Optimizing Distribution Network Design for Short Food Supply Chains: The Case of Company X

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Preface

I am delighted to present my master's thesis, the result of five months of hard work and research. This thesis represents the final step before graduating from the master’s program in Supply Chain Management at Tilburg University and pursuing a career in the field. My academic career started at HAS university in Hertogenbosch where I studied Business Administration. During this period, I discovered my passion for Logistics, which resulted in an application for the Pre-Master Supply Chain Management, and eventually starting the MSc programme in Tilburg.

For this thesis-writing process, I had the opportunity to intern at Logistics Community Brabant (LCB), a research institute focused on logistics. Via this research institute I had the opportunity to work on the case of X. During this period, I gained valuable insights into the operations and processes of a logistic service provider in active in SFSCs.

First of all, I would like to thank Mr. Feng Fang for his guidance and feedback as my supervisor from Tilburg University, both before and during the writing of my thesis. In particular, the additional meetings for our modeling research were appreciated.

Next, I would like to extend my gratitude to LCB and X for the internship opportunity, as well as for the help and feedback I received during the writing period. Special thanks go to Marlou Claes, Peter Kole, and Hans Quak from LCB, and the general and operational manager from X.

Furthermore, I would like to thank my fellow interns and colleagues at LCB for their input, support, and suggestions during my research period. The atmosphere was always positive, and together we spent a lot of time working hard and achieving our goals.

Abstract

Short food supply chains (SFSCs) have garnered significant attention in recent years as a sustainable alternative food system. These chains connect producers and consumers with minimal intermediaries and reduced geographical distances. However, participants face logistical challenges when establishing a short food supply chain (SFSC), stemming from high costs and limited economies of scale. This case study examines the operations of Company X (X), a logistics service provider specialized in SFSCs. It aims to investigate the logistical performance of X's distribution network design (DND) and explore ways to enhance it. Therefore, this study strives to find an answer to the central research question:

"How can Company X strategically modify their distribution network design to enhance logistical performance and establish an efficient short food supply chain based on an assessment of the current distribution network design's effectiveness?

To address this research question, a mixed-method approach was adopted, combining longitudinal case study with formal modeling and simulation approach. Quantitative data were gathered and processed from X's databases and Excel files, while qualitative data were collected through an interview and various conversations.

The research concluded that bundling SFSC initiatives led to significant reductions in operational costs and kilometres travelled. However, underutilized vehicle capacity remains a challenge, necessitating an expansion of the customer base to increase sales and distribution volume. To maintain consistent delivery reliability, X should take proactive measures over time, to increase their key decision variables: the number of vehicles and hub employees.

This study adds to the current literature by conducting practical research to evaluate innovative DNDs in SFSCs, identifying bottlenecks, determining key variables, and proposing improvement strategies. These findings offer valuable insights for SFSC managers and enhance the broader comprehension of DND optimization within SFSC contexts.

Keywords: Short food supply chains, distribution network design, system dynamics simulation, longitudinal case study

Table of contents

Anonymization

Due to the confidential nature of this research, specific values and company names have been anonymized through approximation, a coefficient, and an alias to protect sensitive data.

List of Abbreviations

SFSCs: Short food supply chains
SFSC: Short food supply chain
X: Company X
DND: Distribution network design
SD: System dynamics
B2C: Business-to-consumer
B2B: Business-to-business

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Background

The current state of the food industry signals a need for significant changes. The call for a more sustainable food policy, coupled with the complexities of digitalization and workforce shortages, emphasizes the necessity for a shift towards increased efficiency, simplicity, and transparency (Hassoun, Aït-Kaddour, & Abu-Mahfouz, 2023). In response to these challenges, X, are at the forefront of driving essential transformations within the food supply chain.

Operating as logistic service provider, X take on the responsibility of overseeing the entire food supply chain, catering to both consumers and suppliers. This oversight is achieved through the implementation of chain automation. They utilize this chain automation and their own custom software, serving as an online marketplace, to provide a framework for establishing SFSC's. The online marketplace plays a crucial role in streamlining procurement processes, enhancing market efficiency, and fostering connections between buyers and sellers.

(SFSCs) have gained attention in recent years as a sustainable alternative food system that connects producers and consumers with minimal intermediaries or geographical distances (Jarzebowski, Bourlakis, & Bezat-Jarzebowska, 2020). Mount (2011) and Majewski et al. (2020) state that SFSCs can have positive effects on sustainability, profits and quality. However, X faces logistical challenges when establishing a SFSC. Local food initiatives face challenges in competing with large food supply chains due to their high logistical costs and limited economies of scale (Todorovic, et al., 2018). This research will investigate how X can address this logistical challenge.

1.2 Problem indication

1.2.1 Short Food Supply Chains

As mentioned in the background, X aims to set up SFSCs. SFCSs lead to benefits for both producers and consumers. Producers can enhance profitability through SFSCs by sidestepping intermediaries, cutting transactional costs, and consequently increasing revenue from sales (Majewski, et al., 2020). The benefits of SFSC's align with sustainability principles by reducing food miles, energy consumption, carbon footprint and food waste in comparison to traditional food supply chains (Jarzebowski, Bourlakis, & Bezat-Jarzebowska, 2020). From the consumer perspective, SFSCs can result in fresher and higher quality products due to the shortened physical distance between producers and consumers. This can lead to increased consumer satisfaction and trust in the products (Mount, 2011). X aims to incorporate these SFSCs into their operational practices, ensuring the delivery of local and sustainable products to their customers.

1.2.2 Logistic challenges

Setting up SFSCs for X faces challenges on the logistic aspect. Existing literature recognizes that logistics is currently the main bottleneck for the development and success of SFSCs (Nsamzinshuti, Janjevic, Rigo, & Ndiaye, 2017). Paciarotti & Torregiani (2021) highlight weaknesses in SFSCs, including high logistics costs, absence of scale economies, limited product variety, and organizational challenges. They emphasize that strengthening logistics can address these issues and enhance the resilience of SFSC. This is supported by Bayir et al. (2022), which highlights the inefficiencies and excessive costs associated with the distribution process in SFSCs. The study also underscores the challenges stemming from the absence of processing and/or distribution infrastructure, as well as the difficulty of scaling up. Furthermore, Ljungberg et al. (2013) highlight that SFSCs face various challenges, including logistics costs, quality concerns, responsiveness, product availability, and regulatory compliance. Among these hurdles, logistical organization, especially in transport and distribution operations, emerges as the primary obstacle restraining the development of SFSCs.

Logistics can be defined as: “The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal, and external movements.” (CSCMP, 2013). The performance of logistics can be measured via “Logistics Performance.” Logistics performance is crucial for ensuring the smooth flow of goods and services within the supply chain and can be measured via customer service, delivery operations, freight safety and information accuracy (Wang, 2018).

1.2.3 Distribution Network Design

As mentioned, the logistical costs at X are currently high which is a result of a decline in logistical performance. The potential reason for this decline is the lack of research about the optimal “DND” of X in the operating area of Central-Brabant. DND involves strategically planning and organizing the physical infrastructure and operational components for the distribution of goods or services. This includes determining the optimal location of facilities, such as warehouses and distribution centres, as well as designing transportation routes and networks to ensure efficient and cost-effective product delivery to end customers (Ambrosino & Grazia, 2004). The positive relationship between distribution design network and logistical performance is widely regarded in the literature. Mangiaracina et al. (2015) mention that choices regarding DND have a strong impact on supply chain performance and Olhager et al. (2015) states that the design of distribution networks is critical for the competitiveness of the firm.

There is research available about SFSCs regarding DND. Paciarotti and Torregiani (2019) mention that for the success of SFSCs, actors should be aware of the strategic function of logistics. Logistic improvement opportunities that they address are innovative distribution systems, horizontal and vertical collaboration, and cooperation with researchers to provide in-depth analysis of the current situation and find and implement solutions for the bottlenecks identified. Nsamzinshuti (2017) acknowledges these solutions and mentions horizontal and vertical collaboration and the use of an online platform as solution for SFSCs. Additionally, Mittal et al (2018) executed systematic literature review and addressed three research gaps. They highlight that more research is needed on economically viable logistical solutions, data-driven support and an appropriate framework that gives guidance to practitioners of a SFSC. The current challenge of upscaling SFSCs, attributed to limited access to markets and financial resources, is highlighted by Bayir et al. (2022). They propose that SFSCs benefit from long-term plans involving infrastructure investment, supply chain restructuring, and optimization.

Todorovic et al. (2018) contributes by presenting three distribution infrastructure scenarios, in the form of business process models for SFSCs based on information and communication technology (ICT): digitized "face to face" SFSC, digitized SFSC with a logistic service provider, and a digitized SFSC with crowdsourced distribution. The selection and implementation of these solutions depend on individual cases and business conditions.

Paciarotti et al. (2022) employed a simulation model to evaluate the benefits and feasibility of a local food distribution system, which connects farmers and restaurant owners from a logistic perspective. It also explores the implementation of hybrid food hubs inside SFSC. The results show that the hub has the potential to increase local food consumption. Moreover, the simulation model offers the benefit of testing distribution scenarios in a flexible and risk-free manner. However, it is essential to note that this research is executed through computational experiments in a non-real-world setting.

1.2.4 Objective

As outlined, existing research underscores that DND is currently a barrier to the success of SFSCs. Multiple studies, including those discussed, present possible solutions to enhance the DND of SFSCs, emphasizing the relevance of understanding the optimal DND for SFSCs. Nevertheless, prior research has not conclusively addressed the optimal appearance of a DND for SFSCs or assessed its effectiveness in a practical context through a case study. While these studies provide valuable insights, there is still a need for further research to bridge the existing gaps and offer solutions for the challenges faced by SFSCs.

This research will assess the effectiveness of X's current DND by comparing it to the previous DND and simulating a volume increase to identify potential bottlenecks. Subsequently, the study will explore ways to enhance the DND, contributing to the overall improvement of the firm's logistical performance. This analysis will employ the system dynamics (SD) modeling approach to evaluate the current DND of X in Central Brabant.

1.3 Theoretical Contributions

As mentioned, research about SFSCs regarding DND has already been conducted. However, existing literature on the DND of SFSCs has not been implemented in a case setting to determine its applicability within a practical setting (Paciarotti & Torregiani, 2021; Mittal et al., 2018). Paciarotti & Torregiani (2021) suggest future researchers to assess innovative distribution models using an online platform in real-world settings. This research will examine the current DND of X, drawing conclusions about identified bottlenecks, and proposing strategies for their more effective management or elimination. The relevant variables regarding DND and their expected impact on the performance are assessed using a SD modeling approach, which facilitates the opportunity for enhancements prior to actual implementation.

Previous research presented different non-real-world settings in the form of business process models and simulation models in computational experiments (Paciarotti et al., 2022; Todorovic, et al., 2018). Paciarotti et al. (2022) focused on the introduction of a hub and concluded that the introduction of a hub can have a positive impact on transportation costs. However, the findings in this study are based on a computational setting, so no real-world data is used. As future research in this paper already suggests, specific quantitative case study is necessary to identify the key variables and boundary conditions crucial for increasing performance of the DND for SFSCs, which will strengthen the findings of Paciarotti et al. (2022) and enrich the literature. In this research the reduction of costs and lead time, while maintaining a good delivery reliability will be the main indicator of performance.

The method of this research will add to the literature as it uses a SD approach to determine improvements for the DND of SFSCs in a practical setting. SD analysis is a powerful method for framing, understanding, and discussing complex issues and problems, used for analysing systems. Advantages are the ability to evaluate cause and effect, and the possibility to investigate which structures or parameters need to be changed to improve behaviour. The use of this method can contribute to the literature by finding new behaviours and causations that can lead to the generation of new theory (Keys, 1990).

In summary, this thesis contributes to the literature by employing a SD approach in a company-based case study, utilizing simulation to analyse the DND of a SFSC. It addresses a gap in the literature by testing innovative DNDs utilizing an online platform, demonstrated through a practical case study. The analysis provides insightful perspectives before implementing modifications to the DND, identifying relevant variables and boundary conditions crucial for optimizing performance.

1.4 Managerial implications

This master thesis will not only contribute to theory but will also have practical and managerial implications. As this case study will be conducted for X, it has a strong practical value. This study will offer practitioners with a clear analysis of a SFSC and its characteristics. Additionally, the simulation model will offer valuable insights to industry related companies about the DND of a SFSC and where the main bottlenecks arise in the process. These bottlenecks represent specific areas within the distribution process where opportunities for improvement still exist. When the bottlenecks of the DND are mapped, the second part of the research will be about how these bottlenecks can be better managed or eliminated. The model and findings of this study will help X and other industry related companies to guide the decision-making process and understand the challenges of creating an optimal DND for a SFSC.

1.5 Problem statement

"How can Company X strategically modify their distribution network design to enhance logistical performance and establish an efficient short food supply chain in the Central Brabant region, based on an assessment of the current distribution network design’s effectiveness?"

1.6 Conceptual model

Figure 1, Conceptual model.

1.7 Research questions

<u>Theoretical questions:</u>

1. What defines short food supply chains?
2. How is the distribution network design of short food supply chains structured?
3. What is the impact of distribution network design on the logistical performance of a company in a short food supply chain?
4. What are the applications and benefits of employing system dynamics simulation within the field of logistics?

<u>Empirical questions:</u>

5. How is Company X's current distribution network design structured within the Central Brabant region, and how does it differ from the previous design, especially concerning the bundling of multiple short food supply chain initiatives?

6. How does Company X's distribution network design adapt to an increase in volume, and what bottlenecks emerge during this process?

7. What are the key variables impacting the performance of X's distribution network design, and how can adjustments optimize overall efficiency and effectiveness?

Chapter 2: Theoretical background

2.1 Short food supply chain

2.1.1 Definition SFSC

The definition of SFSCs that will be used is based on the definition by Bayir, Charles, Sekhari & Ouzrout (2022, p. 9): “Short Food Supply Chains are networks of connected and interdependent actors mutually and cooperatively working together to control, manage and improve the flows of information-embedded products, services, resources, and/or information, from farm to fork, seeking a reduction of intermediaries and physical distance between producers and consumers”. SFSCs offer a reliable alternative to traditional supply chains, showcasing food that embodies the qualities of “local,” “healthy”, “reliable” and “natural” (Aguiar, DelGrossi, & Thomé, 2018). These chains are based on various criteria, including the quantity of intermediaries, physical distance, knowledge exchange, locality, governance involvement and social relations between producers, processors, and consumers (Jarzebowksi, Bourlakis, & Bezat-Jarzebowska, 2020).

2.1.2 Advantages SFSC

Advantages of SFSCs can be evaluated in environmental, social and economic terms and are summarized in table 1. The interest in SFSCs has surged in recent years, driven by their potential to contribute to more sustainable food supply chains. The increased interest is a direct result of the reduced transportation involved, leading to a consequent decrease in CO_2 emissions (Canfora, 2015). SFSCs hold the potential to tackle various urgent challenges within the existing food system. These encompass issues such as environmental degradation, concerns about food safety, and the marginalization of small-scale farmers. The importance of SFSCs lies in their capacity to promote local economic development by empowering small-scale farmers and producers (Jia, Shahzadi, Bourlakis, & John, 2024).

From a social perspective reducing the number of intermediaries and consolidating activities in a specific location simplifies the complexities related to food quality and traceability within the supply chain (Sellitto, Vial, & Viegas, 2018). Additionally, during the COVID-19 pandemic the SFSC demonstrated itself to be a supply chain that is flexible and able to adapt quickly in a crisis for both producers and consumers (Usca & Tisenkopfs, 2023).

Due to the limited number of intermediaries, SFSCs are beneficial for producers from an economic perspective. SFSCs enable producers to retain a significant portion of margin that would otherwise be taken up by various intermediaries (Malak-Rawlikowska, et al., 2019). Additionally, research by Feldman & Hamm (2014) reveals that consumers are willing to pay a premium for products produced locally. Consumers express a distinct preference for local and sustainable products, drawn to their perceived advantages such as enhanced food quality, environmental friendliness, and support for local communities (Foti & Timpanaro, 2021).

Table 1, Advantages short food supply chains

Impact	**Advantages**
Economic	• Increases margin for producers • Fair prices • Less intermediaries • Support of local farmers
Social	• Increased knowledge and traceability • Behavioural change
Environmental	• Reducing transportation miles • Reduction carbon footprint • Less food waste

2.1.3 Stakeholders SFSC

As there are fewer intermediaries in SFSCs compared to conventional food systems, the number of stakeholders is reduced. Four types of stakeholders of SFSCs are distinguished by Jia, Shahzadi, Bourlakis, & John (2024):

- Farmers: play a crucial role as stakeholders in the SFSC. Recognizing and supporting farmers in this significant role is vital for enhancing resilience and sustainability in SFSCs.

- Aggregators: also hold a key position in establishing SFSCs, bridging small-scale farms with broader markets. Their role involves fostering collaboration, sharing knowledge, and building trust within the supply chain, resulting in cost reduction and more efficient operations. In the specific case study, X serves as aggregator in the supply chain.
- Retail establishment: contribute to the growth of SFSCs by showcasing local food in their stores, thereby creating a market for small-scale producers.
- Government authorities: play a crucial role in the success of local food systems by formulating policies, regulations, and support mechanisms that bolster and promote SFSCs.

It is essential to note that not all stakeholders are actively involved in every SFSC.

2.1.4 Challenges SFSC

Farmers or producers looking to distribute their products through SFSCs are usually small- to medium-scale farmers with constrained production and logistics capabilities. This limitation arises from a lack of resources, including infrastructure, capital, skills, and workforce. These deficiencies result in limited capacity and hinder effective communication to market the products. The smaller scale of these producers complicates both the initiation of a new SFSC and the enhancement of an existing one (Bayir et al., 2022; Paciarotti & Torregiani, 2021).

Even with different SFSCs needing unique solutions, people involved in SFSCs often deal with similar problems and challenges. Palomar and Cuellar-Padilla (2020) summarize the challenges of SFSCs using the following four criteria:

1. Importance of social links: In numerous cases, SFSCs involve producers collaborating to combine efforts and pursue shared interests. However, this collaboration presents challenges, including the difficulty of managing strains when making collective decisions within a cooperative structure. Another significant social aspect pertains to the customer relationship. When interactions become more transactional, customers tend to decrease order

volume and interest. Additionally, loyal customers frequently serve as advocates, endorsing the product by recommending it to others.

2. Need for diversifying the distribution channels: Private consumer orders are typically small due to household needs, prompting farmers to build extensive customer networks to meet their targets. Consequently, farmers utilize multiple SFSCs for product marketing, resulting in heightened efforts and costs.
3. Product-related constraints: Essential for the success of SFSCs is the requirement for high-quality products. Given the limited number of customers willing to pay extra for such products, producers must identify their market and adapt accordingly. Achieving this involves creating a corporate image and enhancing the format and presentation of their products.
4. Need for logistical infrastructure: Producers need a certain logistical infrastructure, which varies as a function of the type and volume of the produce itself, the need for processing, storage conditions, distribution points and relationships with consumers. Currently logistics is the main constraint to the success of SFSCs.

This study will concentrate on the final challenge: the requirement for logistical infrastructure. It will explore methods using a simulation model to enhance this infrastructure, in this research called DND, to enhance the logistic performance of X.

2.2 DND of short food supply chains

2.2.1 Definition logistics performance

As stated in the previous chapters, logistics is currently the main barrier for successful implementation of SFSCs. The definition of logistics can be described as: “The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal, and external movements.’’ (CSCMP, 2013). Kukovič et al. (2014) examined 26 definitions of logistics in the agricultural sector. They highlight that agricultural logistics includes agriculture product production, purchasing, warehousing, loading and unloading, transportation, packaging, processing, distribution and information processing. These logistical activities extend beyond mere technical services that can be optimized in isolation. In reality, they also serve as strategic coordinating mechanisms facilitating collaboration among SFSC stakeholders (Paciarotti & Torregiani, 2021).

2.2.2 Definition DND

As stated in the previous chapter, logistical infrastructure is a challenge for the success of SFSCs (Rucabado-Palomar & Cuellar-Padilla, 2020). In this research the logistical infrastructure will be defined as “distribution network design (DND.” DND entails the strategic planning and organization of the physical infrastructure and operational elements for the distribution of goods or services. This includes determining the optimal locations for facilities, such as warehouses and distribution centres, and designing transportation routes and networks to ensure efficient and cost-effective delivery of products to end customers (Ambrosino & Grazia, 2004).

An effective DND is vital for ensuring traceability in the food supply chain and plays a key role in implementing environmental strategies. Logistics strategy regarding DND is considered a critical factor for the success of SFSCs. However, local food companies often consider logistics as a secondary function and do not actively pursue the implementation of a deliberate logistics strategy aimed at enhancing efficiency (Paciarotti & Torregiani, 2021).

2.2.3 KPIs logistics performance

The performance of the DND can be measured via “Logistics Performance.” Logistic performance is a measure of both efficiency and effectiveness of a company utilized and the results compared to a goal (Mentzer & Konrad, 1991).

- Efficiency: refers to the internal function of logistics. It is recognized as the capability to deliver the desired combination of products or services at a cost level acceptable to the customer.
- Effectiveness: relates to the ability of an organization to achieve pre-defined objectives, for example meeting the requirements of customers.

Efficiency can be assessed by comparing the actual utilization of a company's resources—such as time, costs, space, units, or energy—against a standard benchmark or objective. By evaluating effectiveness of a company, cost and customer service levels need to be considered simultaneously. These criteria represent a dual goal, indicating that while it is important to minimize costs, it's equally important to maintain high levels of customer service (Mentzer & Konrad, 1991). Therefore, the main KPIs in this research are total operational costs, lead time and delivery reliability. The goal of this research is to reduce costs while concurrently maintaining or enhancing lead time and delivery reliability.

