem statements, appropriate sampling methods, valid data collection techniques and rigorous statistical analysis to ensure the reliability and generalisability of results.

A quantitative research method was chosen to provide a concrete numerical understanding of how much current delivery reliability costs for the company and how it could be achieved more cost-efficient way. Empirical part is an exploratory case study that focuses on understanding how things are now in the case company. The data provided by the company have been presented in percentage terms and in charts to protect the company's confidential information.

3.2 Overview of data collection and analysis

In the design phase of the study, the company's operations were explored in cooperation with the supply chain director, who provided insights into the research topic. Once the core issue, the challenge of maintaining high delivery reliability of perishable food products in the most cost-effective way were identified, the focus shifted to identify the key factors influencing this issue.

To address this problem, the factors selected for the data analysis include delivery reliability, overtime, total working hours, surplus, ordered products, delivered products and raw material shortages. The data utilized in this study is quantitative in nature, covering the years 2023 and 2024 and is analysed at the weekly level. It should be noted that the data covers the entire production of the company, i.e. the study does not focus on specific products, product mix or examine them separately. Products have been treated equally, without taking into account their different characteristics, values or production times. This approach was adopted because the study aims to provide a broad overview of the current situation, therefore product-specific analysis was considered unnecessary.

This study focuses on the analysis of the company’s fresh product segment. In this context, surplus refers to products that have been frozen without a predefined purpose, as well as those that could not be sold due to the expiration date requirements set by retailers. It is important to note that surplus does not necessarily mean waste, as such products can still be sold to retailers at a reduced price with a shorter shelf life. However, for the purposes of this analysis, these products are classified as surplus because they do not generate the expected revenue for the company.

The delivery reliability data include all product groups and are calculated when the customer has requested the product to leave the factory, i.e. confirmation of departure. Overtime hours simply include the total amount of overtime worked in each week. The analysis does not specify whether the overtime was due to illness or equipment failure, for example, or whether the overtime was due to production planning.

3.3 Data analysis techniques

The data has been analysed in Excel. The data came from the company in a good and clear format, so there was not much special sorting to do with the data. The first step in analysing the data was to prepare current state analysis, where I started comparing the data for 2023 and 2024. The aim at this stage was to get a clear picture of how the business has evolved over the year.

The current state analysis collected total data of hours worked, overtime hours, labour costs, quantities ordered and delivered products, average of delivery reliability, raw material shortages and surplus for the years 2023-2024. Once the totals for the sub-areas had been calculated, the next step was to calculate the percentage change between years to identify whether the change between years was positive or negative. A bar chart was also created to visualise the amount of change.

For the current state analysis, Excel was also utilized to produce a line graph for the different sub-areas to analyse the change between years on a weekly basis. The line graph enables to see more clearly if there have been more changes at a specific point in time. After conducting the current state analysis, a correlation matrix was generated to understand whether there is relationship between certain sub-areas.

After the correlation matrix, six different scenarios were created in Excel, to provide the case company concrete options the most cost-effective way in order to maintain high delivery reliability. In each scenario, the number of overtime hours was reduced in the 2024 data and in some scenarios the number of workforces was also increased. This has been used to calculate how much labour costs are in each scenario and how this has affected the quantity of products delivered and the delivery reliability. The aim is to identify potential solutions to maintain delivery reliability in a more cost-effective way.

3.4 Reliability and limitations of research

Reliability and validity are the two of the most essential and fundamental characteristics in the evaluation of any measuring instrument or tool in order to achieve good results in research (Mohajan, 2017). Reliability of the research is essential in ensuring the credibility and accuracy of the final results. Reliability measures consistency, precision, repeatability and trustworthiness of the research and validity refers to how accurately a research instrument measures what it is intended to measure (Mohajan, 2017). It ensures that the results are truthful, meaningful, and aligned with the goals of the study. To evaluate the quality of a quantitative research, we need to look at both validity and reliability. Validity makes sure we measure the right things, while reliability ensures that our measurements are consistent and can be repeated. Together, these two parts are essential for trustworthy and credible quantitative research.

In this study, the literature review is extensive, and many references have been used, which makes the theoretical part of the research reliable. Articles that have been used for this research are from 2007-2025 and mostly from 2017 to 2024, hence the research literature is recent. Most of the articles consider manufacturing and supply chain of perishable products, but the study has also made general use of various articles on supply chain management. The numerous and recent references make the theoretical part of the thesis reliable.

The data of the empirical part was provided by the company and they use it to monitor the company’s performance. The empirical part has been carried out in cooperation with the company for the benefit of its business, hence it can be assumed that the data have not been manipulated. The data was collected over a period of two year and was analysed in a week level, which gives the analysis repeatability. The quality of the data can be considered as reliable.

Overall, the study can be considered reliable, but there are a few limitations to be noted. These include, for example, the fact that the study has not considered all possible factors in the empirical part. For example, the data has not been processed on a product-specific level, meaning that different product mixes, varying production times, and individual product characteristics have not been considered. In addition, the scenario analysis phase does not take into account that, in some weeks, the increased staffing levels resulted in higher total working hours compared to the original situation. This could mean that delivery reliability might have improved under these conditions. However, it is assumed that the volume of products produced in the scenario analysis cannot exceed the actual 2024 values. This is because it is unclear whether the additional hours would have been beneficial given other constraints such as production line capacity and raw material volumes.

4 Results and findings

Next, the study will focus on results and findings from the analysed data. The purpose of this analysis section is to identify potential areas for development for the company that they should consider in their operations. The analysis section begins with a current state analysis by comparing the 2023-2024 data, including for example regular working hours, overtime, order quantities, raw material shortages, surplus, delivery reliability, and additionally, cost of working hours. The analysis focuses on examining the change between the two years. In the charts the data on the Y-axis have been removed to prevent the company's confidential information from being utilized.