2.2.4 Customers

SFSCs are primarily identified through direct and indirect channels (table 2).
In direct channels, producers sell products directly to consumers. This can occur at markets, on-farm shops, or through online orders with home delivery or pick-up point options. This model is known as business-to-consumer (B2C). Conversely, indirect channels involve selling products through intermediaries, typically business-to-business (B2B) customers. These intermediaries can include other producers, physical retailers, wholesalers, restaurants and catering services, or online platforms and shops operated by third parties representing producer groups or product-based groups (Rucabado-Palomar & Cuellar-Padilla, 2020; Enthoven & Van den Broeck, 2021).

Table 2, Distribution channels short food supply chains

Direct	Indirect
• Markets/Fairs • On-farm shop • Online orders	• Producers • Retailers • Wholesalers • Restaurants and catering • Online platform/shop

2.3 Logistic challenges and solutions SFSCs

2.3.1 Challenges

The logistics infrastructure of SFSCs is frequently less advanced compared to industries like electronics or automotive. This is attributed to the fragmented and less efficient nature of SFSCs in contrast to the centralized distribution networks found in traditional supply chains. Consequently, SFSCs frequently face a range of challenges in transportation and warehousing.

Transportation:

Transportation-related challenges that are present in every industry are: capacity shortages, issues with contamination and security and concerns over environmental impact. Transportation in SFSCs is frequently less efficient compared to conventional supply chains, even though the food travels much shorter distances from the farm to the consumer. This is due economies of scale that can be achieved with long-distance freight movement of full truckloads. In fact, even though transport distances in conventional supply chains may be longer, the improvements in fuel efficiency per unit of product transported can offset or neutralize the negative impact of these increased distances. This is especially applicable to producers of specialty crops and niche food products, where handling and shipping costs are elevated due to the complexities of managing their movement from farm to market. The need to keep niche products separate from bulk commodities and the smaller volumes further contribute to these increased costs. Transportation inefficiencies in SFSCs become more evident at the beginning and end of the supply chain, where short and inefficient last mile routes elevate the cost of transportation per unit. Small farmers often use their own transportation to deliver the products, which leads to low volumes and less environmental impact (Mittal, Krejci, & Teri, 2018; Paciarotti & Torregiani, 2021; Todorovic et al., 2018)

Warehousing:

This includes the efficient and safe handling, packaging and storing of products. Especially for SFSCs this is important because of the perishability of products. Existing physical infrastructure designed for high-volume transactions in conventional food supply chains proves inefficient and impractical for SFSCs. Unfortunately, suitable infrastructure for small-scale producers is unavailable, posing a significant challenge for SFSCs. Thus, there is a crucial need for specialized warehousing infrastructure and supply chain models tailored to SFSCs to enhance logistics efficiency for larger volumes of regional food products. Another operational challenge for SFSCs is warehouse labour availability (Mittal, Krejci, & Teri, 2018; Todorovic, et al., 2018).

2.3.2 Solutions

SFSCs involve particular logistics solutions that hinge on the characteristics of the product, distribution system, and network. The strategic deployment of tools like supply chain re-engineering and logistics innovation is crucial for enhancing local food supply chains. Improving DND of SFSCs holds the potential to be a solution for the challenges related to transportation and warehousing as discussed (Paciarotti & Torregiani, 2021; Mittal, Krejci, & Teri, 2018).

2.3.3 Hybrid food hubs

Improvements of SFSCs can be made through restructuring the supply chain. Martikainen et al. (2014) detected the need for specialized and cost-effective logistical services that could be provided by a third-party logistics service provider, which was expressed by different chain participants of a SFSC in Finland.

This accounts for the rise of hybrid food hubs as an innovative organizational model for aggregation and distribution, with the goal of enhancing the link between producers and consumers. These hybrid food hubs incorporate physical infrastructures (e.g. logistical skills, IT management systems and contracts) and operational infrastructures (e.g. vehicle fleet, packaging equipment and storage structure) of conventional food systems. The hubs provide an extensive array of services surpassing the capacities of individual farmers, advantages of hybrid food hubs are presented in table 3. To let hybrid food hubs succeed, participants need to collaborate (Paciarotti & Torregiani, 2021). In this case X are the logistic service provider and operate the hybrid food hub.

Table 3, Advantages hybrid food hubs

Advantages of hybrid food hubs
• Facilitate cooperation and communication between producers and consumers (e.g. online platform) • Offer fair prices for farmers • Cost savings associated with storing, delivery and distribution • Can offer new distribution channels • Play an educational role by increasing awareness across supply chain • Help increase transparency

2.3.4 Hub-and-Spoke

The DND, in which X operates a central hub, is called a hub-and-spoke model. The concept behind hub location models is to centralize traffic from various origins and efficiently route it either directly or through intermediary hubs to diverse destinations, particularly on hub-to-hub connections during the longer segments of transit. This strategy aims to capitalize on economies of scale and increased truck utilization. Higher volumes facilitate economies of scale in the hub-and-spoke model, spreading fixed costs across more shipments and lowering average costs per unit of freight. This increased volume also allows for more efficient transportation utilization, enabling fuller loads and maximizing resource efficiency, resulting in reduced transportation costs and improved overall efficiency (Abdinnour-Helm, 1999; Lumsden, Dallari, & Ruggeri, 1999).

In the case of X, multiple hubs are bundled into one central hub with the goal of improving efficiency. When there is sufficient volume, incorporating more hubs can enhance cost and transportation efficiency by capitalizing on economies of scale, especially during longer transit segments (Abdinnour-Helm, 1999; Lumsden, Dallari, & Ruggeri, 1999).

2.3.5 Digitization

Existing literature emphasizes the importance of digitalization in SFSCs. Digitalization, in the form of an online platform can enhance efficiency and effectiveness among the supply chain and by the implementation of hybrid food hubs (Paciarotti & Torregiani, 2021; Burgess, 2022).

The online platform refers to a digital or physical marketplace where buyers and sellers converge to conduct transactions, typically involving the purchase and sale of goods or services. It serves as an intermediary, facilitating the exchange of products or services between multiple parties. The centralization aspect implies that the platform aggregates various buyers and sellers in one location, providing a unified space for conducting transactions. The online platform plays a crucial role in streamlining procurement processes, enhancing market efficiency, and fostering connections between buyers and sellers within a specific supply chain or market (Blind & Pohlisch, 2020).

Burgess (2022) investigated the quality requirements of online platforms. Burgess concluded that real-time data about inventory, logistics and price is necessary be. Other important requirements are the exchange of information with supply chain participants, traceability, and supplier information. In this case, X utilize their own platform to streamline processes.

2.4 Decision variables

Mentzer & Konrad (1991) mention transportation, warehousing, inventory control, order processing and logistic administration as logistic areas that can be measured to define logistic performance. However, in this case, inventory control and logistic administration are left out of scope. Table 4 outlines the decision variables crucial for defining the optimal DND of X, influencing KPIs in this study. An explanation of the variables is given below the table.

Table 4, Decision variables DND

Logistic area	Decision variables
Transportation	• Labor utilization • Number of vehicles • Vehicle type • Delivery frequency
Warehousing and order processing	• Labor utilization • Hub location • Number of hubs

Regarding transportation, the variables labour utilization and number of vehicles are related, and both refer to the quantity of vehicles employed for product transportation. More vehicles can have a positive effect on the lead time and delivery reliability but increases total costs. Variable labour and vehicle costs are related to transit- and on-stop handling time, distance and number of stops. The type of vehicle directly impacts transportation efficiency, costs and capacity. Vehicles have different capacities, speed and fuel efficiency, which impact route planning and load optimization (Mentzer & Konrad, 1991; Bayir, Sekhari, Charles, & Ouzrout, 2022). Delivery frequency indicates how often products are delivered to customers, and directly impacts vehicle utilization. Finding the right delivery frequency is essential to ensure optimal vehicle utilization and minimize transportation costs. However, lower delivery frequency affects customer satisfaction (Krämer, 2010).

As mentioned, warehouses in SFSC serve as a hybrid food hub, offering logistic service to producers and customers. Optimizing labour utilization is important because it directly impacts efficiency and operational costs. An optimized workforce can have positive effect on order processing time, but more labour leads to more costs (Mentzer & Konrad, 1991). The location of a hub is crucial because it directly impacts transportation costs, transit times, and overall efficiency of the distribution network. Strategic placement of hubs can minimize transportation distances, reduce delivery lead times, and optimize the flow of goods to and from various locations within the network. The number of hubs in a DND plays a crucial role in balancing transportation costs and service levels. While adding hubs can enhance travel time by consolidating shipments and optimizing routes, it may also lead to increased transit time due to added stops and handling procedures. Additionally, more hubs increase infrastructure and operational costs (Abdinnour-Helm, 1999; Campbell, De Miranda, De Camargo, & O'Kelly, 2015).

2.5 Simulation model-based research

2.5.1 Simulation model

This thesis will use a simulation to model changes to the DND and test different scenarios. Studies conducted by Akkermans (1995) and Davis-Sramek and Fugate (2007) revealed a growing advocacy among companies and academic researchers for increased research based on simulation models in the field of logistics.

Simulation encompasses a diverse range of methods and applications designed to replicate the behaviour of a real-world situation in a computer-based model. They excel in addressing uncertainty and are widely applied to challenges demanding simultaneous consideration of both time and space integration (Davis-Sramek & Fugate, 2007). Previous literature addresses the advantages of a simulation model. Primarily, a simulation model affords the opportunity to experiment with diverse scenarios and asses the results of making various adjustments in the variables under examination. Furthermore, a simulation can be replicated and fine-tuned multiple times without influencing the actual situation in the real world or causing disruptions in real processes (Disney, Naim, & Towill, 1997).

The benefits of process simulation are particularly valuable in the field of logistics and DND. In the logistics sector activities are closely related. For instance, if products are not collected and delivered to the hub on time, it can lead to delays in subsequent activities like order picking and outbound transport. Process simulation allows researchers to model the entire situation, revealing insights that would go unnoticed using other methods (Davis-Sramek & Fugate, 2007). In particular, simulation allows for the assessment of a design's scalability and facilitates the comparison of multiple designs in a computational environment to identify the most effective one. Additionally, as noted, simulation enables the adjustment of decision variables, such as delivery frequency, number of vehicles, and capacity, and allows for the testing of the impact of these adjustments in different scenarios on the system and the identification of boundary conditions (Aguado, Astorga, & Matias, 2010). Interesting is how these adjustments impact logistics KPIs as costs, lead time, delivery reliability and utilization (Dybskaya & Sverchkov, 2017).

To make use of these benefits, constructing the model with a high degree of reliability is crucial to ensuring that the conclusions drawn can be applicable to real-world scenarios. Sterman (2002) argues that all models that are created are wrong, however, the objective of validation is to attain a model that is grounded in objective truth. Barlas (1996) opposes the idea that a model should solely consist of formal and objective elements to fulfil its specific purpose, because no case can completely incorporate by only truth. Barlas (1996) emphasizes the importance of gradually building confidence in the model. Regardless of the debate over the precise definition of validation, there is a widespread consensus that constructing a model should be approached with care, emphasizing reliability and adhering to a structured method of model development.

2.5.2 SD modeling

A Causal Loop Diagram (CLD) is a visual tool used to illustrate the causal relationships among variables in a complex system. It helps to understand how changes in one variable can affect others, allowing for the identification of feedback loops and potential interventions to improve system behaviour (Dhirasasna & Sahin, 2019). CLD can illustrate the cause-and-effect relationships within X's DND processes, providing a foundation for developing a formal SD model for simulation analysis. This approach aligns with the objectives of this research. SD model analyses facilitate theory expansion by exploring a broader array of scenarios beyond those observed in empirical cases, while also identifying boundary conditions (Fang, van der Valk, Vos, & Akkermans, 2023).

Abbas & Bell (1994) argue that SD can contribute to transportation modeling, SD offers several key advantages in transportation modeling. Firstly, it provides a logical and detailed representation of complex transportation systems, explicitly considering dynamic feedback interactions between supply and demand. Second, SD facilitates the development of experimental transport tools, allows for tracing short and long-term behaviour of transport systems, and supports identification of controls for system improvement, all at a low cost and with ease of updating. This research will choose SD modeling over discrete event and agent-based modeling because it has the ability to model complex, dynamic systems with simpler equations. This allows for easier interpretation and understanding of the model, making it more accessible to stakeholders involved in the DND process. Additionally, a advantage of SD is its ability to capture continuous changes and feedback loops within the system. SD models allow for a holistic understanding of how several factors interact and influence the overall behaviour of the distribution network over time (Greasley, 2009; Borshchev & Filippov, 2004).

2.5.3 Existing simulation research

Research on simulation within the context of SFSCs is limited, with only a handful of studies utilizing simulation methodologies about improving DND.

Paciarotti et al. (2022) used computer-generated randomized spatial network simulation to detect the viability and advantages of a hybrid food hub that establishes connections between farmers and restaurant owners, focusing on logistics considerations. In order to compare various distribution scenarios, they created a simulation model to evaluate the results of these different scenarios. Results state that the introduction of a food hub positively impacts travel distances and transportation costs, which highlights the benefits of collaboration for SFSCs. This research will strengthen the research of Paciarotti et al. (2022) by determining the key variables and boundary conditions crucial for increasing performance of the DND of SFSCs in a real-world setting, as proposed in their study.

Bayir et al. (2022) developed an agent-based model on a simulation platform, which can be used to seek performance improvement strategies for a SFSC of a particular case study. They created a simulation model and will model different scenarios and evaluate their effects on KPIs related to performance of the DND. These KPIs are: demand, capacity, service and operational efficiency. However, while this study sets the foundation for offering decision support to practitioners at the strategic and tactical levels, it does not directly simulate a real-world scenario. Therefore, this thesis aims to enhance the research of Bayir et al. (2022) research by utilizing decision variables and KPIs that are proposed to develop a SD-based model, seeking strategies for improving the performance of SFSCs.

Cramer & Fikar (2023) used a decision support system based on agent based and DES modeling to study the use of a crowd logistics platform for local food distribution. Crowd logistics utilizes spare logistics capacity, such as non-professional transportation, through information technology platforms to integrate online deliveries into existing trips, enabling cost savings and extended market reach. Crowd logistics serves as a concept to reduce transportation costs, this thesis however takes a different approach by focusing on identifying key variables and boundary conditions for improving the DND of the SFSC of X using a SD approach.

Chapter 3: Methodology

3.1 Research nature

3.1.1 Research design

To build theory on the examination how the DND of X can be modified to improve logistical performance, this research will adopt a mixed-method approach, combining longitudinal case-study with formal modeling and simulation analysis (Creswell, 1999).

In this study, the theory emerges from the interplay between existing literature and empirical findings, reflecting the flexible and exploratory nature of abductive reasoning. This involves connecting empirical observations gathered via interviews and company data to the literature to develop theories (Kovács & Spens, 2005). Subsequently, this gathered theory is captured in a CLD and translated in a SD model to be used for simulation analysis. Simulation modeling can help in theory building by allowing researchers to test scenarios and boundary conditions in complex, dynamic systems, thereby refining and advancing existing theories or generating new ones (Disney, Naim, & Towill, 1997).

The unit of analysis of this study will be X's DND in the Central Brabant region. This encompasses the interconnected components of the supply chain, including producers, distributors, the hub, logistical operations, and consumers. The time horizon of this study is from February 2024 to late May 2024.

3.1.2 Case study

This study uses a case study, which involves an in-depth examination of a single instance or phenomenon within its real-life context, aiming to provide rich and detailed insights into complex issues or phenomena (Yin, 2009). In instances where theory exists but fails to address the specific research question, case studies prove to be a well-suited method for gaining valuable new insights (Eisenhardt, 1989). By employing this method of transitioning from literature with broad applicability to a case-specific context, concerns regarding the extent to which the conclusion can be generalized can be minimized (Aastrup & Halldórsson, 2008). A case study is well-suited for this research due to the distinctive nature of establishing a SFSC for X in the Central Brabant region, and enables to delve deeply into the unique dynamics, challenges and opportunities in setting up a SFSC. Additionally, given the practical nature of this research, a case study offers the opportunity to have a direct applicability to industry practices, aiding practitioners and policymakers in making informed decisions (Eisenhardt, 1989).

3.1.3 Research approach

As elaborated in the literature review, this study will use a simulation model based on SD to model the DND of X, and gain insights into policies that positively impact logistic performance. Since the model is a simplification of the reality, it is based on assumptions which could lead to inaccuracies (Sterman, 2002). To ensure both reliability and validity, it is essential that the model-building process follows a structured approach (Barlas, 1996). The participative modeling approach proposed by Akkermans (1995) serves as a valuable framework to guide this research, providing structure to the process and enhancing the validity of the resulting model. This thesis will use this participative modeling approach and follow the prescribed project phases for data collection. The participative modeling approach has four phases as presented in table 5.

Table 5, Phases of participative modeling approach

Phase	**Explanation**
Project definition phase	The objective, scope, and stakeholders of the modeling project are identified and defined, along with the examination and identification of the processes within the case company.
Model conceptualization phase	The conceptual model is formed based on literature review and elaborated with interviews and company data
Modeling formalization phase	The formal simulation model is built based on the conceptual model and validated to ensure its accuracy and relevance
Knowledge dissemination phase	The validated model is used to explore scenarios and boundary conditions to generate recommendations

3.2 Research process

As mentioned, the participative modeling approach of Henk Akkermans (1995) will be used for this study. Based on the four phases, this study aims to develop both a qualitative- and quantitative model. These phases outline the activities and steps involved in gathering the necessary data.

3.2.1 Project definition phase

During the project definition phase, the groundwork for this research is established. Firstly, the emphasis was on getting familiar with the organization and processes of X. This approach enables a thorough understanding of the context surrounding the presented problem and determining the key KPIs that resemble the performance of the DND of X, in this case costs, lead time and delivery reliability. After that, clear boundary conditions to the project looking at constraints, such as scope, data- and resource availability and time horizon are determined. Additionally, the research problem is formulated and a problem statement and theoretical- and empirical research questions are established.

Finally, to get familiar with the problem, the key KPIs and relevant variables, a literature review will be conducted. This literature review consists of desk research to formulate an answer on the first three theoretical research questions. The aim of the theoretical questions is to gather insights from previous research, which lays the foundation for addressing the empirical questions. Relevant variables and policies for the DND of X are obtained from the literature and processed in the conceptual model.

3.2.2 Model conceptualization phase

In the model conceptualization phase the qualitive model will be developed, in the form of a CLD. A CLD gives a clear understanding of the variables and causal relationships that impact the costs and lead time of the DND, as explained in the theoretical background. Qualitive data, in the form of an interview, observations and company data, has been gathered to build the qualitive model. The interview took place at the start of the research to get familiar with the problem and organization of X as explained in the project definition phase. The interview was semi-structured, which provided the flexibility to explore complexities of the subject matter while maintaining a degree of structure in questioning (DiCicco-Bloom & Crabtree, 2006).

The interview was conducted with the owner and operational manager of X, at their office. Because the interview was of a exploring nature, a strict coding scheme is not employed in analysing the interview data, but the transcript can be found in Appendix 1. After the interview, a guided tour was given through the hub which led to firsthand insights and understanding of the organization's operations. Based on this qualitive data a list of key variables and causations can be created.

The qualitive data in combination with the theoretical background led to the development of the causal loop diagram (CLD). The CLD is constructed using the computer program Kumu.io, which is specifically designed for creating CLDs and offers robust features for this purpose, making it a suitable choice.

The conceptual model determines the structure of the simulation model, and therefore is a crucial step. To make a valid and reliable analysis, it is of high importance that the simulation model corresponds to the real situation. This structure validity can be evaluated using direct structure test (Barlas, 1996). To ensure structure validity, the relationships in the conceptual model will be verified and compared against existing knowledge.

3.2.3 Model formalization phase

Fang, van der Valk, Vos, & Akkermans (2023) argue that the intrinsic limitation of the CLD is the qualitive and conceptual nature, because there are no ways to argue that the behaviour generated by the CLD is inherent consistent. Therefore, to evaluate this consistency, a SD simulation model is developed from the CLD. The SD simulation model allows to test practical scenarios with numerical inputs, as explained in the literature review. To translate a conceptual CLD into a formal model, relationships need to be made explicit and thus suggests many formalization choices (Fang, van der Valk, Vos, & Akkermans, 2023).

This simulation model will be made using the computer program Silico. Silico is a simulation and modeling tool which can be used to analyse complex systems and processes. SD models in Silico utilize three key elements: variables, flows, and stocks. A variable in SD modeling represents a dynamic factor or parameter that changes over time and influences the behaviour of the system being modeled. flows represent the rate of movement or transfer of quantities between stocks, while stocks represent the accumulations or reservoirs of quantities within the system over time

(Sterman, 2002). Implementing the conceptual model with the quantitative values in Silico enables to replicate real-world behaviour. However, since all models are wrong, ensuring the validity of the model is essential to draw meaningful conclusions, this will be discussed in the model formalization phase (Sterman, 2010).

After formalizing and analysing of the conceptual model, it is essential to obtain the necessary data for quantifying the variables. This quantitative data, like average lead times, costs and number of suppliers and customers, will be retrieved via multiple data sources from X and assigned to the relevant variables within the conceptual model. The type of data and how this data is retrieved is presented in table 6. The majority of data is acquired from the interview, available Excel files and historical data from the routing app "Circuit."

Table 6, Data sources

Data	**Data Source**
- Suppliers number & location	Excel: Shared Transport
- Average demand - Hub fixed costs - Average crates per order - Wages - Number of pick-up points	Excel: Hub Brabant Financial Plan
- Order process time - Delivery days - Fuel consumption - Vehicle type, number, capacity and fixed costs - Number of employees hub - (un)loading time	Interview with: - General manager - Operational manager Observation: - Company tour
- Routes, collecting and delivery lead times - Avg. km per stop - Avg. time per stop - Number of inbound stops	App: Historical routes in Circuit
- Traffic congestion	(Christidis & Rivas, 2012)

During the model formalization phase, important model building decisions are discussed and aligned with the stakeholders to improve reliability and validity of the model. This is based on an iterative process in which the model is adjusted and improved.