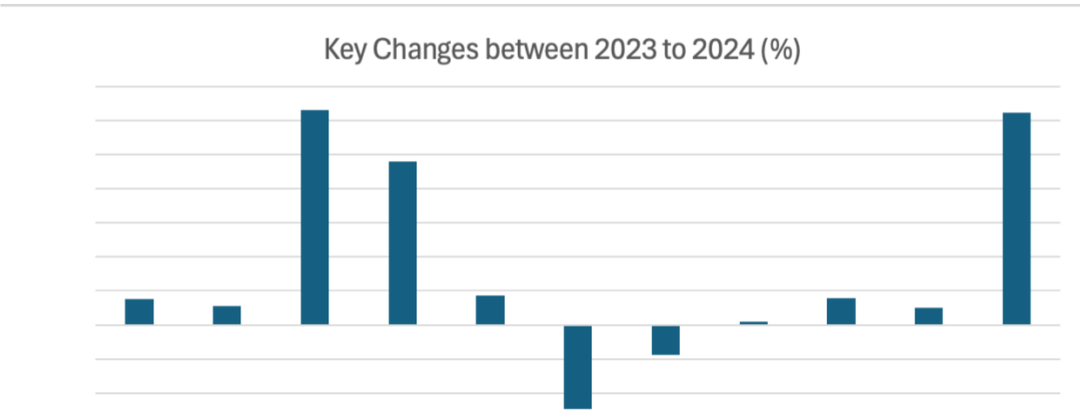
After the current state analysis, the study investigates whether there is a clear correlation between the variables that could help interpret how maintaining a high level of delivery reliability affects the company's operational efficiency. Additionally, different scenarios have been created in the analysis to examine how reducing the overtime would impact to delivery reliability, cost of overtime and the quantity of products produced.

4.1 Current state analysis

The current state analysis aims to provide an overview of how the company's operations have developed over the past two years. The analysis of the current state gives the company a good picture of how their business has developed and whether there may have been a deterioration in some areas. Moreover, this is important for the study in order to get a clear picture of the current situation of the company. Figure 1 shows the percentage changes in selected factors between 2023 and 2024.

Figure 1 shows that there is growth in all other components, except for the shortage of raw materials and surplus. The reduction in the shortage and surplus of raw materials is positive, especially the figure shows that there is almost a 50% improvement in the shortage of raw materials. This suggests that the long-term demand forecasting has been more successful, as raw materials must be ordered from the supplier in well advance and after that no changes to the raw material orders can be made.

Figure 1 also shows that the demand has increased by about 20% compared to 2023, which indicates that the case company has managed to increase sales, which is positive. Also the average of delivery reliability is increased slightly which means that the company has been able to respond better to customer orders. As a result of the increase in sales, it is expected that the number of working hours will also increase to meet the demand. However, it should be noted that the share of overtime has increased by more than 100% compared to last year and that the share of overtime in total hours worked has also increased by almost 100%. The study aims to examine overtime costs and whether it would be more cost-effective to hire more workforce. Next, we will go through most important areas in more detail to analyse changes at specific times of the year and whether there is a temporal link between the changes.



	Total Working Hours	Regular Working Hours"	Overtime	Overtime Proportion of Total Hours	Ordered Products	Raw Material Shortages	Surplus	Average Delivery Reliability	The total cost of all working hours	The total cost of basic hours	The total cost of overtime
Series1	15,33 %	11,12 %	126,02 %	95,97 %	17,27 %	-49,41 %	-17,63 %	2,10 %	15,45 %	10,13 %	124,68 %

Figure 1. Key Changes between 2023 to 2024

4.1.1 Ordered products 2023 – 2024

Figure 2 illustrates the distribution of demand during 2023-2024. Overall, demand has increased in 2024 compared to 2023 across nearly all periods, except for weeks 19, 23, 26, 41 and 52. Even in these weeks, the drop in demand was no significant. It's worth noting that week 19 in 2024 Ascension Day, public holiday, which likely impacted demand. Similarly, the Christmas bank holiday in week 52 fell midweek in 2024, aligning with a factory closure, which likely contributed to the lower demand during that period.

The figure 2 also highlights distinct demand spikes, particularly in weeks 15 and 21 of 2024. These peaks may reflect promotional campaigns in supermarkets during those periods, which could have temporarily boosted demand.

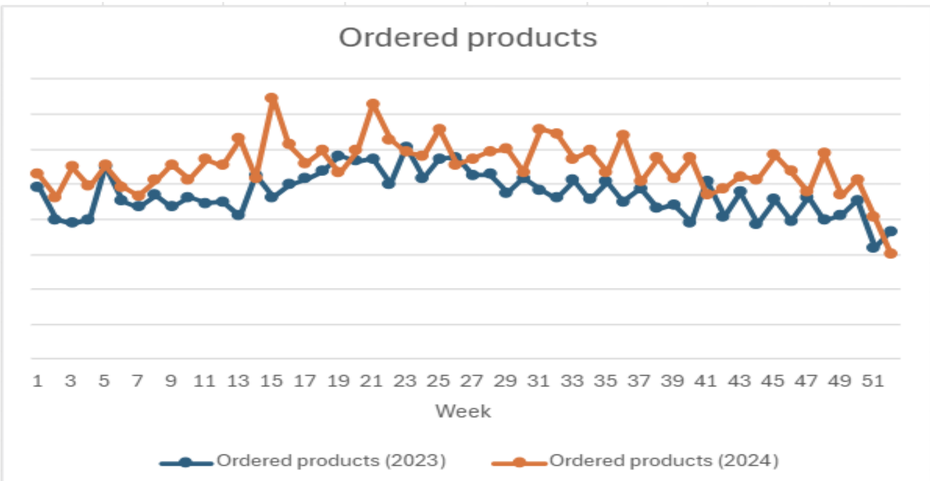


Figure 2. Ordered products

In figure 3, the ordered products are divided into four cycles: weeks 1-13, 14-26, 27-39 and 40-52. The average number of ordered products has been calculated for each period and the figure has been created to help visualize whether any seasonal patterns can be observed. Figure 3 shows that demand consistently peaks during weeks 14-26 and 27-39 in both years, highlighting a clear seasonal pattern. This suggest that the company experiences its highest demand in late spring, throughout summer, and into early autumn.

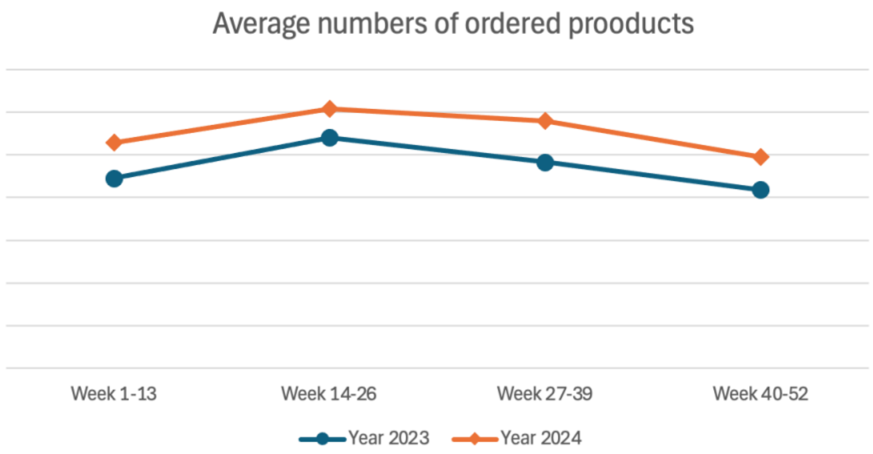


Figure 3. Average numbers of ordered products

4.1.2 Raw material shortage 2023-2024

Figure 4 illustrates how raw material shortage were distributed across 2023 and 2024. As shown earlier in Figure 1, overall shortages decreased in 2024 compared to 2023, suggesting improved long-term demand forecasting. However, there are noticeable spikes in 2024, particularly during weeks 14-16, where shortages increased significantly. Referring to Figure 2, a sharp rise in ordered products is visible in week 15, indicating a potential mismatch between forecasted and actual demand. This suggests that demand may have been underestimated, leading to insufficient raw material orders. Similar patterns can also be observed in weeks 21 and 25. Figure 4 also shows that week’s 20-21 and 26-27 of 2023 will experience the highest raw material shortages. However, no significant spikes in ordered products are observed, which may suggest that either too few raw materials were ordered from the supplier or the supplier faced delivery difficulties.

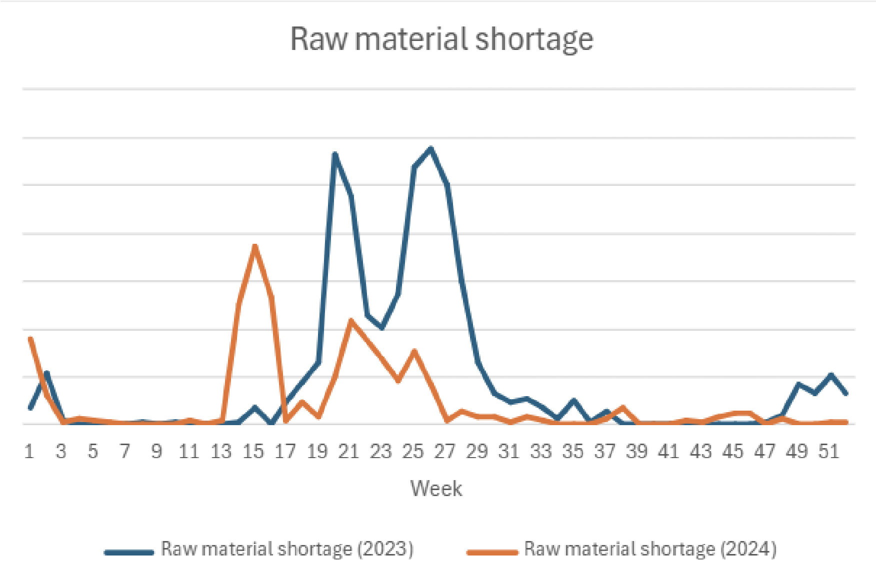


Figure 4. Raw material shortages

4.1.3 Delivery reliability

Figure 5 shows that in 2024, delivery reliability has remained stable throughout the year, except for a dip in week 14-16. If we look at delivery reliability in 2023, there has been more variation. For example, in weeks 20-21 and 25-27, delivery reliability was relatively lower. Looking at Figure 4, it can be concluded that the shortfall in 2024 is due to a shortage of raw materials. The same can be observed if we analyse the delivery reliability and the shortage of raw materials in 2023, which shows the important role that successful raw material ordering plays in maintaining a firm's delivery reliability.

Furthermore, figure 1 show that the number of overtime hours has increased in 2024 compared to the 2023. This rise in overtime may have played a role in maintaining a high level of delivery reliability throughout the year, as additional working hours likely helped the company respond more effectively to fluctuations in demand and potential disruptions.