After the model is initialized and verified with the stakeholders, it must undergo further validation. The process of creating a valid model is based on the research of Barlas (1996) and Sterman (2010). This validation process consists of two parts, behaviour correctness and sensitivity analysis. Behaviour correctness in simulation modeling refers to the accuracy of the model in replicating the expected behaviours of the real-world system, and therefore is related to the structure of the model. As mentioned, mistakes in the structure can lead to incorrect outcomes. To prevent this an extreme condition test, and validation analysis will be performed. An extreme condition test involves subjecting the model to scenarios or conditions that are at the limits or extremes of what is expected in the real world. By observing how the model responds to these extreme conditions, analysts can assess whether the model behaves correctly under both normal and extreme circumstances. This validation technique provides insights into the model's validity and robustness, ensuring that it produces reasonable results even under extreme conditions, thereby enhancing confidence in its practical utility. The aim of the validation analysis is to compare real-world data with the output of the model, thereby validating its accuracy and reliability (Barlas, 1996).

When the behaviour correctness of the model is determined, a sensitivity analysis will be performed. A sensitivity analysis is necessary to assess the robustness of a model and understand how changes in input variables affect the output. It helps identify which variables have the most significant impact on the results and which are less influential. By conducting sensitivity analysis, researchers can gain insights into the model's behaviour under different conditions and make informed decisions based on varying scenarios (Sterman, 2010). The variables that significantly impact the output require more attention and validation before drawing conclusions.

3.2.4 Knowledge dissemination phase

The knowledge dissemination phase starts after the model is initialized and verified with the stakeholders and all the further validation checks are completed. In this phase a scenario analysis will be performed. The scenario analysis assesses the effects of adjusting key variables on delivery reliability, costs and lead time. Conclusions aimed at improving X's DND can then be drawn from the simulation data and effectively communicated

3.5 Reliability and validity

Yin (2019) proposed four benchmarks for evaluating the trustworthiness of a qualitative case research design: reliability, construct validity, internal validity and external validity.

3.5.1 Reliability

Reliability in research refers to the consistency and stability of measurements or findings obtained through a specific research method or instrument. It ensures that the results are replicable and trustworthy, regardless of who conducts the study or when it is conducted (Yin, 2009).

This study was performed using the participative modeling approach of Henk Akkermans (1995). This participative modeling approach consists of four phases, each playing a crucial role in shaping the study and structuring the research process. Additionally, triangulation contributes to the reliability of this research and increases the probability that the same results are obtained when redoing the study (Riege, 2003). Finally, documentation about the model decisions and assumptions is provided, which contributes to transparency.

3.5.2 Construct validity

Construct validity involves the extent to which the operationalization of variables accurately reflects the theoretical concepts or constructs being studied, ensuring that the measures used actually assess the intended constructs (Yin, 2009).

To ensure the validity of the constructs in this research, first a thorough literature review was conducted. In this literature review the concepts, operational measures and challenges (network, transportation, costs and efficiency) of the main topics, SFCSs and DND, are defined. Additionally, three data sources of evidence were applied, interview, observation (e.g. company tour) and archival documents (e.g. Excel sheets, process schemes, historical routing data), which contributes to the validity of the constructs (Riege, 2003). The transcript of the interview was shared with the interviewee to avoid wrong interpretation by the interviewer. During the research period, stakeholders were provided with reports, facilitating the acquisition of feedback.

3.5.3 Internal validity

Internal validity refers to the degree to which the observed effects in a study can be confidently attributed to the intervention or treatment being studied, rather than to other factors. It involves controlling for potential confounding variables and establishing a causal relationship between the independent and dependent variables (Yin, 2009).

As addressed in the model conceptualization phase, to examine the validity of relationships between variables in the model, a direct structure test will be performed. This direct structure test verifies the causal connections between variables and assessing whether they align with the underlying theory (Barlas, 1996).

It is worth mentioning that the simulation model includes several assumptions, which are inevitable because not all data can be precisely replicated. To ensure the validity of these assumptions and the overall operation of the model, multiple meetings and discussions were held with the general and operational managers of X to gather their insights on the model's inputs and outputs. Additionally, to test the validity of the simulation model, an extreme condition test, validation analysis and sensitivity analysis will be performed, to identify potential weaknesses and to ensure that the model behaves appropriately across a wide range of conditions, as addressed in the model formalization phase, which increases internal validity (Barlas, 1996; Riege, 2003).

3.5.4 External validity

External validity relates to the generalizability of the study findings beyond the specific context or sample under investigation. It involves assessing whether the results of the study can be applied to other populations, settings, or conditions, thus enhancing the broader relevance and applicability of the research (Yin, 2009).

External validity in simulation modeling case research can be assured by ensuring that the simulation model accurately represents the real-world system it is intended to simulate, which has been done via sensitivity- and scenario testing and the validation analysis. Additionally, the model is validated with empirical data and expert judgment, which further enhances its external validity (Riege, 2003). This study uses parameters that are extracted from company data of X, therefore some results can be company specific. However, the findings from this study can offer valuable insights for practitioners operating within a comparable SFSC environment and want to improve their DND.

Chapter 4: Findings

4.1 Project definition

The first phase of the participative modeling approach involves project definition. This encompasses formulating the problem and providing background context, detailed in the introduction of this thesis. Subsequently, the literature review is conducted, building upon the problem formulation and establishing the theoretical background of this research. This results in three KPIs that reflect the performance of the DND of X: costs, lead time and delivery reliability.

4.1.1 Research context

The current DND can be explained via the use of a process scheme which can be found in Appendix 2, with more explanation about the process in Appendix 3. Currently X utilize two distribution channels: business to business (B2B) and business to consumer (B2C), matching advised theory (Rucabado-Palomar & Cuellar-Padilla, 2020). Examples of B2B customers include restaurants, retailers, hospitals and schools. B2C customers are individuals who purchase products or services directly for personal use (Manager & Manager, 2024).

X utilizes an online platform to manage its distribution channels, which is crucial for enabling real-time communication, data sharing, and collaboration among stakeholders, thereby enhancing efficiency, transparency, and responsiveness (Blind & Pohlisch, 2020; Manager & Manager, 2024).

4.1.2 Problem

As indicated in the introduction of this thesis, SFSCs often find it difficult to scale-up. SFSCs often lack the infrastructure needed for large-scale distribution, storage, and processing. Building or expanding infrastructure to accommodate increased volume can require significant investment and time. Scaling up SFSCs requires efficient logistics to ensure timely delivery of fresh products to consumers. However, coordinating transportation, storage, and delivery logistics for a larger scale operation can be complex and costly, particularly in rural or remote areas (Bayir, Charles, Sekhari, & Ourzrout, 2022).

X made a first step in scaling-up the SFSC in the Central Brabant region, by bundling the logistics of multiple SFSC initiatives. Previously, these SFSC initiatives operated independently, each with its own hub, vehicles, and online platform. Started on February 1st, 2024, X function as logistics service provider for this initiatives, operating a hybrid food hub, which implies that X manage the online platform facilitating transactions between farmers and customers, organize transportation, and consolidate and process orders (Paciarotti & Torregiani, 2021). As highlighted in the literature review, bundling volumes can enhance efficiency by leveraging economies of scale, optimizing resource utilization, and streamlining routing processes (Abdinnour-Helm, 1999). By recreating the current DND of X and comparing it to the previous DNDs of the SFSC initiatives, one can draw conclusions regarding the impact of bundling on logistical performance, which will be evaluated in the knowledge dissemination phase.

The initiative targeting B2B customers has been excluded from the analysis due to data scarcity. The other three initiatives, which focus on B2C customers, will be compared to the new bundled DND. Approximations of the data of the SFSC initiatives is presented in table 7. All three initiatives used a single vehicle for transport, similar to the Mercedes. Additionally, each initiative operated with deliveries occurring once per week. The operational processes of all the initiatives are identical and match those of X. Therefore, it is assumed that the values of the variables are the same.

Table 7, Specific data of short food supply chain initiatives

Initiative	**Avg. Weekly Customers**	**Inbound transport stops**	**Customers per pick up point**
Initiative 1	5.5x	15-25	1-10
Initiative 2	8.2x	15-25	5-15
Initiative 3	12.2x	15-30	0-8

X expects to grow in the coming years. Given the challenges that SFSCs typically face when scaling up, they are keen to determine the resilience of the current DND to accommodate this increase in volume. Identifying potential bottlenecks is crucial in this regard (Bayir, Charles, Sekhari, & Ourzrout, 2022). This can be modelled by recreating the current DND of X and add an increase in volume through the SFSC. After identifying when and where bottlenecks occur, scenarios can be tested to evaluate potential solutions and optimize the DNDs efficiency and effectiveness. This can be achieved by modifying the decision variables identified in the literature research, including delivery frequency, vehicle type, the number of vehicles, and the number of hub employees (Mentzer & Konrad, 1991).

Given the uncertainty surrounding the volume increase, it would be beneficial to explore whether the current DND of X can be enhanced even in the absence of a volume increase. Currently, X have three delivery days, from which two are for B2B customers. Because logistical costs due to transportation are high, it could be beneficial to test if the delivery days could be reduced. The consolidation of volume from two days can result in increased vehicle utilization on the single delivery day, consequently lowering transportation costs per product (Krämer, 2010). This effect will be examined in scenario analysis.

4.2 Model conceptualization

At the start of the model conceptualization phase, the CLD will be presented. Subsequently, the variables that engage in the DND of X, and presented in the CLD, will be specified.

4.2.1 Causal Loop Diagram

The CLD presented in figure 2 presents a comprehensive framework of the relevant variables and relationships regarding the performance of the DND of the SFSC. An overview of the variables and their definitions is presented in Appendix 4. The CLD is constructed based on insights obtained from the literature review, and further enriched with insights from interviews and observations, resulting in a reliable model. To ensure the validity of the conceptual model, a direct structural test is conducted, summarizing empirical and theoretical evidence supporting the relationships (Barlas, 1996). Details about this direct structure test can be found in Appendix 5. For clarity, the CLD is also presented in a page-size format in Appendix 6. The CLD does not differentiate between the B2B and B2C processes for the sake of visual clarity, as both processes can be effectively represented by this conceptual model.

As explained in the methodology chapter, the variables are identified via academic literature, observations and via an interview. In the theoretical background, Chapter 2, already some variables are introduced based on the literature. However, these are not all the variables involved, and further extension is needed to provide a picture of the whole situation. This extension is grounded in the key areas by which the performance of the DND can be measured: transportation, warehousing and order processing (Mentzer & Konrad, 1991). The extension, which presents the definitions of variables and relationships, is provided in Appendix 7.

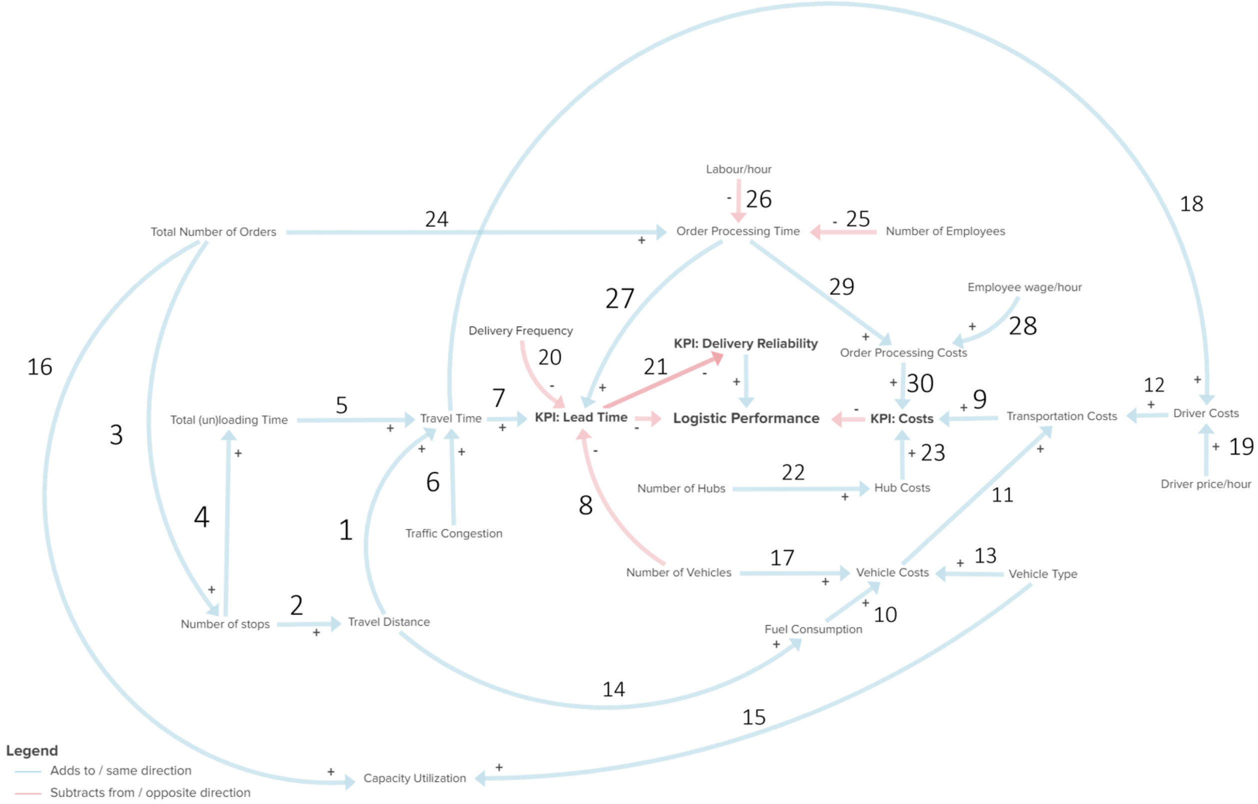

Figure 2, Causal Loop Diagram

4.3 Model Formalization

4.3.1 Quantify variables

The first step in in developing a formal simulation model, is to quantify the variables and relationships from the conceptual model. This involves deriving numerical values from reliable data sources. In cases where such data is scarce, judgmental parameter estimation methods are employed for certain input variables. Judgmental parameter estimation assigns values to parameters based on expert judgment, qualitative information, and experiential knowledge instead of formal statistical techniques. It is used when numerical data is limited, unavailable, or when statistical estimation is challenging due to system complexity (Sterman, 2010). A formal model typically consists of input parameters and variables that are dependent on these input parameters. Input parameters represent the factors or conditions that influence the behaviour of the model, while variables are the quantities or characteristics that are computed or observed as outputs of the model (Sterman, 2010). In Appendix 8, a brief description of the input variables and their calculation can be found.

4.3.2 Formalizing model

After collecting the data to quantify the variables and relationships in the conceptual model, the computer-based simulation model is thoroughly constructed using the Silico computer program. The model is crafted to simulate one week of operational activities at X. The number of operational days in this week is determined by the input variable "delivery days." The model differentiates between the B2B and B2C processes, with all calculations based on a single delivery window. This enables precise modeling of the lead time, associated costs, and delivery reliability of the delivery window. The base model reflects the current situation of X, with input parameters set as of February 1st, 2024. The date when X began utilizing the hub. An image of the computer-based simulation model is made visual in Appendix 9. Additionally, sub-models are made that represent the SFSC initiatives in the old situation. The images of these sub-models are presented in Appendix 10. The calculations of all the variables, flows and stocks are included in Appendix 11. A link to the model in Silico is presented below:

https://silico.app/@mjvanparidon/the-food-directors?s=zZdrqmrKQzugzNZ_bD3G7A

4.3.3 Extreme condition test

In accordance with the methodology chapter, validation checks are imperative to ensure the accuracy of the model. Fang, Lim, and Qian (2018) introduce various methods of formal model validation.

First the behavioural correctness of the model will be validated by performing an extreme condition test. The aim of this test is to verify if the model responds accurately to real-world scenarios, even when subjected to extreme conditions (Barlas, 1996; Sterman, 2010).

To assess if the model behaves correctly when under extreme conditions, the following problems were solved, which showed the importance of the extreme condition test:

1. Upon entering an extreme value of 10,000 for customers into the model, it became apparent that the number of crates collected and delivered from suppliers and to customers was not accurate. This discrepancy arose due to the additional trip time, which was subsequently resolved.
2. Upon entering extreme values of 0 for customers, vehicles, delivery days and number of employees into the model, crates continued to be collected and processed inaccurately. This issue was resolved by implementing the if-then-else function.

4.3.4 Validation analysis

The second formal validation method is the behavior test, which examines whether the model replicates real-world outcomes. This involves comparing the model's output to actual historical results (Fang, Lim, & Qian, 2018).

Throughout the period from February 1st to March 31st, 2024, Company X maintained a delivery reliability of 100%, ensuring that all orders were delivered on time. This aligns with the findings reflected in the simulation output (table 8).

Table 8, Actual vs simulated average delivery reliability

	Actual average	Simulated average
B2B delivery reliability	100%	100%
B2B delivery reliability	100%	100%

Lead time plays an important role in this research, because deadlines are present in the process, and it impacts delivery reliability. Figures 3 and 4 show the difference between the actual and simulated total lead time for the B2B and B2C process. This is the average total lead time from the two B2B delivery days. The figures illustrate the variance between the actual and simulated total lead times. This dataset spans a period of 9 weeks, from February 1st to March 31st, 2024.

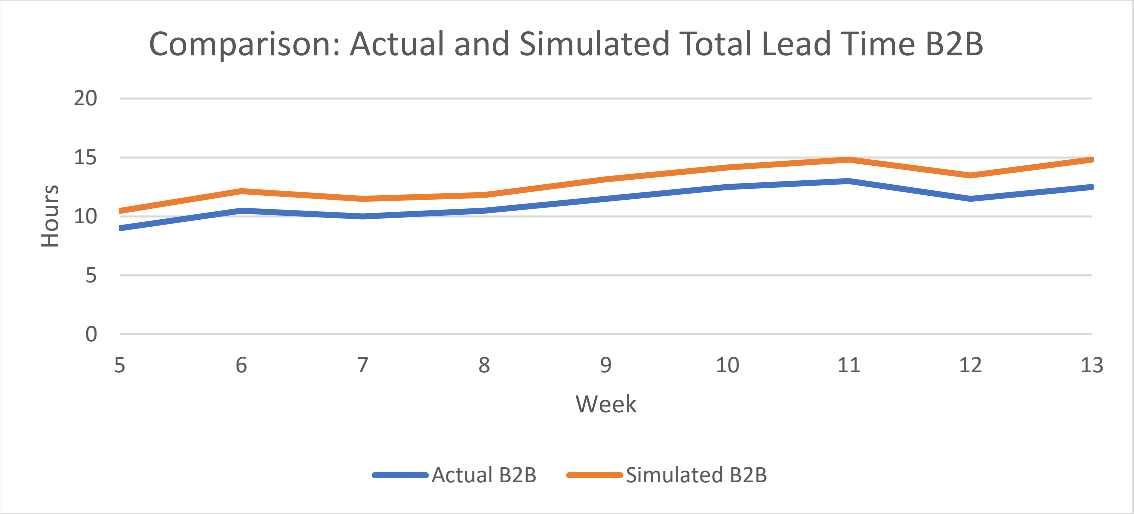

Figure 3, Comparison of actual and simulated total lead time B2B process

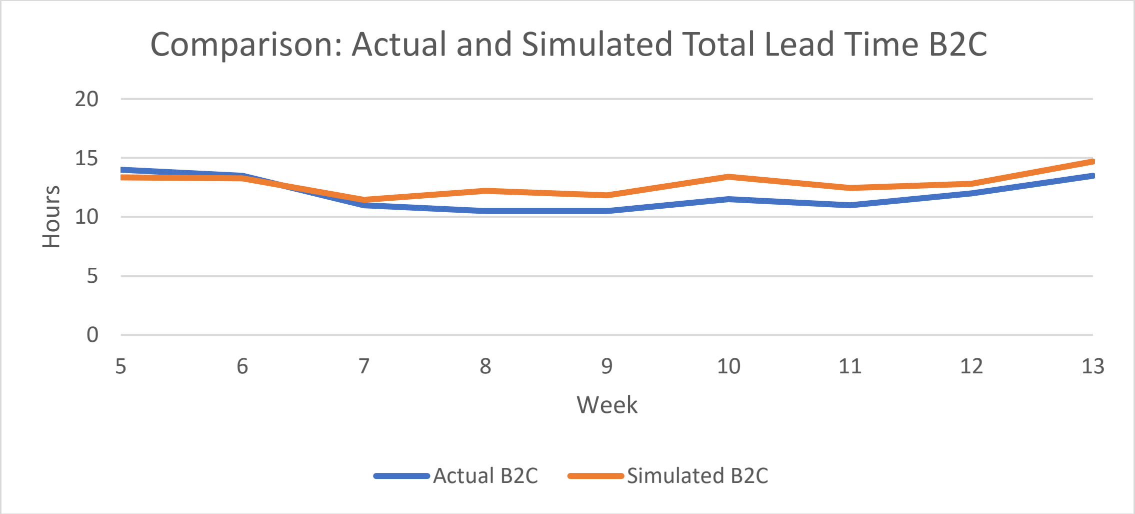

Figure 4, Comparison of actual and simulated total lead time B2C process

Table 9 illustrates the variance between the actual average lead time and the simulated lead time of both the B2B and B2C processes. This difference can be traced back to certain farmers delivering their products to the hub off the record during this period, which led to a decrease in inbound travel time. However, this aspect was not incorporated into the model, as Company X intends to optimize the process by managing all product collections internally.

Table 9, Actual vs simulated average lead time

	Actual average	**Simulated average**
B2B total lead time	11.2	12.9
B2C total lead time	11.9	12.8

Another important KPI in this research is total operational costs, which consist of fixed and variable components. The fixed costs are associated with vehicles and the hub, while the variable costs are primarily influenced by lead times throughout the process—longer lead times result in higher variable costs. Analysing costs is a valuable KPI for evaluating the effectiveness of different scenarios. The difference between the actual and simulated data is evident in figure 5. Both the figure and table 10 demonstrate that the actual costs lie lower than the simulated costs. This discrepancy can be attributed to the same factor influencing the difference in lead time: off-the-record practices. However, the figure depicts a trend that aligns with the lead time graphs, suggesting that the model behaves correctly.