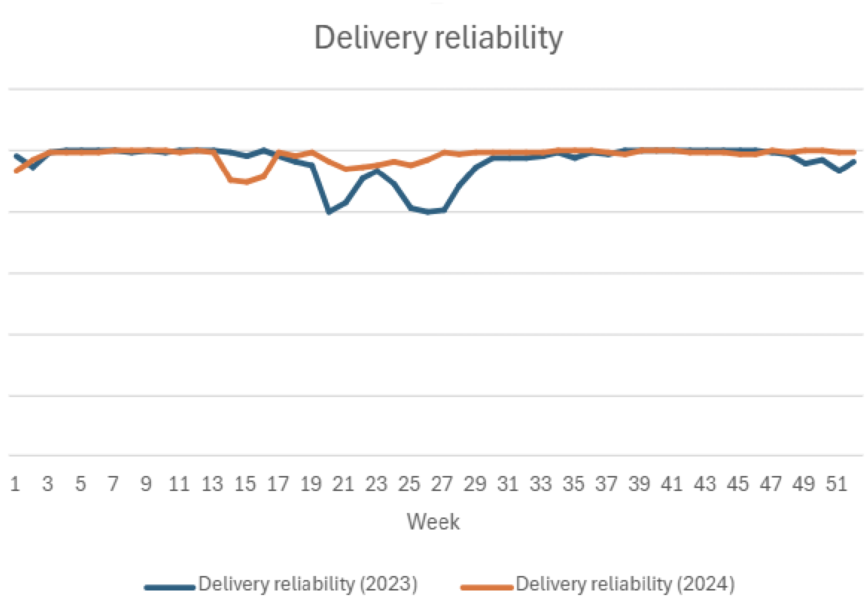


Figure 5. Delivery reliability

4.1.4 Surplus

Figure 6 shows the distribution of surplus in 2023-2024. Overall, the surplus has decreased compared to 2023, although some variability is observed. In week 15 of 2024, only a small amount of surplus was observed. This can be attributed to the high level of raw material shortages during that week. However, it is noteworthy that while raw material shortages were observed in weeks 21-22 of 2024, a surplus was recorded in weeks 20-21. This discrepancy may indicate that demand for certain products categories was high in week 21, leading to raw material shortages, while demand for other products categories remained lower, resulting in a surplus.

When dealing with perishable raw materials, immediate production is often required, which can easily result in surplus. It is important to note that surplus does not directly mean waste. The products may have been sold on at a lower price. This supports sustainable development, but from the financial point of view of the company this is negative, as the expected profit from the products has not been achieved.

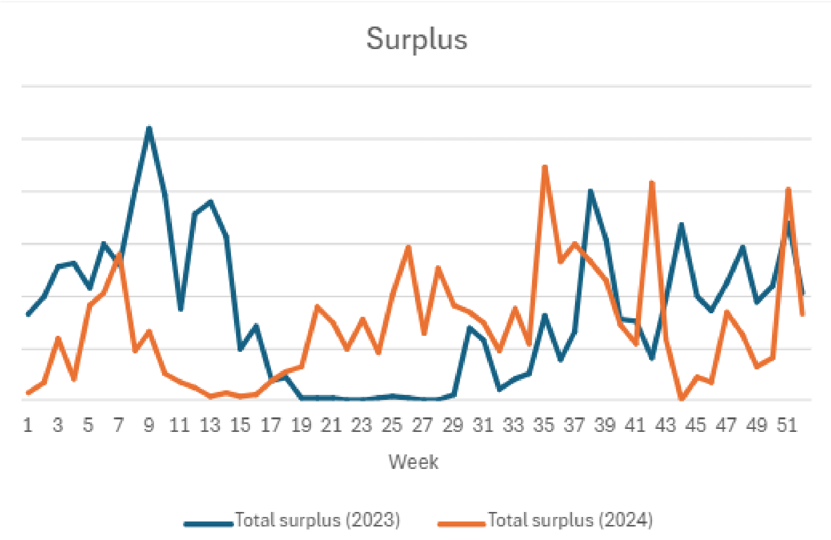


Figure 6. Surplus

4.1.5 Overtime hours

Figure 7 shows the distribution of overtime hours over the whole year in 2023 and 2024. The figure also illustrates the average amount of overtime worked across the years. In year 2024, it can be noticed that average overtime has been exceeded continuously in weeks 18-31, expected in week 27. This suggests that more overtime is worked during the summer season to meet higher demand.

It should be noted that if there is consistently high overtime over a period of time, it would be useful to consider other possible ways of meeting demand. As noted in the theoretical part of the research, long-term overtime may reduce the efficiency of workers. A possible solution could be to increase the number of seasonal workers.

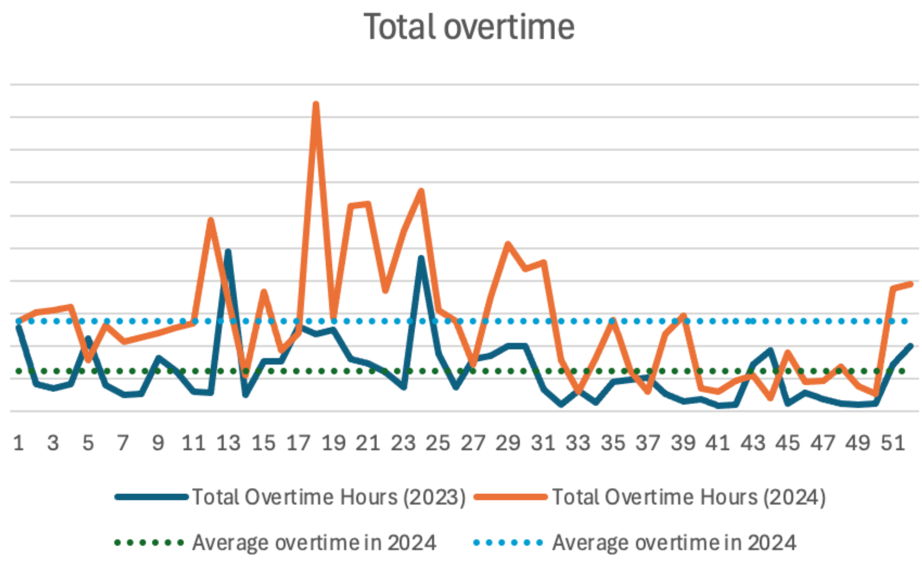


Figure 7. Total overtime hours

4.2 Correlation matrix

The correlation matrix has been created using Excel. Table 1 displays the correlation matrix from 2024 data and table 2 displays the correlation matrix from 2023 data. Correlation matrix illustrates the relationship between the selected variables. The variables selected for the correlation matrix are raw material shortage, ordered products, delivered products, delivery reliability, total overtime, weekend overtime, basic hours, total working hours, surplus, ordered raw material, and actual raw material. Correlation matrix was created for both years to examine whether the variables have consistent relationship, follow similar trends across years, or show significant changer or new trends.

Variables highlighted in yellow indicate strong correlations whereas variables highlighted in red indicate moderate correlations. A positive correlation indicates that both variables tend to move in the same direction, i.e. when one variable increase or decreases, the other variable also moves in the same direction. Negative correlation, on the other hand, demonstrates an inverse relationship, i.e. when one variable increases, the other variable tends to decrease. Variables that are not highlighted are weakly or insignificantly correlated.

Table 1. Correlation matrix 2024

	Raw material shortage	*Ordered products*	*Delivered products*	*Delivery reliability*	*Total overtime*	*Weekend overtime*	*Basic hours*	*Total working hours*	*Surplus*	*ordered raw material*	*actual raw material*
Raw material shortage	1,00										
Ordered products	0,48	1,00									
Delivered products	0,29	0,98	1,00								
Delivery reliability	-0,99	-0,41	-0,21	1,00							
Total overtime	0,25	0,28	0,24	-0,23	1,00						
Weekend overtime	0,05	-0,11	-0,13	-0,06	0,66	1,00					
Basic houurs	0,09	0,56	0,59	-0,04	0,13	-0,02	1,00				
Total working hours	0,17	0,59	0,61	-0,12	0,48	0,22	0,93	1,00			
Surplus	-0,28	-0,19	-0,14	0,29	-0,05	-0,03	0,24	0,20	1,00		
Ordered raw material	-0,02	0,33	0,37	0,05	0,20	0,05	0,84	0,82	0,30	1,00	
Actual raw material	-0,06	0,33	0,37	0,10	0,19	0,07	0,85	0,82	0,34	0,99	1,00

Table 2. Correlation matrix 2023

	Raw material shortage	*Ordered products*	*Delivered products*	*Delivery reliability*	*Total overtime*	*Weekend overtime*	*Basic hours*	*Total working hours*	*Surplus*	*Ordered raw material*	*Actual raw material*
Raw material shortag	1.00										
Ordered products	0.58	1.00									
Delivered products	0.08	0.86	1.00								
Delivery reliability	-1.00	-0.53	-0.03	1.00							
Total overtime	0.22	0.22	0.13	-0.23	1.00						
Weekend overtime	0.01	-0.08	-0.10	0.00	0.66	1.00					
Basic hours	-0.19	0.15	0.30	0.20	0.11	0.19	1.00				
Total working hours	-0.12	0.20	0.31	0.13	0.37	0.35	0.96	1.00			
Surplus	-0.59	-0.60	-0.37	0.58	-0.13	0.13	0.13	0.09	1.00		
Ordered raw material	-0.24	0.12	0.30	0.26	0.23	0.35	0.81	0.81	0.10	1.00	
Actual raw material	-0.21	0.12	0.28	0.22	0.22	0.36	0.81	0.82	0.09	0.98	1.00

4.2.1 Strong correlation

The correlation matrix shows that delivery reliability is strongly and negatively correlated with raw material shortages in both years. This suggests that the level of delivery reliability is affected highly by raw material shortages. In other words, when delivery reliability increases, the number of raw material shortages is the lowest and when delivery reliability decreases, the number of raw material shortages is the highest. Bottlenecks in the supply chain, such as supplier delays, limited availability, long lead times or inaccurately forecasted raw material orders, can slow down or stop production and reduce delivery reliability. This is especially critical when rare or long lead time materials are used, or when there are only few suppliers available.

A strong correlation can be seen also between ordered and delivered products, which is logically, when more products are ordered, more are delivered. Additionally, both basic hours and total working hours show a positive strong correlation with ordered and actual raw material, indicating that increased raw material orders require more labour to complete production.

4.2.2 Moderate correlation

The matrix shows a moderate negative correlation between ordered products and delivery reliability in both years. This may indicate that higher order volumes can challenge the ability to maintain delivery reliability, possibly because of limited supply capacity and large order volumes overload processes because production does not scale quickly to meet demand. A strong negative correlation was also found between raw material shortages and delivery reliability, indicating that shortages have a significant impact on the ability to deliver on time. In addition, the matrix reveals a moderate correlation between raw material shortages and ordered products, suggesting that increasing order volumes may contribute to raw material shortages, which then affect delivery reliability, However, since the correlation is only moderate, other factors may also contribute to raw material shortages, such as inaccurate forecasts, delays from suppliers or limited availability.

In addition, the correlation matrix shows that there is a moderate correlation between the number of ordered products and basic working hours in 2024 data. This may suggest that labour input has been successfully adjusted to match demand, which is positive indicator of operational flexibility and more efficient use of resources.

There is also a moderate positive correlation between surplus and ordered raw materials in 2024. This may indicate that as the quantity of raw materials ordered increases, the surplus tends to rise slightly as well. This suggests that the case company may experiencing higher demand for certain products, requiring more raw materials overall, but demand for other products is not enough high and therefore surplus may occur. Table 2 shows us that there is no correlation between surplus and ordered raw materials in 2023. However, there is negative correlation between raw material shortages and surplus, which is logical. This negative correlation suggests that as the raw material shortage increases, the surplus decreases. This may indicate that a shortage of raw materials limits production or forces a more efficient use of materials, resulting in small or no surplus.