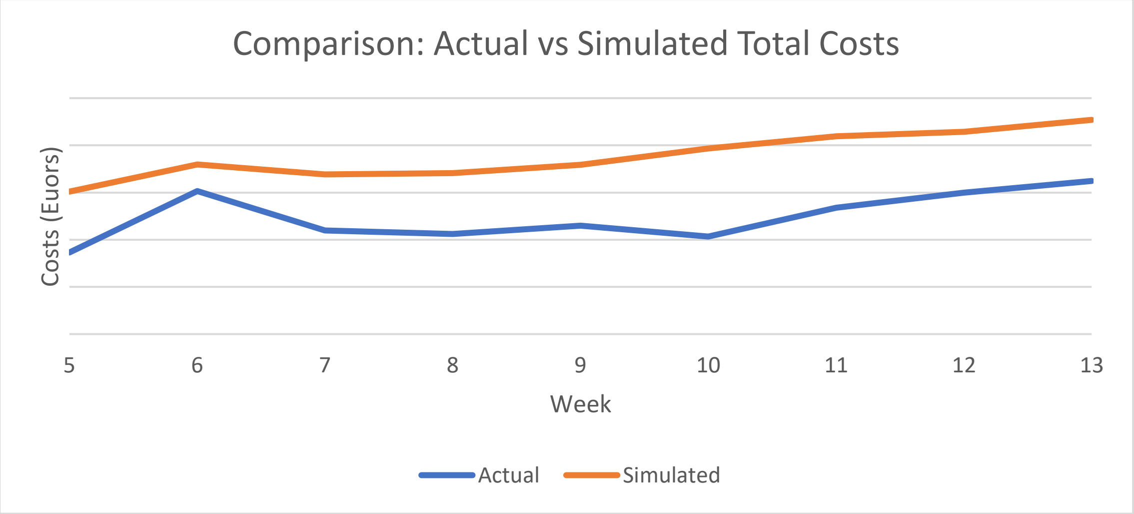

Figure 5, Comparison actual vs simulated operational costs

Table 10, Actual vs simulated average total operational costs

	Actual average	**Simulated average**
Total operational costs	€699x	€751x

4.3.5 Sensitivity analysis

The final validation method to be employed is sensitivity analysis, a structure-oriented behavior test (Fang, Lim, & Qian, 2018). The sensitivity analysis will identify the variables to which the KPIs of the system, lead time, costs and delivery reliability are highly sensitive. The sensitivity analysis is conducted based on the last step of the simulation (December 28, 2028, in the model). For this analysis, it is assumed that the current volume remains unchanged. The sensitivity of these base case input variables will be assessed by adjusting their values up and down by 25%, while keeping all other input variables constant. In the sensitivity analysis, all 32 input variables are analysed.

Most of the variables had minimal impact on the KPIs, however, some had more impact. The variables with medium or high impact in combination with variables with medium or high uncertainty are shown in table 11. This table includes the decision on whether to enhance the accuracy of the variable, as determined by the sensitivity analysis. This decision is made in cooperation with the general manager and operational manager of X. During this discussion, the model was also entirely assessed by the general and operational manager to see if the model behaves correctly and accurate, which enhances validity. This discussion led to the gathering of additional data regarding the average number of customers and the average time per stop, as explained in table 11. The variables that are the same for B2B and B2C are combined in this table (e.g. avg. number of customers, avg. order quantity). The entire sensitivity analysis is added in Appendix 12.

Based on this analysis, it is evident that reducing the number of stops and enhancing order processing speed can positively impact the KPIs (table 12). Therefore, it is wise to identify and implement solutions to improve these factors, a task that can be addressed in future research directions.

Table 11, Variables with medium/high impact and medium/high uncertainty

Variable	**Impact**	**Uncertainty**	**Decision**
Avg. number of customers	High	Medium	This value was extracted from the Excel file “Hub Brabant” provided by X. This was checked with the general manager, and changed for real time order data, because this was now available.
Avg. order quantity	Medium	Medium	This value is based on data provided by X. This was checked with the general manager, and not changed.
Bus (un)loading time	Medium	Medium	The average bus (un)loading time is checked with the operational manager and confirmed again. Therefore, it remains unchanged.
Avg. number of stops inbound	High	Medium	After discussions with the general manager of X, it was decided to keep this number unchanged, as these are the suppliers X aim to grow with.
Avg. time per stop	High	Medium	This value is checked with the operational manager of X, and after receiving more data the avg. time per stop was raised to 16.87 minutes.
Avg. customers per pick up point	Medium	Medium	This value is extracted from the Excel file “Hub Brabant” provided by X. The value is checked with the general manager of X and confirmed again. Therefore, it remains unchanged.
Order process speed employee	High	Medium	After discussion with the operational manager, this value was changed from 10 to 11, which more accurately captures the order process speed.

Table 12, Significant variables

				Difference in percentage			
Variable	**Unit**	**Run**	**Value**	**Lead time B2B**	**Lead time B2C**	**Costs**	**Delivery reliability**
Avg. customers per pick up point	Pick up points	Base	10,00	0,00%	0,00%	0,00%	0,00%
		-25%	7,50	-0,13%	6,03%	1,22%	0,00%
		25%	12,50	0,00%	-10,45%	-1,97%	0,00%
Order process speed employee	Crates/hours	Base	11,00	0,00%	0,00%	0,00%	0,00%
		-25%	8,25	5,27%	7,33%	6,12%	0,00%
		25%	13,75	-9,15%	-13,31%	-10,84%	0,00%
Number of stops inbound	Stops	Base	32,00	0,00%	0,00%	0,00%	0,00%
		-25%	24,00	-11,57%	-16,00%	-7,70%	0,00%
		25%	40,00	25,80%	23,80%	13,35%	0,00%

Table 13 shows the variables that have high impact and low uncertainty. These key variables can be adjusted by X to enhance the performance of the DND and align with the decision variables identified in the literature review. These variables will be used for testing in the scenario analysis.

Table 13, Key variables

				Difference in percentage			
Variable	**Unit**	**Run**	**Value**	**Lead time B2B**	**Lead time B2C**	**Costs**	**Delivery reliability**
Delivery days B2B	Days	Base	2,00	0,00%	0,00%	0,00%	0,00%
		-25%	1,50	14,49%	0,00%	-5,30%	0,00%
		25%	2,50	-27,67%	-1,28%	9,64%	0,00%
Delivery days B2C	Days	Base	1,00	0,00%	0,00%	0,00%	0,00%
		-25%	0,75	0,00%	14,53%	-2,14%	0,00%
		25%	1,25	0,00%	-27,77%	4,48%	0,00%
Number of Renault	Vehicles	Base	1,00	0,00%	0,00%	0,00%	0,00%
		-25%	0,75	10,62%	9,82%	-2,29%	0,00%
		25%	1,25	-23,17%	-20,99%	4,40%	0,00%
Number of Mercedes	Vehicles	Base	1,00	0,00%	0,00%	0,00%	0,00%
		-25%	0,75	10,62%	9,82%	-3,25%	0,00%
		25%	1,25	-23,17%	-20,99%	6,12%	0,00%
Number of employees hub	Hours	Base	5,00	0,00%	0,00%	0,00%	0,00%
		-25%	3,75	5,44%	7,52%	0,00%	0,00%
		25%	6,25	-9,49%	-13,55%	0,00%	0,00%

4.4 Knowledge dissemination

Now that all the validation checks are completed, the model can be used for the execution of simulations. First, the current DND system of X, consolidating the logistics of three SFSC initiatives targeting B2C customers, will undergo comparison with the previous arrangement where the initiatives operated independently. Subsequently, a simulation will be conducted to anticipate bottlenecks in the current process resulting from an increase in volume, along with exploring solutions. Lastly, a test will assess the feasibility of reducing B2B delivery days to one within the existing process, without any simulated volume increases.

4.4.1 Comparison of distribution network designs

This bundled scenario represents the B2C process in the simulation model. To compare the performance of the current DND to the previous one, the expenses and kilometres of the three initiatives are aggregated. Subsequently, the average of the three delivery reliabilities is calculated to assess both situations.

Figure 6 illustrates that bundling the SFSC initiatives has resulted in a decrease in total costs per week, while maintaining the same number of customers. Furthermore, figure 7 demonstrates that the consolidation of the three initiatives leads to a reduction in total kilometres driven, indicating improved efficiency in terms of distance travelled. Finally, as shown in table 14, the delivery reliability remains 100%. For clarity, all the figures from the knowledge dissemination phase are also presented in Appendix 13.

In summary, bundling in this case has resulted in a direct decrease in costs and total driven kilometres, while maintaining 100% delivery reliability.

Table 14, Comparison old situation vs bundled

KPI	**Old DND**	**Bundled DND**	**Difference (%)**
Total costs per week	€767x	€468x	-39 %
Total kilometres per week	1,089	544	-50%
Delivery reliability	100%	100%	0%

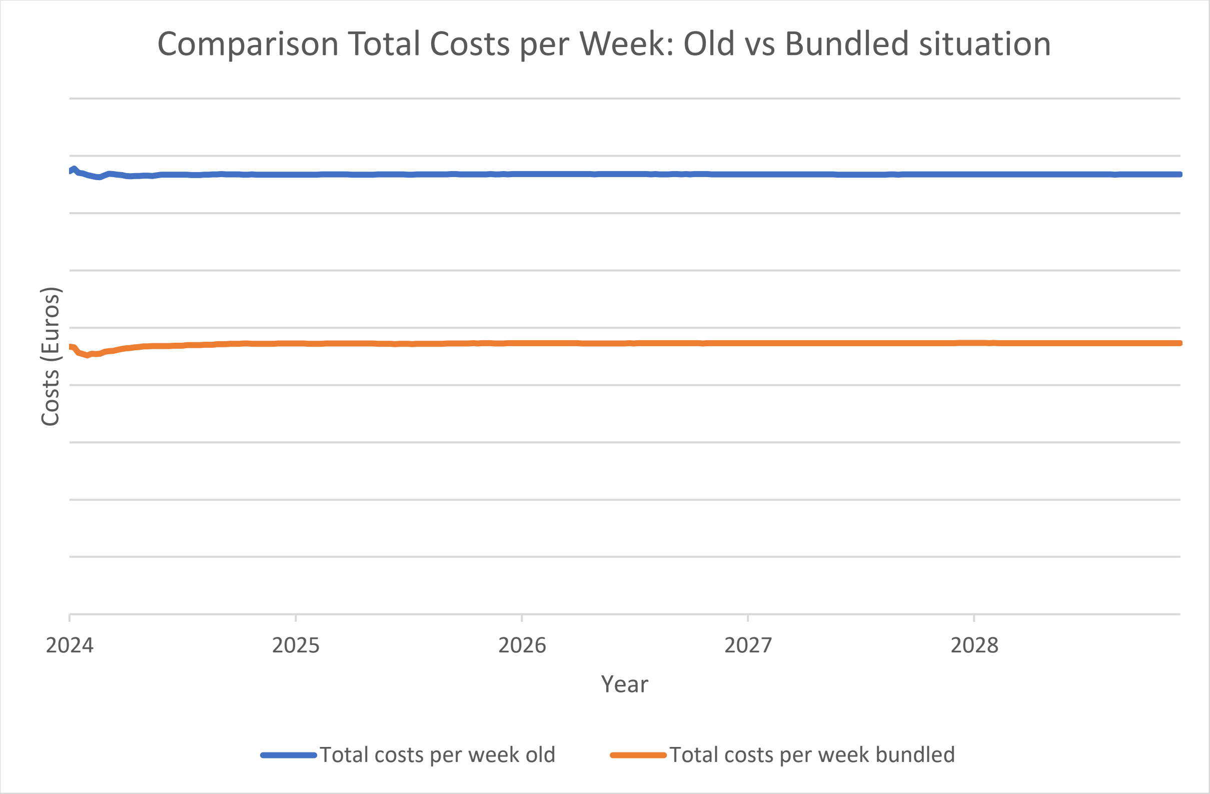

Figure 6, Comparison total costs per week old situation vs bundled

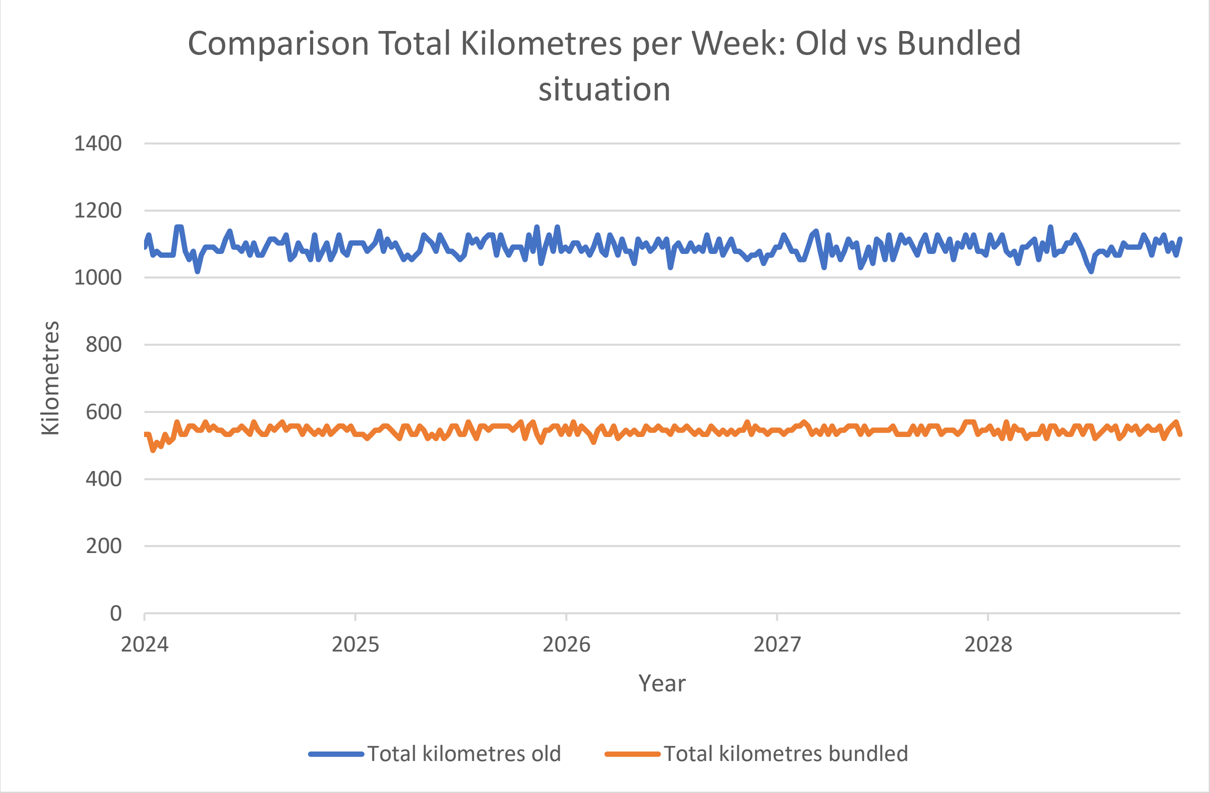

Figure 7, Comparison total kilometres per week old situation vs bundled

4.4.2 Volume increase

In this scenario, a volume increase is incorporated in the simulation model. This volume increase is based on a prognose made by X. The projected number of B2B customers by the end of 2028 is 162 per week, and the expected number of B2C customers is 601 per week. These figures will be entered into the last step of the Lookup Table in Silico, resulting in a linear increase over the years.

As presented in figure 8, both B2B and B2C delivery reliability are expected to decrease. Therefore, it can be concluded that the current DND of X is not resilient for an volume increase. Under the current DND, X can anticipate a decline in B2C delivery reliability by the end of the first year of operation in the new hub, followed by a decrease in B2B delivery at the start of 2025. There are three main causes for this decline in delivery reliability.

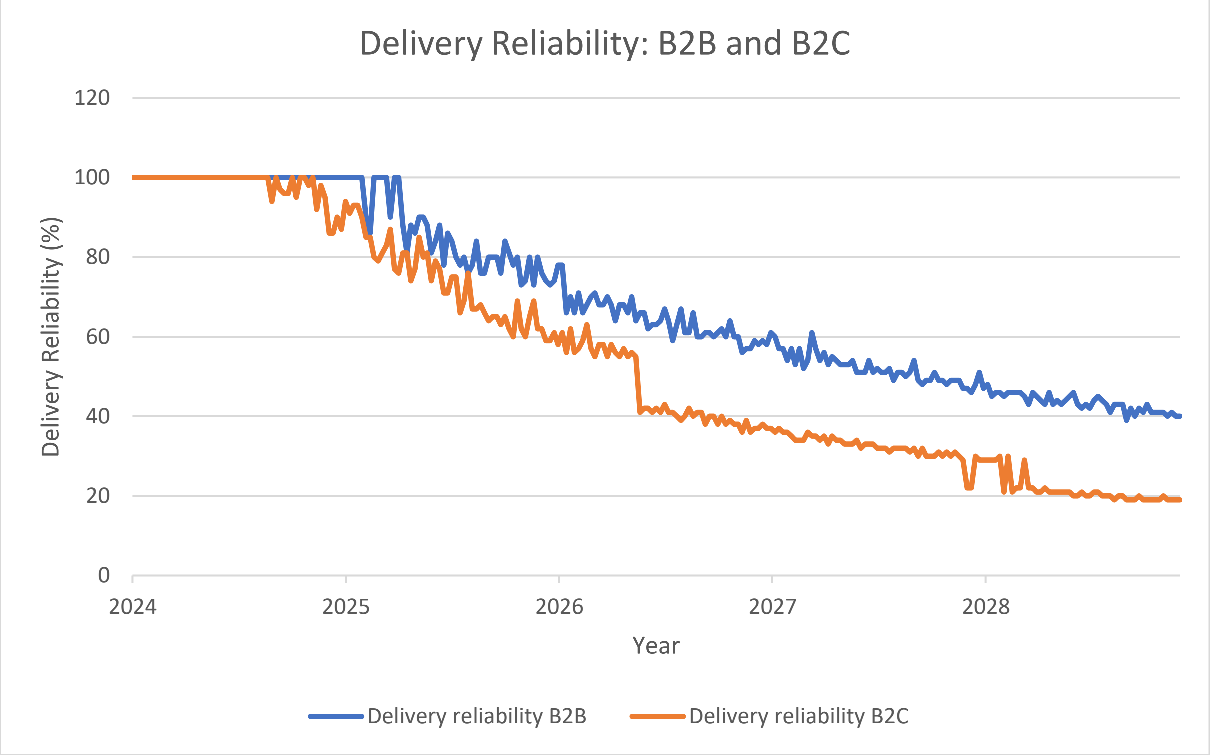

Figure 8, Delivery reliability B2B and B2C with incorporated volume increase

<u>Bottleneck 1: Inbound travel time:</u>

Due to the rise in customers, X have to collect more products from the suppliers, which results in higher capacity utilization of the vehicles (figure 9). Vehicle utilization in the B2C process is higher because more crates need to be collected on B2C days compared to B2B days.

When the maximum amount of vehicle capacity has been reached during collecting the products, the driver must return to the hub to unload before continuing to collect the remaining items, which consumes additional time. As inbound travel time increases, less time is available for order processing. If order processing is not completed on time, delivery reliability decreases.

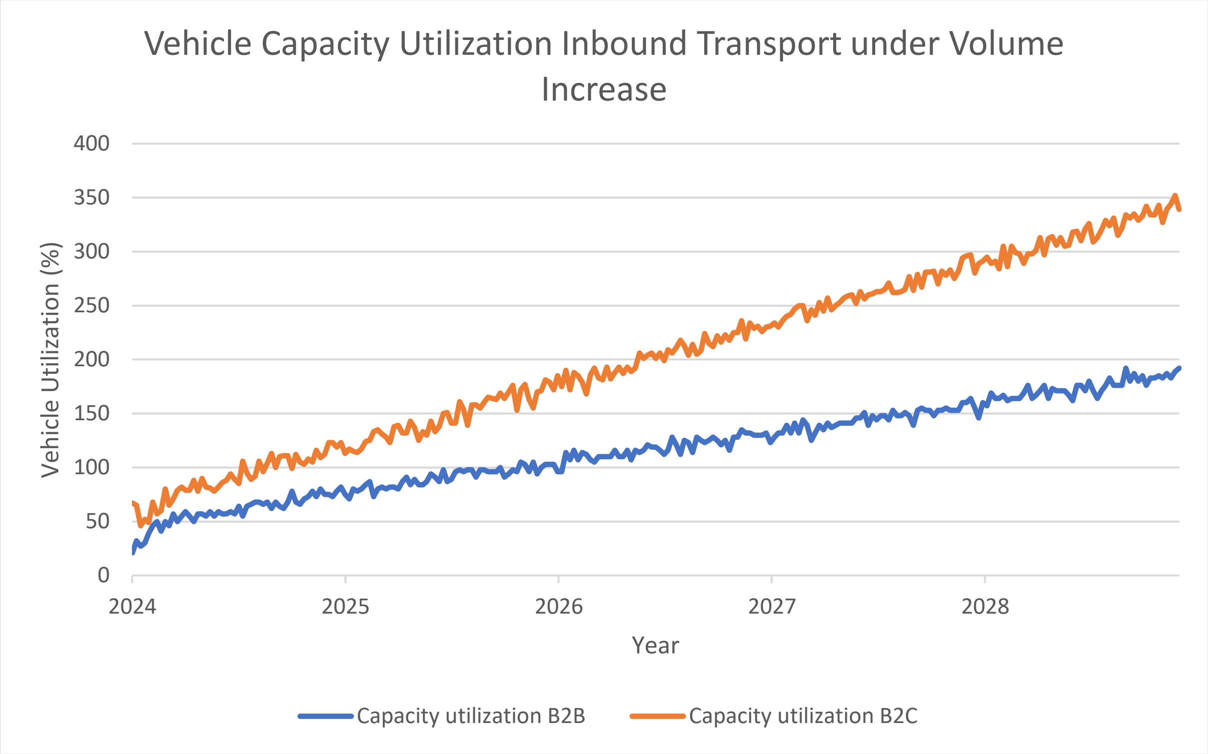

Figure 9, Vehicle capacity utilization inbound transport with incorporated volume increase

Bottleneck 2: Order processing time:

An increase in customers leads to more orders that need to be processed. Order processing is labour-intensive. Currently, employees process an average of 11 orders per hour, resulting in a total capacity of 55 orders per hour with the current five employees. Figures 10 and 11 demonstrate that the total order processing time increases over time. Additionally, as inbound travel time increases, even less time is available for order processing, as indicated by the maximum time for order processing line. This reduction in available processing time leads to a growing backlog, as shown in the figure 12. With the current processing capacity, delivery reliability will decline because not all orders are completed before the deadline. Due to the higher volume of orders, the B2C delivery reliability will decline first.