4.2.3 Weak correlations

Across both 2023 and 2024, several variables showed weak or no correlation with each other (see table 1 and table 2). This may suggest that there is no direct causal relationship between these variables, or that other hidden factors such demand fluctuations, scheduling strategies or production capacity are influencing the outcomes. Operational and supply chain processes are likely interconnected and complex, meaning that no single factor alone determines performance outcomes.

However, an interesting observation from the data is that delivery reliability showed only a weak correlation with overtime hours in both years. This could suggest that the decline in delivery reliability is not primarily driven by changes in overtime. While an increase in overtime hours could potentially support delivery reliability, the data does not provide strong evidence for this relationship. Notably, delivery reliability remained consistently high throughout the year, and overtime hours were observed regularly, which complicates the identification of clear connection between the two variables. Further analysis would be valuable to determine the actual impact of overtime to maintain delivery reliability and to take note of other factors such as production capacity.

According to findings of correlation matrix, increased order volumes and shortages of raw materials are linked to negatively to delivery reliability. This may refer to the fact that there are other bottlenecks in supply chain. For example, scheduling and production flow is inefficient or production line capacity cannot meet demand.

4.3 Scenario analysis

The scenario analysis is based on data for 2024. For the scenario analysis, six different scenarios have been created to see how much delivery reliability changes if overtime is reduced. The objective of the scenario analysis is to find cost-effective ways to maintain delivery reliability while managing labour costs by adjusting overtime hours and staffing levels. In some scenarios, delivery reliability and quantity of products delivered have been reduced to illustrate whether it would be more cost-efficient to accept slightly lower level of delivery reliability and also to assess the cost of maintaining the current level of delivery reliability. The scenario analysis focuses on hiring more employees for the summer season, when overtime hours were higher than average.

The scenario analysis does not take into account production line constraints or product-specific lead times, since the analysed data represents overall production and not individual products, a detailed analysis could not be made. The aim is to provide a general overview that can help the company to reflect on potential improvement actions. While the scenario analysis cannot be directly applied to the company's operations as such, it is intended to spark ideas and support decision-making.

In addition, in the scenario analysis, there are situations where the number of working hours at certain times is higher than in the 2024 data. This is because, in some scenarios, the amount of additional workforce may exceed that of the original situation in some weeks. However, in these cases, it cannot be assumed that delivery reliability and the number of delivered products would be higher than in the actual situation in 2024, as there is no certainty whether the production capacity would have allowed for the additional output.

Table 3 shows the percentage change compared to the original 2024 data in every scenario. The percentage changes in labour cost, delivery reliability, and the number of delivered products have been calculated by comparing each scenario's data to the original data from 2024. In the first step, the required weekly working hours were estimated for each scenario:

Scenario 1: Uses the regular working hours from 2024, with no overtime.
Scenario 2: Working hours = regular working hours from 2024 + 50% of the overtime hours from 2024.
Scenario 3: For weeks 1-17 and 32-52, both regular working hours and overtime hours from 2024 data are used. For weeks 18-31, additional workforce has been hired, and no overtime is allowed during weeks 18-31. The additional workforce requirement is calculated using the average overtime hours from the entire year 2024.
Scenario 4: Same as scenario 3, but overtime is allowed during weeks 18-31, if necessary. The overtime hours for those weeks are calculated as:

$$overtime = \ total\ workhours\ per\ week_{2024} - \ regular\ working\ hours\ per\ week_{scenario}$$

Scenario 5: For weeks 1-17 and 32-52, both regular working hours and overtime hours from 2024 data are used. Additional workforce has been hired for weeks 18-31. The need for additional workforce is based on the average number of overtime hours worked in weeks 18-31 in 2024. Overtime is allowed during weeks 18-31 if necessary. The overtime hours for those weeks are calculated as:

$$overtime = \ total\ workload\ per\ week_{2024} - regular\ working\ hours\ per\ week_{scenario}$$

Scenario 6: Same as Scenario 5, but no overtime is allowed during weeks 18-31

Once the weekly working hours were defined, labour costs were calculated on a weekly basis using salary data provided by the company as follows:

$$Labour\ \cos t\ = (regular\ hours\ \times\ hourly\ wage\ ) + (overtime\ \times\ overtime\ wage)$$

Based on 2024 data, a weekly productivity per hour was calculated as follows:

$$\Pr o\ ductivity\ per\ hour\ =\ delivered\ products_{2024}\ \div\ total\ working\ hours_{2024}$$

Once the weekly productivity per hour was calculated, the number of delivered products per week in each scenario was determined by multiplying the new working hours by the weekly productivity.

$$Delivered\ products\ =\ productivity\ per\ hour\ \times\ total\ working\ hours\ _{scenario}$$

The delivery reliability was calculated on a weekly level by dividing the number of delivered products in scenario by the number of ordered products in 2024.

$$Delivery\ reliability\ (\%)\ = (Delivered\ products_{scenario} \div Ordered\ products_{2024}) \times 100$$

After this calculation of percentage changes in each scenario compared to 2024 data was calculated as follows:

$$Percentage\ change\ =\ \left(\frac{New\ value_{scenario}\ -\ old\ value_{2024}}{old\ value_{2024}}\right) \times 100$$

The total annual labour cost for each scenario was compared to the total labour costs in 2024. The total number of delivered products per scenario was compared to the actual deliveries in 2024. The average annual delivery reliability was calculated for each scenario and compared to the actual average annual delivery reliability in 2024.

Table 3. Summary of scenario analysis

Column1	Changes in labour costs	Changes in average delivery reliability	Changes in delivered products
Scenario 1	11.50%	-6.93%	-7.09%
Scenario 2	4.52%	-3.45%	-3.54%
Scenario 3	2.29%	-4.74%	-1.33%
Scenario 4	0.54%	0%	0%
Scenario 5	0.32%	0%	0%
Scenario 6	1.06%	-0.51%	-0.57%

When analysing the results of the scenario analysis, it is essential to consider which factors carry the most weight. While savings in labour costs may initially appear beneficial, they can come at the expense of service level and customer satisfaction. Over time, a decline in delivery reliability could lead to a loss of customer trust and reduced demand. Furthermore, a decrease in the number of the delivered products will automatically lead to a reduction in revenues.

Table 3 illustrates that by increasing regular working hours and reducing overtime, labour cost savings can be achieved. One of the key strengths of the case company is its ability to deliver fresh products with good shelf life at the right time. Based on this information, scenario 1 can be immediately ruled out. If no overtime is allowed and no additional workforce is hired, delivery reliability would decline significantly.

Although Scenario 2 leads to a 4.52% saving in labour costs, it is accompanied by a considerable decline in service performance, potentially impacting the business negatively. Scenario 3 also deserves attention. It yields a 2.29% saving in labour costs, and although there is only a 1.33% reduction in the number of delivered products. The drop in delivery reliability is significantly larger at 4.47%. This suggests that in some weeks during the summer period, delivery reliability deteriorated sharply, reducing the average reliability downwards. In such a situation, it would be reasonable to consider allowing overtime on specific days in scenario 3 to stabilize delivery reliability.

If the company aims to maintain its current level of delivery reliability in the most cost-effective way without losing delivery performance at all, then scenario 4 emerges as the most suitable option. In this scenario, additional workforce is hired for weeks 18-31, based on the annual average of overtime. Overtime is allowed when necessary to uphold service levels. This approach still enables the company to achieve 0.51% savings from labour costs. However, if the company is willing to allow a slight decline in delivery reliability, greater savings from labour costs compared to scenario 4 can be achieved through scenario 6. In this case labour cost savings would amount to 1.06%, while changes in average delivery reliability would decrease by only 0.51%.

5 Conclusion and discussion

The objective of this thesis was to analyse the challenges in maintaining high delivery reliability in the food industry, taking into account the specific characteristics of the case company. Research questions were:

1.What are the costs involved in maintaining the current level of delivery reliability in the case company?

2. How can the case company maintain a high level of delivery reliability while optimizing cost efficiency?

By answering these questions the aim was to meet the following objectives:

1. To identify and analyse the cost associates with maintaining current level of delivery reliability in the case company.
2. To identify cost-effective strategies for maintaining a high level of delivery reliability in the case company.

5.1 Main findings

Maintaining delivery reliability at the current level in the case company has required an effort that has been effectively managed by the organisation. The company has managed to maintain a steady high level of delivery reliability throughout 2024. The average level of delivery reliability in 2024 was 98.4%. According to Sarmiento et al. (2007), ensuring high delivery reliability is crucial for maintaining customer satisfaction, strengthening trust, and sustaining long-term relationships. All of the above will improve company's competitive position. According to the case company, an important factor in its competitiveness in the market is its ability to deliver products with a good shelf life and short lead times, ensuring timely deliveries.

In addition to maintaining the high level of delivery reliability, the company has been able to reduce raw material shortages almost 50% and surplus around 20 % in 2024 compared to 2023. Study by Zamani Dadaneh et al. (2023) supports that efficient management of raw materials is critical for companies to remain competitive and achieve cost savings. The reduced raw material shortages suggests that long-term demand forecasting has been successful in enabling better planning and ordering of raw materials in 2024 compared to 2023. Lower raw material shortages may also indicate that suppliers have been more capable of delivering raw materials in 2024 compared to 2023.

The demand of the case company has increased by 17% in 2024 compared to 2023, which may partly reflect an improvement in customer satisfaction. According to Cugini et al. (2007), increased customer satisfaction has a direct impact on customer loyalty, repeat business and positive brand image, which in turn can lead to increased demand and stronger financial performance.

Analysis of the company's data show that overtime has been useful in meeting demand and keep delivery safety in good level. The company has used more overtime in 2024 compared to 2023 in relation to normal working hours to ensure that demand meets the supply. In 2024, the amount of overtime worked was more than twice as high as in 2023. Findings from the scenario analysis shows that if no overtime had been done in 2024 then delivery reliability in 2024 would have been 6.93% less and around 7% fewer products would have been delivered, but 11.5% savings from labour cost would have been achieved. Sansone et al. (2017) support that maintaining delivery reliability faces challenges when balancing costs, flexibility and resource allocation. Additionally, Sarmiento et al. (2007) noted that punctuality may sometimes require measures such as overtime.

When examining research question 1, it can be observed that maintaining a high level of delivery reliability has resulted in additional costs for the company. In particular, overtime costs have increased. The amount of overtime relative to total working hours rose by 96% in 2024 compared to 2023. Figure 1 from current state analysis also shows that the total costs of overtime is increased over 100% in 2024 compared to 2023. Based on the scenario analysis, if no overtime had been done in 2024, labour costs would have been reduced by 11.50% compared to the actual 2024 situation. Furthermore, figure 7 shows that overtime at the weekly level has been a regular occurrence in the case company. When overtime becomes a regular practice, in addition to fixed overtime wage costs, potential decrease of productivity must also be taken into account. However, it should be noted that a high level of delivery reliability contributes to customer satisfaction and has a positive impact on brand image and future demand, hence the benefits and drawbacks of overtime need to be carefully assessed.

The aim of the second research question was to identify cost-effective strategies that would allow the case company to sustain a high level of delivery reliability while optimizing cost efficiency. The correlation matrices were utilized to examine how different variables correlate with each other, with particular focus on identifying correlations between delivery reliability and other variables. The correlation between delivery reliability and raw material shortages was high and negative, suggesting that an increase in shortages is associated with decrease in delivery reliability. This implies that accurate forecasting of raw material need is crucial for maintaining delivery reliability. To address this challenge, the company should focus on improving their ability to respond to changes in demand by developing more resilient and agile supply chains. Resilience can be enhanced by creating flexible systems that are capable of withstanding disruptions, while agility refers to the ability to quickly adapt to fluctuating demand patterns.