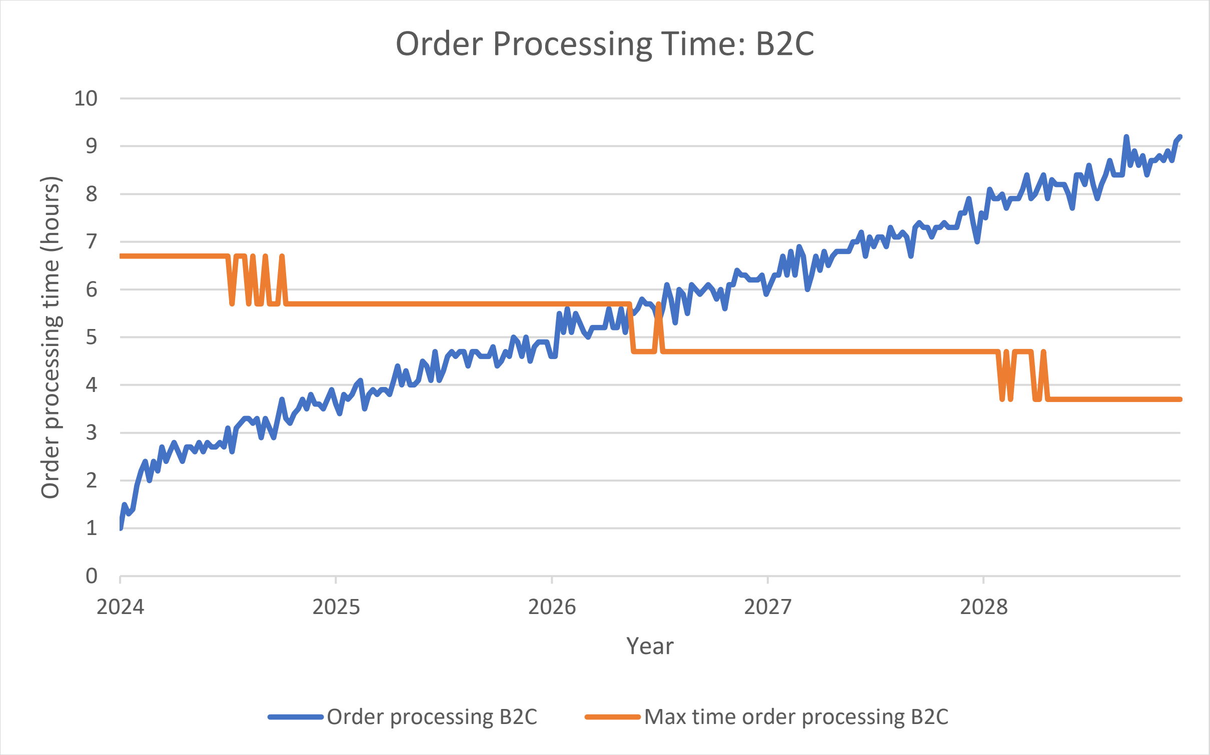

Figure 10, Order processing time B2C and the max time order processing, with incorporated volume increase

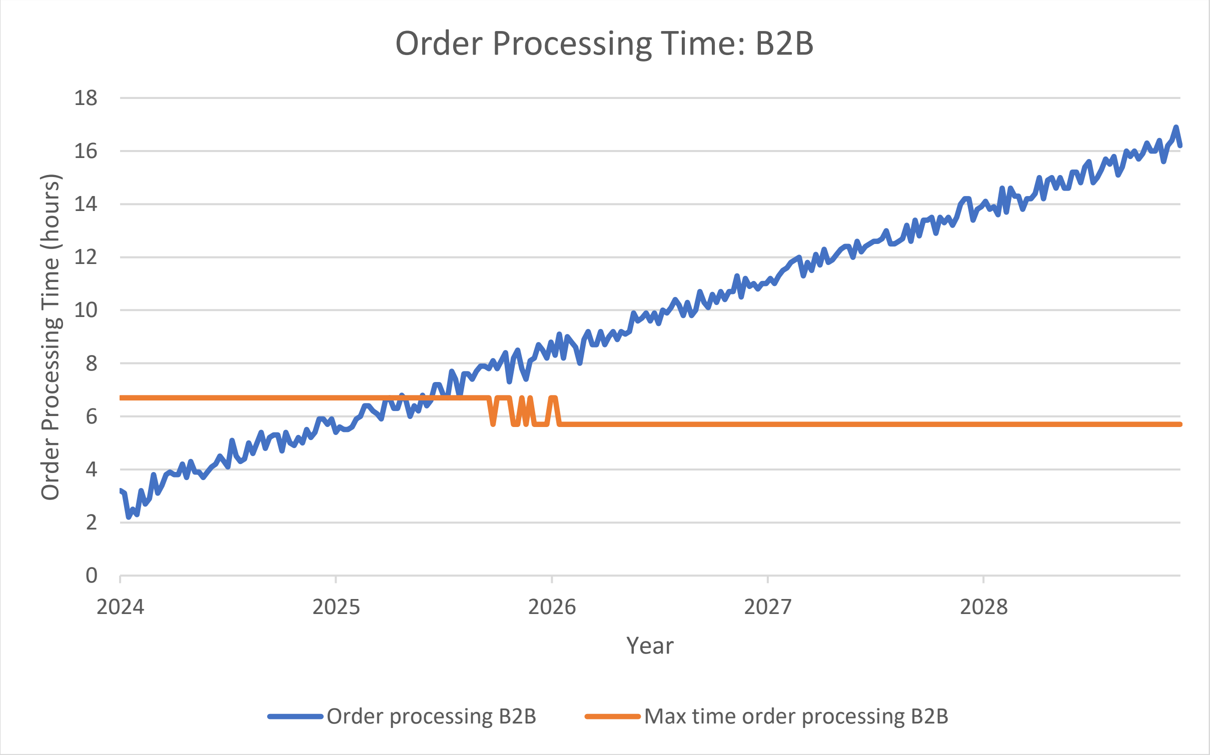

Figure 11, Order processing time B2B and max time order processing, with incorporated volume increase

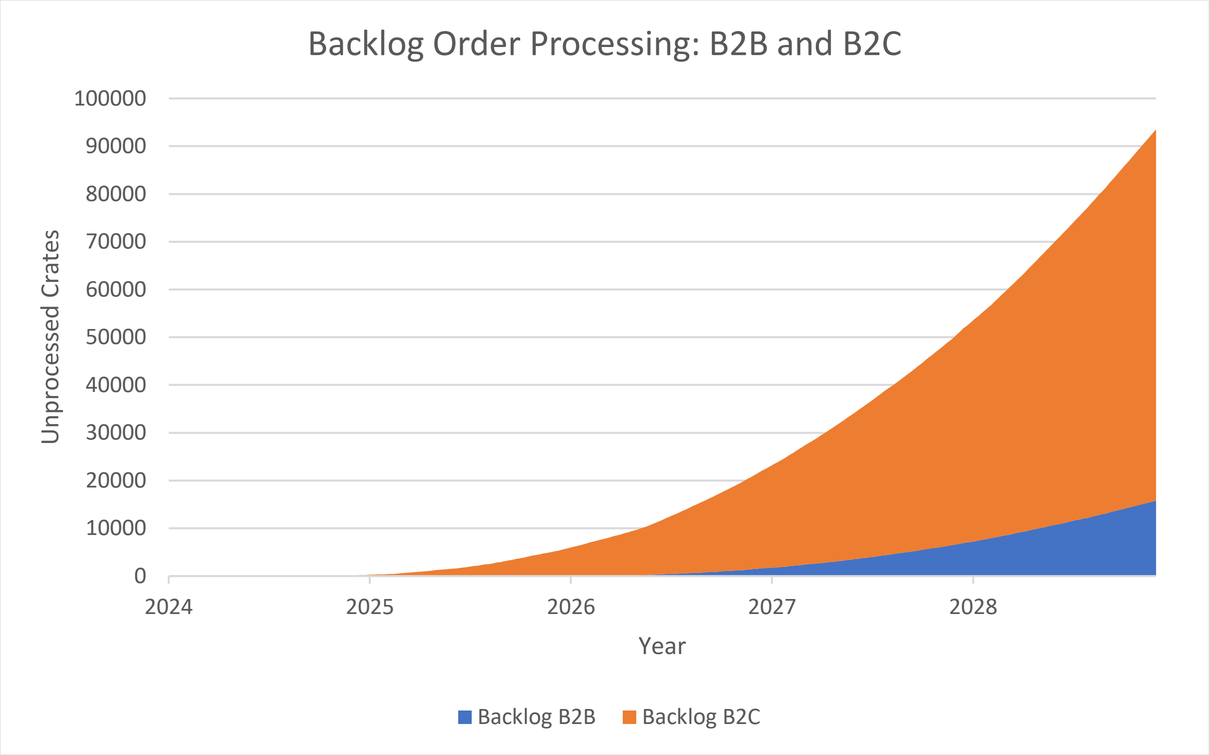

Figure 12, Backlog order processing B2B and B2C with incorporated volume increase

Bottleneck 3: Outbound travel time

An increase in customers results in more stops that have to be made when delivering the products. Additional stops result in more outbound travel time (figure 13). B2B outbound travel time is higher than B2C because each order must be delivered separately, resulting in more stops. With the current number of vehicles, delivery reliability will decline because not all orders are delivered before the deadline. For B2B customers, this decline will start halfway through 2025, and for B2C customers at the end of 2026.

In summary, pressure will especially arise in the hub during order processing for the B2C process, whereas in the B2B process, pressure will arise during order delivery to the customers.

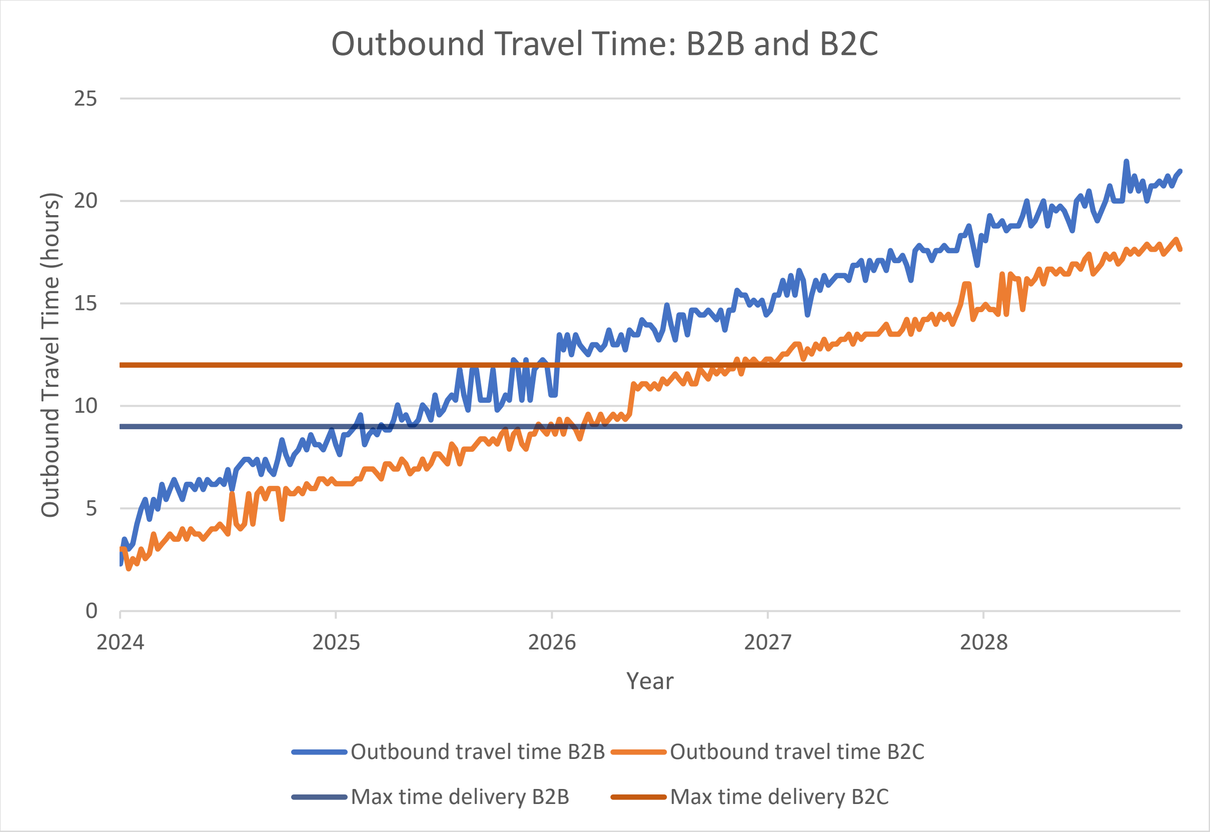

Figure 13, Outbound travel time and max time delivery, with incorporated volume increase

Now that the causes of potential future declines in delivery reliability have been identified, scenarios can be tested to prevent this from happening. This will be achieved by adjusting the key variables identified in the sensitivity analysis. The increase in customers will remain constant, but key variables will be adjusted to allow for the testing of two scenario combinations

Sub-scenario 1: Increasing number of vehicles

In this sub-scenario, the number of vehicles available to X is increased, in combination with the incorporated volume increase. The combinations and the impact on the KPIs are made visible in table 15. The delivery reliability and costs are the average of the entire period of 256 weeks.

Table 15, Increase of number of vehicles and the effect on the KPIs

Number of extra vehicles	Type(s)	Delivery reliability	Costs
1	Renault	85% (+27.8%)	€1441x (+5.2%)
1	Mercedes	85.5% (+28.6%)	€1454x (+6.2%)
2	Renault / Mercedes	92.5% (+39.1%)	€1517x (+11%)
2	Renault	92.5% (+39.1%)	€1548x (+9.3%)
2	Mercedes	93% (+39.8%)	€1520x (+13%)
3	Renault	94.5% (+42.1%)	€1568x (+14.5%)
3	2 Renault / Mercedes	95% (+42.9%)	€1595x (+16.5%)

As table 15 shows, increasing the number of vehicles positively impacts delivery reliability, with minimal differences between vehicle types. However, it is not immediately necessary to lease more vehicles. Figure 14 indicates when an additional vehicle needs to be added to maintain high delivery reliability. While increasing the number of vehicles improves B2B delivery reliability to 100%, this is not the case for the B2C process. The reason for this discrepancy lies in the order processing process, where a bottleneck arises.

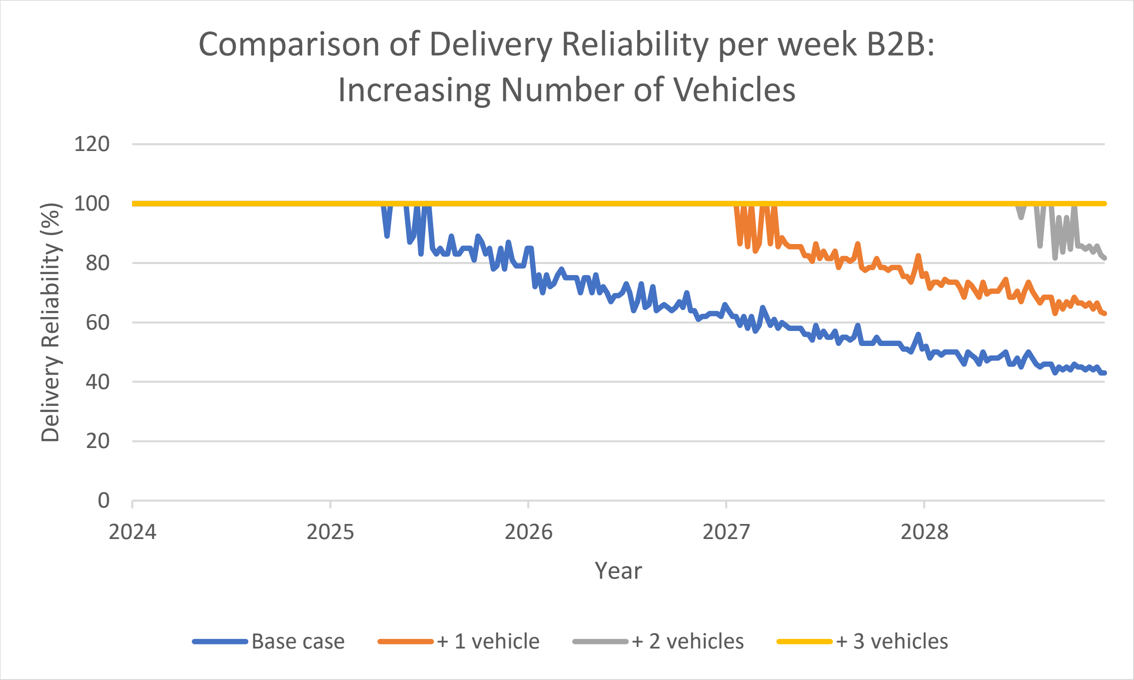

Figure 14, Effect of increasing number of vehicles on delivery reliability B2B process

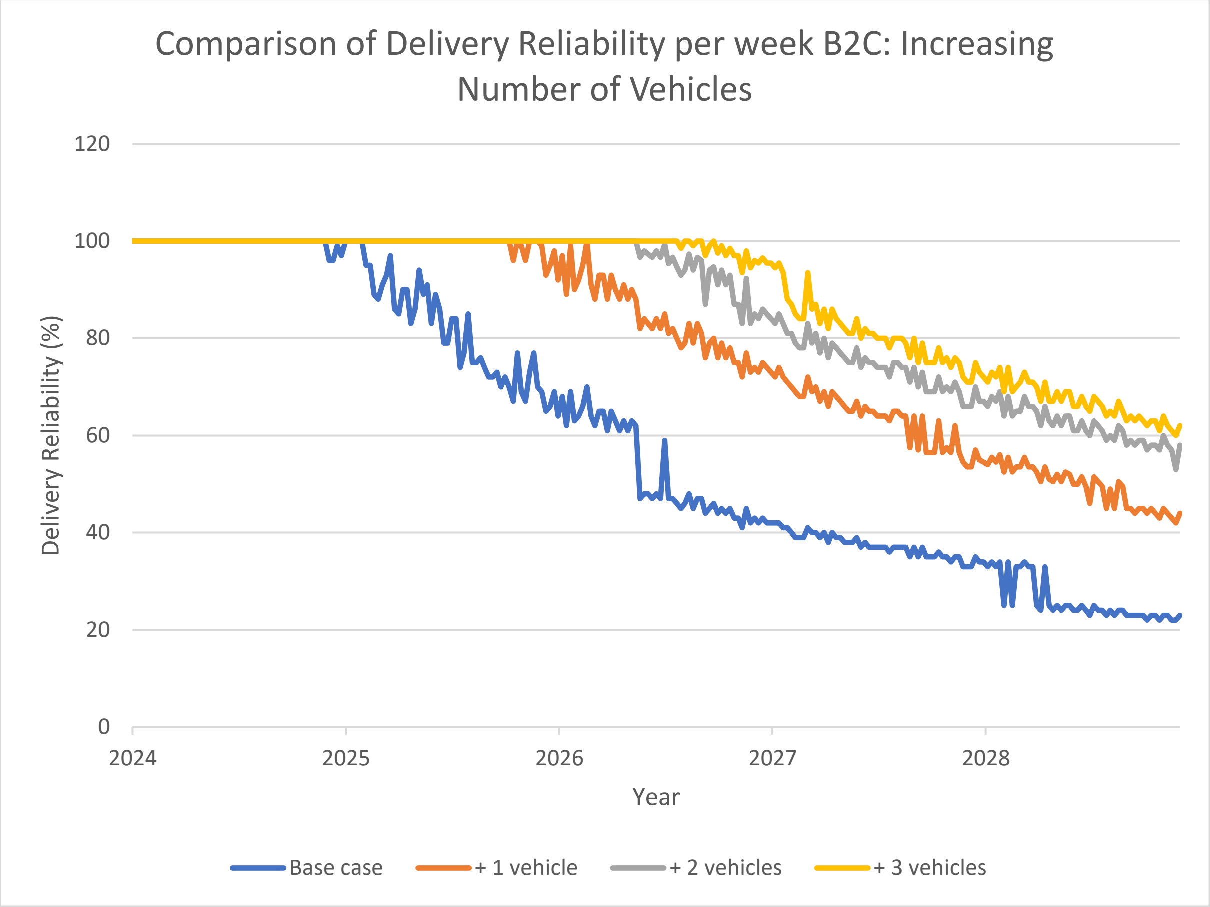

Figure 15, Effect of increasing number of vehicles on delivery reliability B2C process

<u>Sub-scenario 2: Increasing number of hub employees</u>

In this scenario the number of hub employees that process the orders is increased. Figure 16 shows that increasing the number of hub employees improves delivery reliability to B2C customers. However, during 2026, adding more hub employees alone will not guarantee 100% delivery reliability. This means that adding three hub employees will resolve the bottleneck. Adding more hub employees does not improve delivery reliability to B2B customers, indicating that the primary bottleneck lies with transportation. Since hub employees are paid per hour, increasing their number does not lead to higher operational costs.