In addition, a moderate negative correlation was found between delivery reliability and number of products ordered suggesting that a higher number of products ordered may slightly reduce delivery reliability. This could indicate that the company's production line may not be able to meet higher demand levels due to capacity constraints, and it would be valuable to examine the flexibility of the production flow. Identifying potential bottlenecks in the production process is crucial to improve overall capacity and responsiveness. One approach to address these capacity constraints is Theory of Constraints, which focuses on identifying and eliminating bottlenecks that limit the flow of production.

An important observation was that there was no clear correlation between delivery reliability and overtime hours, implying that increasing overtime does not necessarily improve delivery reliability. Similarly, no clear correlation was found between the number of ordered products and overtime hours, indicating that a higher number of orders does not automatically lead to increased overtime. One possible explanation for the lack of correlation could be that overtime is performed regularly, regardless of changes in delivery reliability or order volumes. This consistent pattern of overtime work may prevent noticeable variation that would otherwise result in a stronger correlation.

When relying continuous overtime work, it is important to consider potential decline in productivity as well as the cost associated with employee sick leave. A study by Collewet and Sauermann (2017) supports that workers' productivity decreased as working hours increased, and Chang and Woo (2017) support this claim. Chang and Woo also state that physical and mental fatigue due to overtime affects productivity. It should be noted that there has not been an increase in sick leave and accidents in the case company.

One important part of addressing research question 2 was conducting a scenario analysis. The goal of the scenario analysis was to examine how reducing the amount of overtime would impact labour costs, delivery reliability and the number of delivered products, and to identify the most cost-effective approach. The scenario analysis demonstrates that reducing overtime hours while increasing workforce during the summer months contributes to labour costs savings, while still maintaining a high level of delivery reliability. However, the analysis also reveals that if overtime hours are reduced without increasing workforce during summer period, delivery reliability drops significantly. Furthermore, when combining the results of the correlation analysis and scenario analysis, it becomes evident that maintaining high level of delivery reliability requires broader investigation, particularly considering the capacity of the production lines.

5.1.1 Practical implications for the case company

As discussed in section two, the food industry faces a variety of challenges, including seasonality, strict safety requirements, variable demand, short shelf-life, a wide product range and allergen management. Due to hygiene requirements, cleaning must be performed between production runs. Given the wide product range and different set up times, it is crucial to optimize production batch sizes to maintain an efficient production flow to maintain a high level of delivery reliability.

Based on the research findings, I recommend the company to consider the amount of overtime from a financial point of view and to consider potential alternatives to reduce the number of overtime hours. First, I recommend hiring an additional workforce during the summer months. According to scenario analysis, this approach could lead to savings in labor costs while still maintaining a high level of delivery reliability. Secondly, the research indicates that it would be beneficial to review the production capacity and flow. It would be important to investigate whether there are specific bottlenecks in production that are slowing down operations. For instance, it could be more efficient to produce larger batch sizes, which would improve production flow. A more efficient production flow would enable a higher output within the same timeframe, enhancing overall productivity and reducing the need for overtime hours. However, producing larger batches could lead to higher inventory levels, which in turn might negatively affect the products' shelf-life requirements.

If potential bottlenecks and capacity limitations of the production line are not investigated, increasing workforce during summer months may not bring any benefits. On the contrary, it may only lead to higher costs. If the production line's capacity is insufficient to meet demand, for example if machine capacity cannot support the required production volume, hiring additional workforce will not improve the situation. Instead, the additional workforce would remain underutilized, generating unnecessary costs for the company. An important next step following this study is to determine whether the need for overtime stems from an insufficient number of workforce or from production capacity constraints.

5.1.2 Reflection on the research process and methodological limitations

At the beginning of the research process, one of the main challenges was how to define the research problem and determine a feasible scope for the empirical part in a way that would be manageable within the available resources. For example, the empirical analysis was not conducted at a product-specific level in order to keep the analysed data manageable. The research cannot be directly adapted to the company's operations precisely because no product specific analysis has been conducted, nor have the production setup times been taken into account. However, this study provides the company an overview of its operations and helps to identify specific areas that require attention for improvement.

Additionally, it was challenging to find literature that was specially focused on the perishable food industry, especially ones that discuss maintaining delivery reliability within this sector. Due to this challenge, the study has drawn on existing literature that focuses also on perishable goods in general, as well as research from other industrial sectors. This approach allowed for the application of broader insights into delivery reliability and related issues.

5.1.3 Future research

Further research should focus on analysing product-specific demand patterns, delivery reliability and production lead times. By examining demand at the product level, it would be possible to identify which items exhibit more stable and predictable consumption. For these products, maintaining higher safety stock could be a viable strategy to enable larger production batches, eventually improving efficiency and reducing changeover frequency in production lines.

In addition, analysing delivery reliability on a product specific would help to identify specific products that pose challenges in terms of on-time delivery. Understanding these patters could inform decisions about where additional buffers or process improvement might be necessary. Analysing production lead times in more detail can also reveal whether certain products require significantly more resources or involve complex changeovers in the production line. If such products can be grouped and produced in larger batches, it could facilitate streamline production scheduling, optimize resource allocation, and reduce overall lead time and overtime working.

From the perspective of the literature, future research should also focus more broadly on perishable food products and examine in greater detail the benefit and disadvantages of overtime in the food industry, where products often have lower profit margins. Additionally, future studies should emphasize developing more effective forecasting methods, enhancing collaboration within the supply chain, and exploring new techniques for balancing inventory levels under the constraints imposed by perishable products.

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