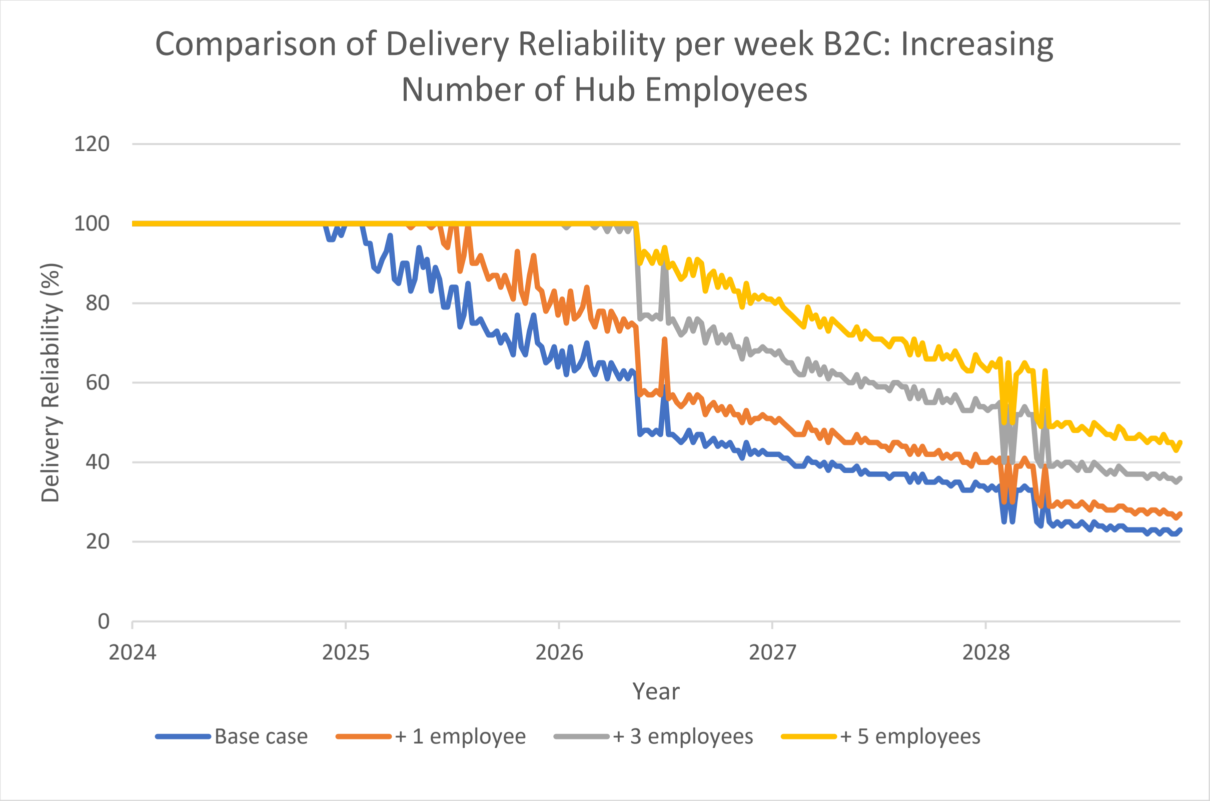

Figure 16, Effect of increasing number of employees on delivery reliability B2C process

Sub-scenario 3: Increasing number of vehicles and hub employees

In this scenario, the outcomes of sub-scenarios one and two are combined. As the type of vehicle minimally influences delivery reliability, the more affordable option, the Renault, is selected. Figure 17 shows that a delivery reliability of 100% to B2C customers can be achieved if X add an extra vehicle at the start of 2025 and 2028 and hire five additional employees to process the orders. However, this will not be sufficient to achieve 100% delivery reliability for B2B customers, as the primary bottleneck lies with outbound transport.

Figure 18 shows that 100% delivery reliability to B2C customers can be achieved by adding an extra vehicle at the end of 2024, 2025, and 2027, and by hiring three additional employees to process orders. This will also ensure 100% delivery reliability for B2B customers. The figure shows that eventually X should have an fleet of five vehicles to deliver all the products on time with the current delivery frequency. To minimize costs, it is best to wait as long as possible before adding extra vehicles and initially try increasing the number of employees.

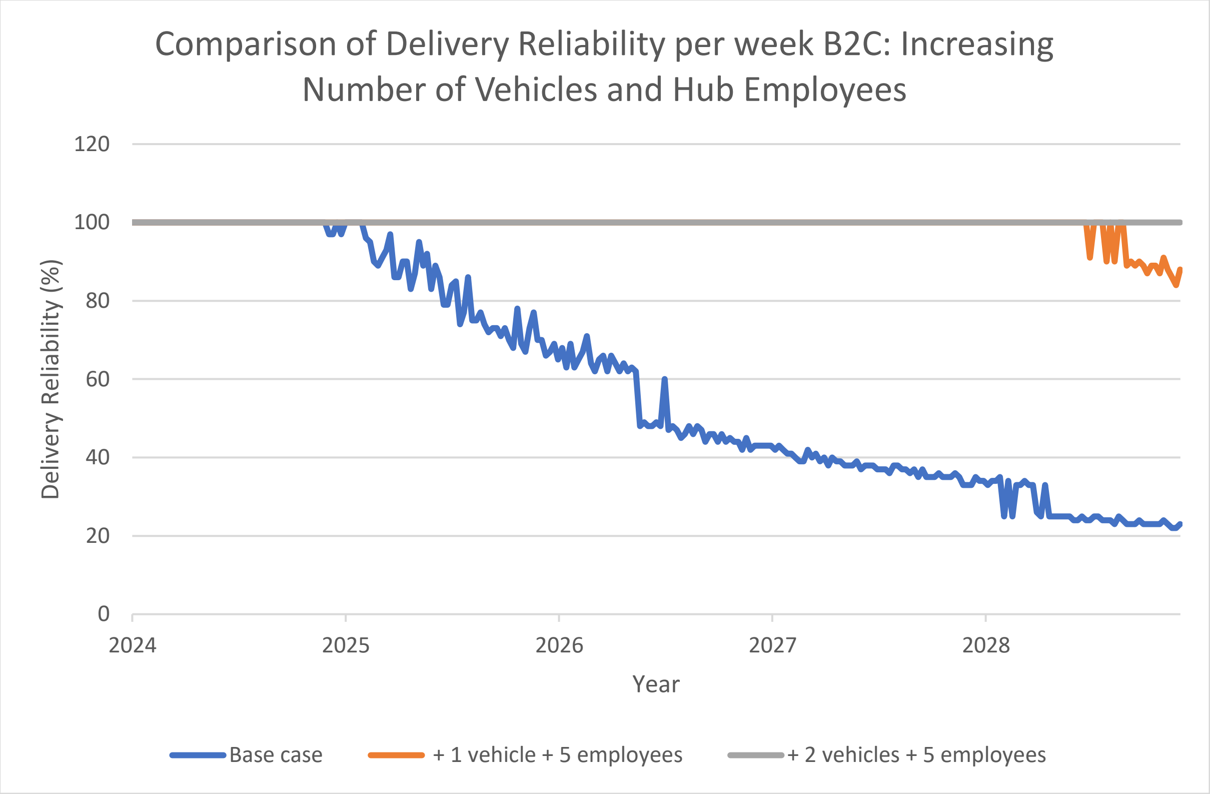

Figure 17, Effect of increasing number of vehicles + adding 5 hub employees on delivery reliability B2C

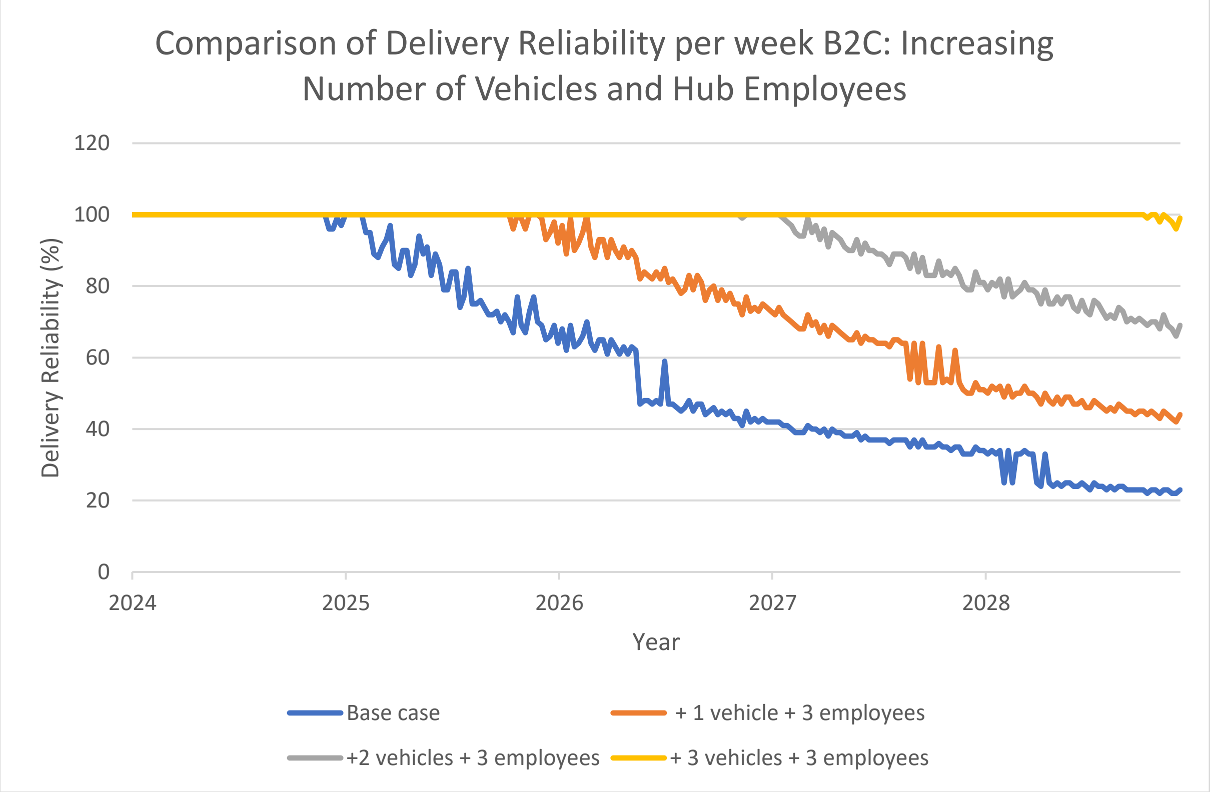

Figure 18, Effect of increasing number of vehicles + adding 3 hub employees on delivery reliability B2C

Sub-scenario 4: Increasing delivery frequency

In this scenario, the delivery frequency of X is increased. Table 16 presents the averages of the entire period of 256 weeks and demonstrates that increasing the delivery frequency reduces the pressure on the current DND and enhances delivery reliability.

However, adding an extra delivery day will increase costs due to the additional operational expenses. Keep in mind that X have a limited number of vehicles. Currently, Thursday is the only day when X must collect and deliver orders on the same day. However, adding an extra delivery day will create an additional day when this occurs. This increases pressure and can particularly lead to problems with B2B customer deliveries, as these are time-consuming.

Table 16, Effect of extra delivery day on KPIs

Extra delivery day	**Outbound travel time**	**Order process time**	**Capacity utilization inbound**	**Delivery reliability**	**Costs**
1 B2C	4.8 (-51%)	4.9 (-49.5%)	102% (-50%)	94 % (+56.7%)	€1445x (+5.5%)
1 B2B	8.1 (-52%)	3.8 (-32.1%)	78% (-47%)	91 % (+24.7%)	€1447x (+5.7%)

Sub-Scenario 5: Increasing B2C delivery frequency, hub employees and vehicles

In this scenario, all the previous scenarios are combined. Increasing the delivery frequency to B2C customers from one to two days and adding three hub employees will lead to 100% delivery reliability to B2C customers. This means that X could deliver their B2C customers without having to add more vehicles. However, delivering to B2B customers is time-consuming. Given that the delivery frequency is increased, vehicles must complete both collection for B2C customers and delivery for B2B customers within a maximum of 9 hours on the same day, thus requiring an increase in the number of vehicles through time (figure 19). Taken this into account, table 17 outlines the boundary conditions necessary to achieve 100% delivery reliability by the end of 2028 when delivery frequency is increased by one day for B2C customers, one day for B2B customers, or a combination of both, with the desired increase from the base case provided in brackets. The costs in table 17 have been anonymized; however, they clearly indicate that increasing the delivery frequency to B2B customers by one day is the most preferred strategy. This increase will alleviate pressure on outbound transport to B2B customers, allowing for reduced vehicle usage and, consequently, lower costs.

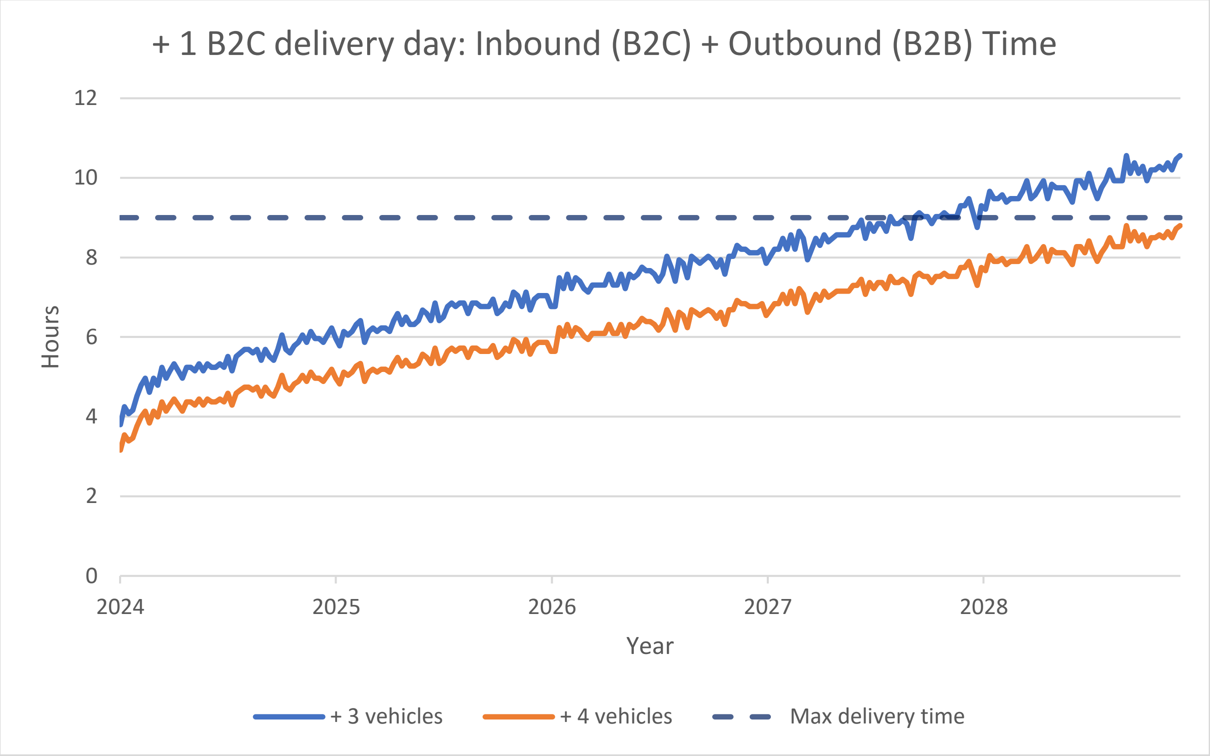

Figure 19, Inbound (B2C) + Outbound (B2B) time and max delivery time B2B

Table 17, Boundary conditions to reach 100% delivery reliability when delivery day is added

Delivery days	**Hub employees**	**Vehicles**	**Average Costs**
+ 1 B2C	8 (+3)	6 (+4)	€1708x
+ 1 B2B	10 (+5)	4 (+2)	€1579x
+ 1 B2C / + 1 B2B	8 (+3)	5 (+3)	€1717x

Comparison sub-scenarios volume increase

Figure 20 compares the total weekly costs of sub-scenario 3, which involves only increasing the number of vehicles and hub employees, with sub-scenario 5, which increases the delivery frequency to B2B customers with one day. Based on the graph and table 18, it can be concluded that adding an extra delivery day for B2B customers, when there is sufficient volume, involves a trade-off. Sub-scenario 5 alleviates pressure on B2B outbound transport, resulting in reduced vehicle fleet and consequently lower vehicle fixed costs. However, adding an additional delivery day also increases operational costs because it requires product collection on an extra day.

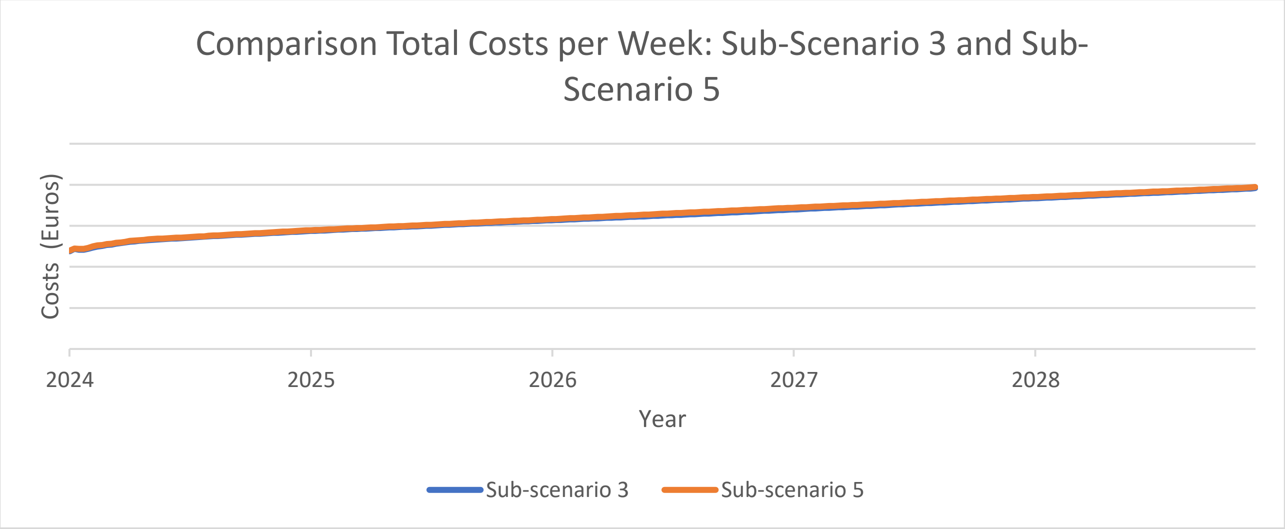

Figure 20, Comparison total costs per week sub-scenario 3 and sub-scenario 5

Table 18, Comparison sub-scenario 3 and sub-scenario 5

	Sub-scenario 3	**Sub-scenario 5**	**Difference**
Avg. weekly costs	€1568x	€1579x	0.7%

4.4.3 No volume increase

In this scenario, sub-scenarios are simulated within the current DND framework without any volume increase. With the current number of customers, the delivery reliability remained 100% throughout the simulation. However, the average capacity utilization over this period was only 61.6%, indicating that the vehicles are underutilized and can accommodate more volume.

Sub-scenario 6: Increasing number of vehicles

As delivery reliability is currently 100%, increasing the number of vehicles or number of hub employees will not make a difference on this KPI. However, adding an extra vehicle will increase the operational costs and reduce lead time (table 19). Therefore, this will not be beneficial to X.

Table 19, effect of increasing number of vehicles on KPIs

Number of extra vehicles	**Type**	**Delivery reliability**	**Costs**	**Lead time**
1	Renault	100% (+0%)	€936x (+9%)	21.21 (-26.5%)
1	Mercedes	100% (+0%)	€967x (+12.6%)	21.21 (-26.5%)

Sub-scenario 7: Increasing number of hub employees

In this sub-scenario, the same principle applies as when increasing the number of vehicles, since delivery reliability stands at 100%. However, increasing the number of hub employees can reduce lead time without incurring significant additional operational costs (table 20). Therefore, while adding more hub employees is not essential, it can effectively decrease lead time.

Table 20, Effect of increasing number of employees on KPIs

Number of extra hub employees	**Delivery reliability**	**Costs**	**Lead time**
1	100% (+0%)	€858x (+0%)	27.91 (-3.3%)
3	100% (+0%)	€858x (+0%)	26.67 (-7.6%)
5	100% (+0%)	€858x (+0%)	25.94 (-10.1%)

Sub-scenario 8: decreasing B2B delivery days

In this sub-scenario, the delivery days to B2B customers are reduced from two days to one day per week to assess if X can still maintain 100% delivery reliability. Increasing delivery days would only lead to higher operational costs, as the DND is currently underutilized

By consolidating deliveries to a single day, products need to be collected only once a week, resulting in lower operational costs. Table 21 presents the averages over a period of 256 weeks. Figure 21 shows that delivery reliability decreases due to a bottleneck in outbound transport. Consequently, removing a delivery day is not beneficial, as the high number of stops on the remaining delivery day prevents orders from being delivered before the deadline.

Table 21, Effect of reducing delivery day on KPIs

B2B delivery day	**Delivery reliability**	**Costs**	**Lead time**
-1	87.3% (-12.74%)	€789x (-7.8%)	38.05 (+ 31.8%)

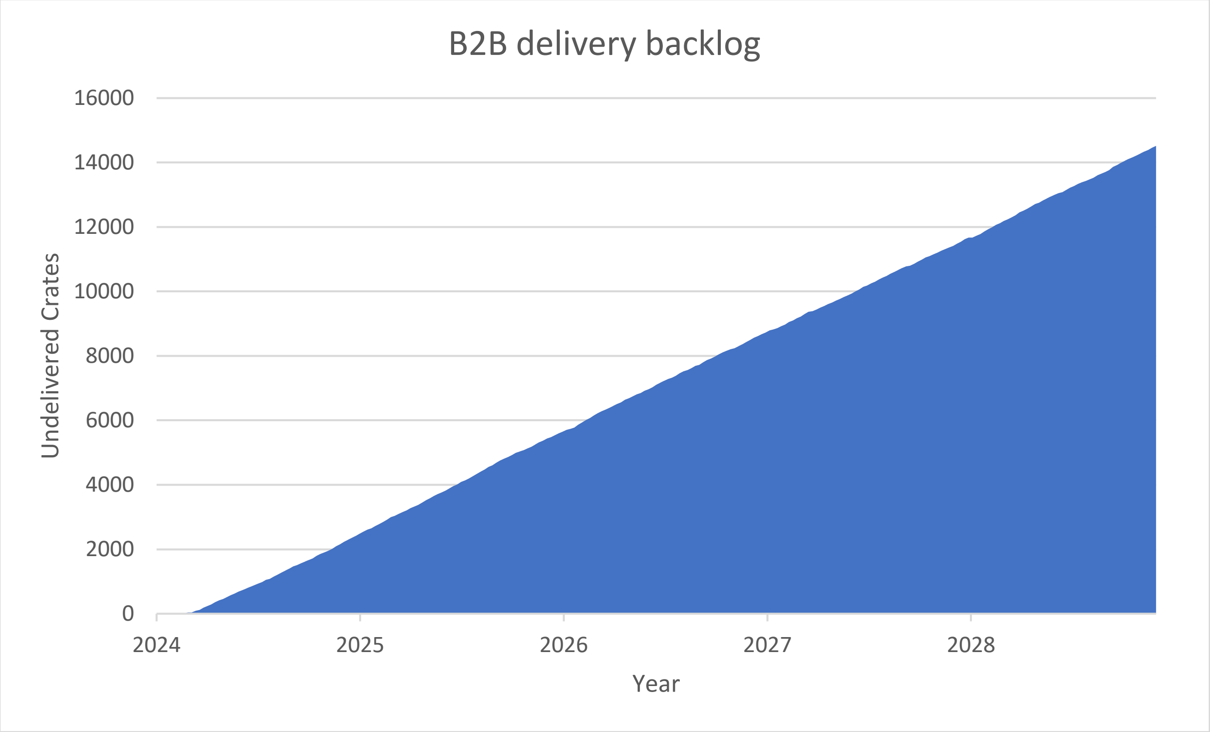

Figure 21, Bottleneck in outbound transport B2B

4.4.4 Key findings knowledge dissemination phase:

- **Bundling:** The consolidation of the three SFSC initiatives will reduce future operational costs by 39% and future kilometres driven by 50% compared to the previous situation without the bundling of logistics.
- **Volume increase challenges:** The DND of Company X is not resilient against a volume increase, leading to bottlenecks in inbound transport, order processing, and outbound transport.
- **B2B and B2C bottlenecks:** The primary bottleneck in the B2B process occurs on the delivery day when orders are being delivered. Additionally, the main bottleneck in the B2C process lies in order processing.

  Optimal strategy: As volume increases, Company X faces a strategic trade-off between adding an extra delivery day for B2B customers and increasing the vehicle fleet, as these are both effective strategies. Furthermore, to address the order processing bottleneck in the B2C process, increasing the number of hub employees to eight becomes essential.
- **B2C delivery day:** Adding an extra B2C delivery day is not advantageous due to the complexity of coordinating both B2C inbound and B2B outbound transport on the same day.
- **Current volume:** The scenarios aimed at optimizing Company X's current DND without increasing volume did not yield significant benefits. The current 100% delivery reliability can be attributed to the underutilization of the DND. However, responding to this by reducing the number of B2B delivery days will result in a decrease in delivery reliability.

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Chapter 5: Discussion

The concluding chapter outlines the primary findings of the study, its theoretical contributions, and managerial implications. It also addresses the research limitations and provides recommendations for future research.

5.1 Conclusions

The main purpose of this research was to investigate the logistical performance of X's current DND and, based on these findings, to identify ways to optimize the design by adjusting key variables. For this purpose, the following research question was formulated:

"How can Company X strategically modify their distribution network design to enhance logistical performance and establish an efficient short food supply chain in the Central Brabant region, based on an assessment of the current distribution network design's effectiveness?"

To address the research question, a comprehensive approach was adopted, incorporating literature review, empirical research conducted at X, and the development of a simulation model using the SD approach.

The main research question can be addressed by drawing conclusions from the empirical research questions. Upon comparing the previous situation with the bundling of three initiatives, it becomes evident that the integration of the logistics of these SFSC initiatives has resulted in enhanced performance of the DND, matching findings from the literature review (Abdinnour-Helm, 1999). The consolidation will reduce future operational costs by 39% and future kilometres driven by 50% compared to the previous situation without the bundling of logistics.

As mentioned in the literature review, SFSC companies have difficulties scaling up, therefore a volume increase was incorporated in the simulation model to test if the current DND is resilient (Bayir, Charles, Sekhari, & Ourzrout, 2022). Simulating this scenario reveals that the current DND lacks resilience to accommodate a volume increase, primarily due to three causes: inbound travel time, order processing time, and outbound travel time. The main pressure is observed in the order processing stage for the B2C process, and in the order delivery phase for the B2B process.

The causes can be solved by adjusting the key variables identified in the literature review and confirmed by the sensitivity analysis: number of vehicles, hub employees and delivery frequency (Mentzer & Konrad, 1991). Other key variables identified through sensitivity analysis include the number of stops and the speed of order processing, both of which, when improved, will positively impact the DND.

Based on the scenario analysis, it is advisable to increase the number of vehicles and hub employees as volume increases. Additionally, as volume increases, Company X faces a strategic trade-off between adding an extra delivery day for B2B customers and increasing the vehicle fleet. Adding a B2B delivery day alleviates order delivery pressure, reducing the need for additional vehicles. However, this also requires an extra collection day, leading to higher operational costs. Conversely, adding more vehicles to the fleet is another option, but it increases fixed costs (Krämer, 2010). In contrary, adding an extra B2C delivery day negatively impacts DND performance. This increases pressure on B2B outbound transport, given the complexity of coordinating B2C inbound and B2B outbound transport on the same day. As a result, the increased vehicle requirement incurs higher fixed costs. Moreover, increasing the number of hub employees addresses the bottleneck in order processing for the B2C process, making an additional delivery day unnecessary.

Finally, scenarios were tested to improve the current DND of Company X without increasing the volume. However, these scenarios did not yield significant benefits. Given that the current DND is underutilized, an increase of volume would reduce the fixed costs per order and enhance the performance of the DND. Therefore, to enhance efficiency further, Company X should proactively seek to expand their customer base, thereby increasing their volume of sales and distribution.

These conclusions provide a comprehensive answer to the main research question. The bundling of the SFSC initiatives has improved DND performance. However, the current DND of Company X is underutilized, so it is recommended to seek new customers and partners to increase volume. As volume increases, bottlenecks are likely to emerge in B2C order processing and B2B deliveries. To address these bottlenecks, the optimal strategy is to introduce an additional B2B delivery day and add extra vehicles and hub employees as needed to maintain delivery reliability.

5.2 Theoretical contributions

As indicated at the start of this study, SFSCs often struggle to succeed due to poor logistical performance, which is significantly impacted by the design of their DND. Existing literature on the DND of SFSCs has not been implemented in practical case setting to determine its applicability. Most research has focused on creating models and recommendations without implementing them in real-world settings (Paciarotti, Mazutto, Torregiani, & Fikar, 2022).

To examine the current DND, this study employed a practical, mixed-method approach by combining a longitudinal case study with SD modeling. This involved constructing a simulation model that incorporates real-case data from an SFSC company. Based on this simulation model, several significant academic contributions emerge from this research. The bundling of multiple SFSC initiatives has primarily showcased enhanced efficiency in terms of reduced kilometres travelled and increased effectiveness through cost reduction, attributed to the optimized utilization of vehicles and the hub, matching findings from the literature review (Abdinnour-Helm, 1999). This provides novel insights to theory by offering empirical evidence of the effectiveness of logistics bundling in SFSCs, demonstrating its potential to drive operational efficiencies and cost savings. Moreover, it recognizes the significance of social connections and the collaboration of stakeholders, as highlighted in the literature review (Rucabado-Palomar & Cuellar-Padilla, 2020)

Consequently, existing research has suggested practical case studies to test innovative DNDs utilizing an online platform. Therefore, this study aimed to fill this gap by assessing the current DND of an SFSC utilizing an online platform, identifying bottlenecks and key variables, and proposing improvement strategies, thereby contributing to and enhancing the research of Paciarotti et al. (2022).

The online platform is a boundary condition for the success of SFSCs and X, providing valuable insights to theory by demonstrating its practical effectiveness in streamlining procurement, improving market efficiency, and enabling stakeholder data sharing within SFSCs, consistent with findings from the literature review (Blind & Pohlisch, 2020).

The sensitivity analysis and scenario analysis showed that decision variables as number of vehicles, hub employees and delivery frequency indeed are key variables in the DND of a SFSC, confirming findings in the literature review (Mentzer & Konrad, 1991). The scenario analysis revealed that optimizing these key variables has the potential for enhancing the performance of SFSCs' DND and mitigating bottlenecks, as emphasized in the conclusions section.

Other significant variables identified, not considered as decision variables, include the number of stops and the speed of order processing. A higher number of stops adds greater strain to the system, underscoring the importance of minimizing them. Consequently, speeding up order processing can relieve system pressure and reduce costs. A pivotal boundary condition for the success of the SFSC is the assurance of adequate volume, as it holds the potential to lower costs per order through economies of scale (Mittal, Krejci, & Teri, 2018).

Overall, these key variables and boundary conditions contribute to a more comprehensive and nuanced understanding of DND theory for SFSCs, bridging the gap between theoretical concepts and practical implementation in real-world supply chain contexts.

5.3 Managerial implications

The findings and conclusions of this thesis provide valuable insights for practitioners in SFSCs, particularly for the managers of X. The results demonstrate that managers should focus on scaling-up by seeking new customers and partners. The bundling of the three SFSC initiatives has indeed improved the performance of the DND. However, considering the high logistical costs associated with SFSCs due to underutilization, it is advisable for managers of SFSC companies to pursue partnerships to bundle their logistics. This strategic approach can enhance efficiency and effectiveness by leveraging the benefits of economies of scale.

Furthermore, the integration of an online platform is pivotal for the success of SFSC initiatives, facilitating streamlined procurement, enhanced market efficiency, and effortless data sharing among stakeholders within SFSCs. Thus, it is strongly recommended that all managers involved in SFSCs consider adopting a tailor-made online platform to optimize their operations.

For X, the simulation revealed that the current DND lacks resilience to accommodate a volume increase, leading to the emergence of bottlenecks over time. Therefore, it is advisable for managers to maintain continuous monitoring of DND performance and make necessary adjustments to key variables such as the number of vehicles, hub employees, and delivery frequency. This proactive approach is essential to ensure ongoing operational optimization and efficiency.

If volume increases, X face a trade-off between adding an extra B2B delivery day or expanding the vehicle fleet to maintain 100% delivery reliability. Adding a delivery day alleviates pressure on existing B2B delivery days, reduces fixed costs, and improves customer flexibility. Conversely, adding more vehicles can also support the B2C process, reduce lead times, and manage larger volumes. However, this option also requires hiring additional staff.

However, adding another B2C delivery day is not recommended because it would increase pressure on B2B outbound transport, complicating the coordination of B2C inbound and B2B outbound transport on the same day, which in turn would lead to higher fixed costs due to the increased vehicle requirement. Moreover, increasing the number of hub employees can address the bottleneck in order processing for the B2C process, making an additional B2C delivery day unnecessary.

Finally, X can explore methods to enhance their order processing speed, such as automation. This initiative will decrease reliance on hub employees and streamline the process for greater efficiency. Moreover, when implemented effectively, it has the potential to yield cost reductions.

5.4 Limitations

This study also has its limitations. Firstly, while a simulation model aims to replicate real-world scenarios, it inherently faces constraints related to time and feasibility. The simulation model employed in this research simplifies real-world processes. For example, while order processing has been examined, innovative improvements have not been thoroughly analysed. Furthermore, transportation modeling does not incorporate routing specifics but relies on averages for calculations. In addition to that, due to complexity constraints, seasonal variations in product variety and cost fluctuations are not factored into the model. Finally, a limitation of this study is that the identified bottlenecks emerge following a simulated volume increase, prognosed by X. However, since this projected volume increase is uncertain, it remains unknown whether X will indeed expand their volume, and if so, whether it will align with the simulated pattern. Overall, these limitations highlight the need for cautions interpretation of the study's conclusions and suggest avenues for future research to address these constraints. As a result, the simulation model holds more exploratory and strategic value for long-term planning rather than immediate, operational precision.

Furthermore, the construction of the simulation model relied on available data from the company, interviews, and existing literature. Due to X's recent establishment of their new hub, data was only available for a limited period. This restricted access to a comprehensive dataset for analysis, leading to uncertain values as presented in the sensitivity analysis. The involvement of suppliers delivering products off the record to X posed challenges for model validation. This discrepancy between actual and simulated data made the validation process more difficult. The restricted dataset from a short timeframe limits the thoroughness and reliability of the findings. Moreover, discrepancies between actual and simulated data during model validation undermine confidence in the simulation outcomes and the robustness of the derived conclusions, despite potential explanations for these disparities. By acknowledging these limitations, managers can make more informed decisions and plan further steps to obtain more robust and reliable insights.

5.5 Future research directions

Building upon the insights gained, this section explores potential avenues for further academic research and identifies areas where future studies could contribute to a deeper understanding of DND within SFSCs. Future research on the DND of SFSCs is necessary, given their pivotal role in ensuring food security, sustainability and local economic development, as highlighted in the introduction and literature review of this study (Jia, Shahzadi, Bourlakis, & John, 2024). Understanding and optimizing their distribution networks can enhance their efficiency and effectiveness in meeting these objectives. Additionally, SFSCs face challenges such as scalability issues and lack of logistical infrastructure (Bayir, Charles, Sekhari, & Ourzrout, 2022; Rucabado-Palomar & Cuellar-Padilla, 2020). Further research can help address these challenges by identifying innovative solutions and best practices. Moreover, as the food industry continues to evolve with technological advancements and changing consumer preferences, ongoing research is essential to keep pace with these developments and ensure that SFSCs remain resilient and competitive (Hassoun, Aït-Kaddour, & Abu-Mahfouz, 2023).

Firstly, future research could conduct more case-specific studies to gain a more comprehensive understanding of the DNDs of SFSCs. These studies could encompass both national and international contexts, focusing on professionally operated SFSCs with access to registered historical data. Adding more case studies can offer a broader perspective and deeper insights into the diverse dynamics and challenges faced by SFSCs' DNDs. It allows for a more comprehensive understanding of how different factors and contexts influence logistical performance, facilitating the development of more tailored and effective strategies for optimization.

Secondly, this research could explore more detailed modeling of order processing and routing aspects. Moreover, future research could delve into alternative processing methods or technologies, such as automation and AI-driven solutions, to assess their potential impact on overall performance. This would enable researchers to contribute to the development of more efficient and effective DND strategies tailored to SFSCs.

Furthermore, researchers can investigate ways to improve collaboration and trust among stakeholders in SFSCs. Strong relationships between farmers, restaurants, and logistics providers are essential for coordinated logistics activities and the success of SFSCs. Enhancing collaboration can lead to more efficient and resilient supply chains, with better coordination and communication among stakeholders (Rucabado-Palomar & Cuellar-Padilla, 2020). An example highlighted in this research is the bundling of logistics, which enhances the performance of the DND.

Also, future research could develop models that account for seasonal variations in product variety and fluctuations in costs. This would provide a more accurate representation of the dynamic nature of SFSCs and enable better-informed decision-making.

Last, researchers could focus on integrating sustainability metrics into the simulation model to assess the environmental impacts of different distribution scenarios. This would provide a more thorough understanding of SFSCs' overall sustainability, improving decision-making in sustainability efforts and potentially enhancing product marketing if SFSCs are proven to be sustainable.

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Appendix 1: Transcript interview

Interviewees:	General manager (G) Operational manager (O)
Interviewer:	Marc van Paridon (M)
Date:	27 February 2024
Location:	X’s hub

This interview was held with simultaneously the general manager, and the operational manager. The interviewees were informed about the subject and purpose of the interview and research beforehand. Prior to the interview, the questions were sent to them via email. Subsequent to the interview, additional data was provided in the form of Excel sheets. Permission was obtained from the interviewees to record the interview, with the assurance that all information would be treated confidentially and solely utilized for research purposes in this study. While the interview was originally conducted in Dutch, it has been translated for the sake of clarity and readability. As the interview was semi-structured, deviation from the question list found place to allow for flexibility in exploring emergent topics and following the interviewees' responses more closely, ensuring a more organic and comprehensive discussion.

Questions mailed before interview:

1. Subject: Farmers/suppliers
    a. How many suppliers does X have, and what kind of products to they mostly deliver?
    b. How cooperative are the suppliers?
    c. How are the suppliers managed?
    d. How are the products delivered?
    e. How many delivery days are there?

2. Subject: Network design
    a. How does the logistic process at X look like when an order is received?
    b. Is there a chosen strategy to process the orders?
    c. Is there inventory at the hub?

   d. What are the information flows of X?
   e. How are the products shipped?
   f. What is the strategy to plan a route?
   g. What kind of volumes are currently shipped?
   h. What are currently the bottlenecks in the operational process?
   i. Which stakeholders are involved, and what are the agreements?

3. Subject: Data
   a. What kind of data is currently registered at X?
   b. At which places in the process is data registered?
   c. Where and how is this data registered?

4. Subject: Customers
   a. How many customers does X currently have?
   b. How many orders are shipped per week on average?
   c. Is there an upward trend in shipped orders per week?
   d. What are the preferences of the customers?

(M): Can we go step by step through the operational process of X. From when an order comes in, until it gets delivered to the customer.

(G): We use the platform, which is a platform designed by ourselves. The platform is originally designed as online buying platform. Which makes it possible for restaurant owners to buy products at different suppliers. I used this system at a restaurant owner in Amsterdam, but after Covid I tried to find a solution to use the platform for another purpose. From customers I got asked more frequently if they could buy products from SFSC suppliers. Via a partner, who also used the platform, I got in contact with Initiative 3. Initiative 3 is an initiative who gathers farmers to sell products directly to the customer. Initiative 3 used a web shop, but this was very inefficient. Together with Initiative 3 we began research how we could it more efficient for farmers to sell in a SFSC, because we found a gap here. After this we rebuilt the online buying platform for restaurants, to an online buying platform for farmers participating in a SFSC. On the one side for customers, B2C and B2B, how can we facilitate their buying process. For B2C we made an app, which makes it easy to order. And for B2B, every organization has its own buying environment, in which it can buy at suppliers that are linked to the platform. After that we also began cooperating with Initiative 2 and made the process more efficient through time.

Currently, there are order moments, dependent on whether the customer is a B2B or B2C customer. This customer places orders with different suppliers in one transaction, and the system processes these orders and forwards them to the suppliers. The supplier views the ordered items and the scheduled delivery time, then prepares the order for shipment.

(M): When is the delivery moment for B2C and when for B2B?

(G): How we managed our system, is that we have different marketplaces. Initiative 3 has a marketplace, this is an order environment that already has customers, farmers and their own delivery deadlines. Another initiative, Initiative 2, has the same initiative, but other delivery and collecting days. Also, with B2B you see that corporate caterers want to get delivered early in the week, while restaurant owners want to be delivered at the end of the week. But because we started this hub, we started bundling, to make the transport more efficient. Currently we are driving three days a week, but if the volume is enough, we can drive more days per week. In the future we hope to drive 5 to 7 days a week, because then we will have enough volume. Currently our goal is to get the vehicles full.

So, at the order moments, the orders are forwarded to the farmer. It is always day A ordering, day B processing and day C delivering. And then on day B the orders are collected and processed in the hub.

(M) So, if I understand correctly, the orders received from customers are directly send to the farmers?

(O): Yes, except from the B2C orders. They are first stacked in the system and then send in bulk to the farmer, so the farmer does not see the order at customer level, but in bulk. It is possible for the farmer to see in the system how many orders are stacked, so the supplier can see what he can expect. The order deadline for customers is Tuesday at midnight, and the farmer receives the order at 1:00.

(G): I will send the details about delivery days and deadlines via mail. After the farmer has prepared the order for shipment, we will go and collect the order, and after that the order processing starts. If the order processing is finished, we will deliver the products to the customers. We can get the addresses of suppliers and customers out of the platform, but we do not have the connection with a routing system, but we are working on this. So, the planning of the routes is currently done by hand, or with the app Circuit. We have fixed delivery days for the B2B customers and the B2C pick up points.

(M): Can you explain a bit more about these pickup points?

(O): Yes, these are farmers that cooperate with the platform, and often supply products themselves. They want to be a pickup point to attract customers to their farm, which leads to more customer contact.

(M): With how many vehicles does X work?

(O): Currently we have two vehicles available, I will send the details via mail.

(M): Where do the bottlenecks lay in the current process?

(G): Currently B2C customers only want to get delivered on Thursday. When we grow this can be a bottleneck because we will have a peak on Thursday. This will result in challenges regarding the number of vehicles that have to be available.

(O): Another problem we currently have is that sometimes we collect products from a supplier, and the next or same day we visit the supplier again to deliver products. However, it is not possible to bundle these shipments due to capacity reasons. Delivering products takes time, but when we collect products, we have time constraints, because we need to order process these products. Therefore, these vehicles cannot stop to cross-dock, which could have let to less kilometres.

(G): What you also see is that of course we want to gain more customers, to increase the volume through the SFSC. Of course, we want customers that fall in the range that we drive, but when an new customer lays far away, we do not refuse, because we want to gain new customers and increase volume which leads to lower costs per products. These are trade-offs we have to make. To tackle this problem, we are investigating the option of adding minimal order quantities, or shipment costs for customers far away.

(M): Do customers have a minimal order value or quantity?

(G): Yes, in the past we did not have this, but for B2C we are introducing a minimal order value of €25 euro and for B2B €350 euro. If the order value is below this number, the customer has to pay shipment costs, which are currently fixed. However, we want to make this variable based on delivery distance.

(M): How long does it take to collect and deliver the products on average?

(O): Currently, this is not all registered. In this cooperation we want to get this visible. But I got the routes in Circuit of the past weeks that I can share.

(M): What are important stakeholders I should know of?

(G): Suppliers, customers and the people at the hub.

(M): Any connection from the province or local authority?

(G): Yes, we have subsidies from an initiative, which helps to pay the rent of the hub. And currently we are in talks with the province or local authorities to gain more attention, however, they are slow.

(M): At what places in the current process is data registered?

(G): Quite a lot already. When an order is placed data is registered until when it gets delivered. These are mostly customers and suppliers’ details, and information regarding the order.

(M): So, no scan moments or clock times are registered?

(G): No, this is not registered at the moment. But in the future it is an option to scan when products arrive at the hub.

(M): What is currently the average order count per week, and is there an increase in this number?

(G): Yes, for sure, I will share these numbers via mail.

(M): Thanks. Lastly, what are the customer preferences?

(G): Customers want to buy local, but they want to convenience of the Albert Heijn or Sligro, and also the delivery reliability that they have. There is a difference between expectation and realization. I believe in local and short food supply chains, but this will never completely replace the retail markets. Because you always want to eat products like mango and strawberries.

(M): What is currently the delivery reliability?

(O): Because we have no inventory, sometimes fresh products cannot be delivered, because they are simply not available due to wheatear or unforeseen circumstances. Therefore, we tell customers that they we will not completely replace a catering wholesaler, but we replenish them. Therefore, we should focus now on customers that already understand us, before we start adding customers that want to test us.

(M): Maybe it is interesting to see the online buying platform?

(G): Yes, I can show this.

Information received after the interview via mail:

1. Delivery days:
   - B2C (Business to Consumer) -> Order until Tuesday 11:30 PM via the Web App -> Received by the farmers (per marketplace) at 12:00 PM -> Bulk order -> Picked up and cross-docked (distributed) at the hub on Wednesday, finished before 10:00 PM-> Delivered to pick up points on Thursday before 8:00 PM.
   - B2B (Business to Business) -> Order by Friday for delivery on Tuesday or order by Wednesday for delivery on Friday. The deadline on delivery day is 5:00 PM. Beginning of the week suitable for catering companies and businesses (company restaurants), end of the week (for the weekend) suitable for the hospitality industry.
2. Documents:
   - Hub Brabant Financial (Excel)
   - Lease contracts of vehicles (PDF)
   - Packing costs (Excel)
   - Shared transport (Excel)

3. Routes:
    - Routes from the period of February until April from the app Circuit.
4. Vehicle information:

Table 22, Vehicle specifications

Vehicle type	**Capacity**	**Euro/km**	**Fixed costs per week**
Mercedes	163 crates	€ 0,12	€ 108x
Renault	100 crates	€ 0,13	€ 77x

5. Additional questions after the interview via mail

Answered by general manager:

Q: How many inbound supplier stops are made when collecting the products?
A: On average around 32 inbound stops are made every delivery window.
Q: What is the time for loading and unloading the vehicle at a stop?
A: On average, this is around 8 minutes.
Q: How many people are working in the hub when the orders get processed?
A: 5 people.

Appendix 2: Process scheme B2B and B2C

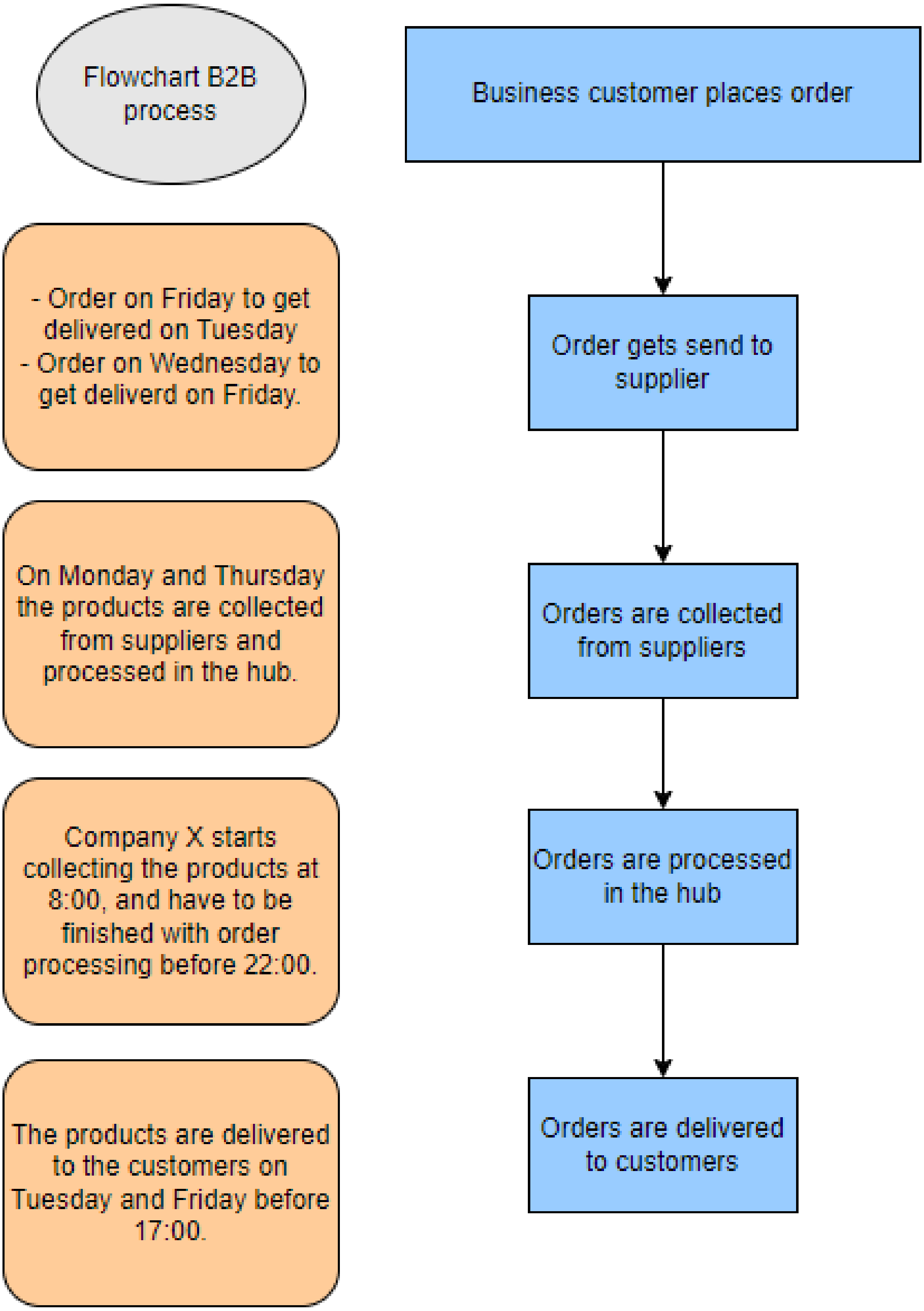


Figure 22, Process scheme B2B

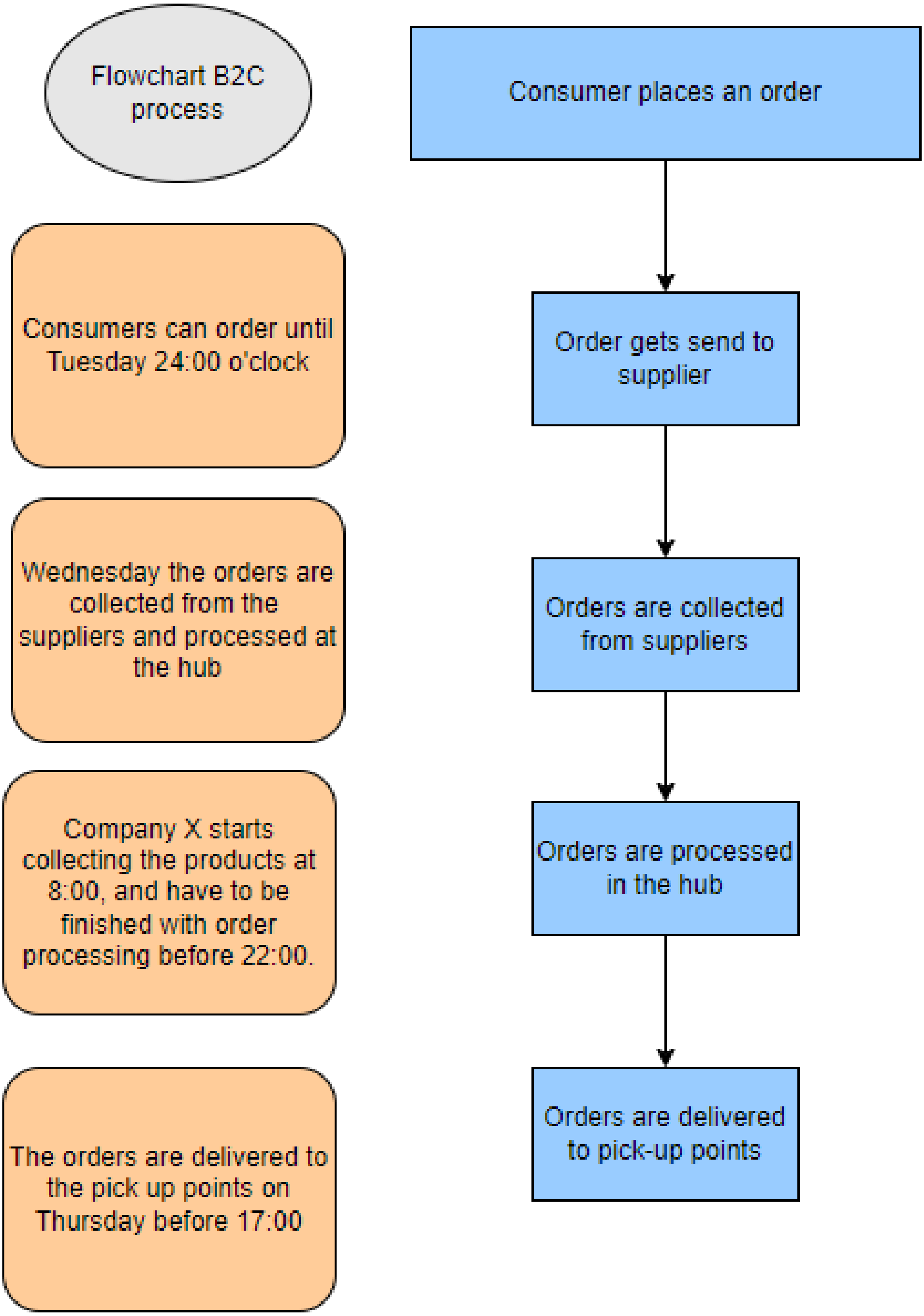


Figure 23, Process scheme B2C

Appendix 3: Operational process and details

The processes of both types of customers are similar, but slightly different. Currently, the delivery frequency to B2B customers is twice per week. Customers can order until Friday midnight to get delivered on Tuesday, and until Wednesday midnight to get delivered on Friday. Every Monday and Thursday the products are collected from the suppliers and processed in the hub. The next day the products are directly delivered to the customers (Manager & Manager, 2024).

The B2C process follows a similar pattern, with the distinction lying in the delivery method. Processed orders are directed to designated pick-up points for customer retrieval. Additionally, the delivery frequency of the B2C customers is once per week, with orders accepted until midnight on Tuesdays. After that the products are collected and processed on Wednesday and delivered to designated pick-up points on Thursday. These pick-up points are connected partners of X, primarily suppliers. Thursday is X's busiest day, starting with the collection of products in the morning for processing for B2B customers, followed by the delivery of orders to B2C customers later in the day (Manager & Manager, 2024).

The delivery window for both B2B and B2C orders, the time dedicated to picking up, processing, and delivering products, spans two days. The B2B process operates from 8:00 AM on the first day until 5:00 PM the following day. The B2C process runs from 8:00 AM on the first day until 8:00 PM the next day. All orders must be collected and processed by 10:00 PM on the first day to meet the deadline (Manager & Manager, 2024).

X currently has two vehicles available: a Renault and a Mercedes, each with its own specifications. Both vehicles are leased through a third-party company, with the option to lease additional vehicles if needed (Manager & Manager, 2024).

The routes for the inbound and outbound transport are made with the free app Circuit. This is an app that calculates the fastest route when implementing multiple addresses. Currently, some suppliers deliver their products to the hub off the record. However, X plan to streamline this process by collecting all the products themselves (Manager & Manager, 2024).

Both B2B and B2C orders are shipped and processed inside crates. Order processing requires significant labour input, and the capacity is related to how many employees are simultaneously working the hub (Manager & Manager, 2024).

Appendix 4: Variables and their definition

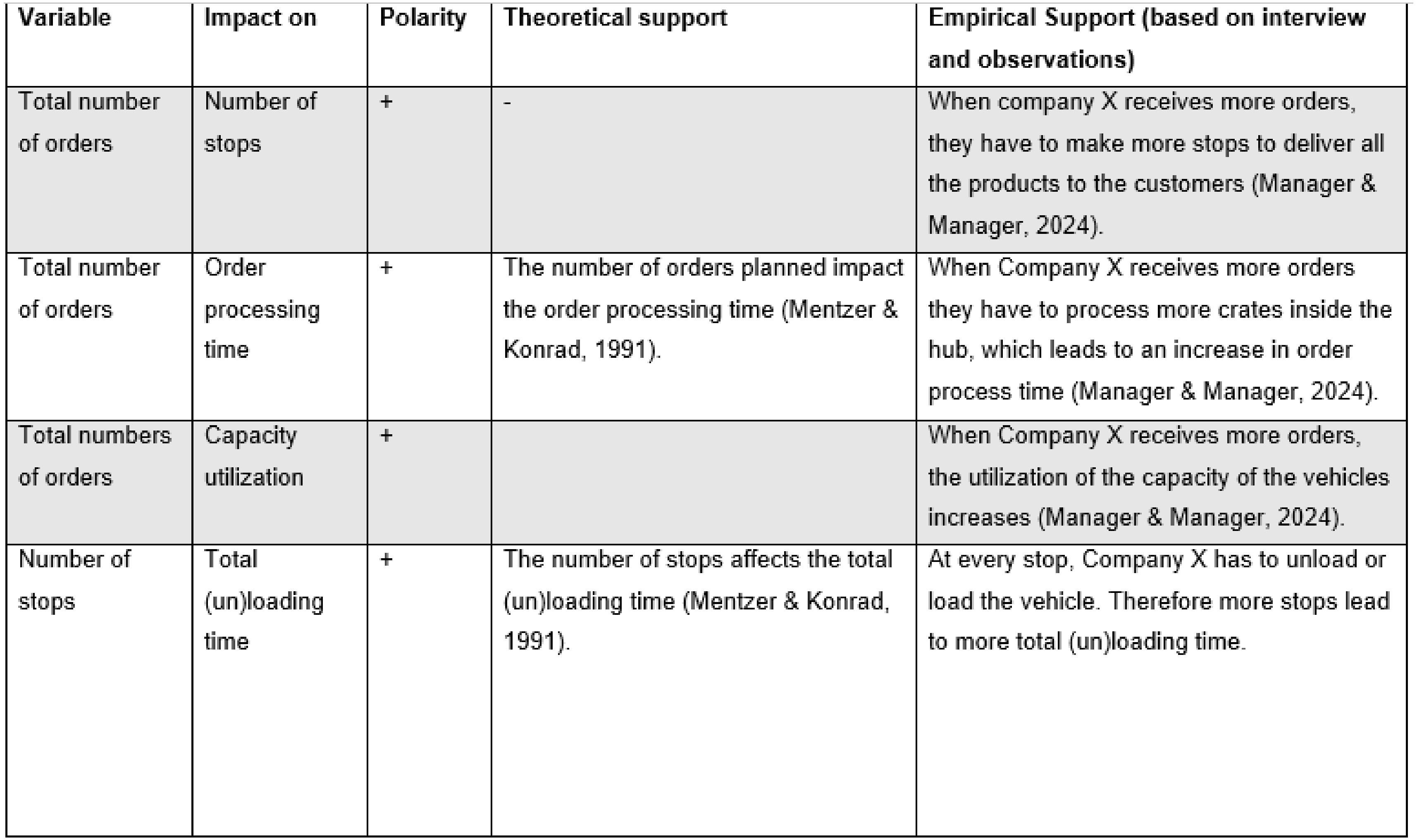
Table 23, Variables and their definition

Variable	Definition
Total number of orders	The number of B2B and B2C orders received by X.
Number of stops	The number of stops at suppliers and customers to pick up and deliver all the products.
Total (un)loading time	The time it takes to load and unload the vehicle at location at the suppliers and customers
Travel time	The time it takes to pick up and deliver all the products to the suppliers and customers.
Travel distance	The travel distance of picking up and delivering the products to suppliers and customers.
Capacity utilization	The utilization of the capacity of the vehicles when picking up and delivering the products.
Vehicle type	The type of vehicle that is used and its specifications like capacity, fuel consumption and associated fixed costs.
Vehicle costs	All the costs related to the vehicle.
Fuel consumption	The consumption of fuel per km.
Traffic congestion	Delay during transportation due to traffic.

Number of vehicles	The number of vehicles that are used.
Number of hubs	The number of hubs that are used.
Driver price/hour	The hourly labour cost attributed to driver salaries.
Number of drivers	The number of drivers that are driving.
Driver costs	The costs associated with the driver.
Transportation costs	All the costs associated with transportation.
Order processing time	The time it takes to process all the orders.
Labour/hour	The number of orders an employee process per hour.
Number of employees	The number of employees that are working in the hub to process the orders.
Employee price/hour	The hourly labour cost attributed to employee salaries.
Order processing costs	The costs associated with the processing of the orders.
Delivery frequency	The frequency per week the B2B and B2C orders can be ordered and delivered.
Lead time	The total time it takes to process the B2C and B2B orders.
Costs	The total amount of costs associated with the DND of X.
Delivery reliability	The percentage of orders that are delivered on time to the customers of X.

Appendix 5: Direct structure test

Table 24, Direct structure test



Variable	Impact on	Polarity	Theoretical support	Empirical Support (based on interview and observations)
Total number of orders	Number of stops	+	-	When company X receives more orders, they have to make more stops to deliver all the products to the customers (Manager & Manager, 2024).
Total number of orders	Order processing time	+	The number of orders planned impact the order processing time (Mentzer & Konrad, 1991).	When Company X receives more orders they have to process more crates inside the hub, which leads to an increase in order process time (Manager & Manager, 2024).
Total numbers of orders	Capacity utilization	+		When Company X receives more orders, the utilization of the capacity of the vehicles increases (Manager & Manager, 2024).
Number of stops	Total (un)loading time	+	The number of stops affects the total (un)loading time (Mentzer & Konrad, 1991).	At every stop, Company X has to unload or load the vehicle. Therefore more stops lead to more total (un)loading time.

Number of stops	Travel distance	+	-	More stops means that Company X has to visit more suppliers and customers, resulting in extra travel distance (Manager & Manager, 2024).
Travel distance	Travel time	+	More travel distance results in more travel time (Mentzer & Konrad, 1991).	An increase in travel distance increases travel time because it takes longer to cover a greater distance, resulting in more time spent on the road.
Travel distance	Fuel consumption	+	Fuel consumption is influenced by travel distance (Mentzer & Konrad, 1991).	Traveling a longer distance requires more fuel consumption because the vehicle needs to exert more energy over a greater distance, leading to increased fuel usage.
Traffic congestion	Travel time	+	Traffic congestion leads to more travel time (Christidis & Rivas, 2012).	Traffic congestion increases travel time because it slows down the movement of vehicles, resulting in delays and longer time spent on the road to cover the same distance (Manager & Manager, 2024).
Fuel consumption	Vehicle costs	+	-	An increase in fuel consumption increases vehicle costs as it directly contributes to operational expenses.

Number of vehicles	Vehicle costs	+	-	More vehicles increases vehicle costs due to more vehicle related fixed costs.
Number of Vehicles	Lead time	+	-	More vehicles reduce lead time for Company X by allowing for simultaneous usage, resulting in fewer stops per vehicle during product collection and delivery (Manager & Manager, 2024).
Vehicle Type	Capacity utilization	+	-	Using a vehicle with better specifications regarding capacity, affects capacity utilization positively.
Vehicle type	Vehicle costs	+	-	Vehicles with better specifications regarding capacity, fuel consumptions and technologies are associated with higher fixed costs. Therefore, the Mercedes at Company X is associated with higher costs than the Renault (Manager & Manager, 2024).
Vehicle costs	Transportation costs	+	-	An increase in vehicle costs results in an increase in transportation costs.

Driver price/hour	Driver costs	+	-	An increase in salary for the driver per hour, increases total driver costs.
Driver costs	Transportation costs	+	-	More driver costs result in higher total transportation costs.
Transportation costs	Costs	+	-	An increase in transportation costs results in higher total costs.
Number of hubs	Hub costs	+	More hubs increases hub costs due to more infrastructure and operational costs (Campbell, De Miranda, De Camargo, & O'Kelly, 2015).	An increase in the number of hubs leads to more hub-related costs for Company X, because each additional hub requires investment in infrastructure, staffing, and maintenance, thereby increasing operational expenses.
Labour/hour	Order processing time	-	An increase in labour/hour per employee decreases order processing time (Mentzer & Konrad, 1991).	Increased productivity among hub employees of Company X leads to a reduction in order processing time (Manager & Manager, 2024).

Lead Time	Delivery reliability	-	An increase in lead time, results in lower delivery reliability (Handfield & Pannesi, 1992).	Increased lead time can result in missed deadlines for delivery, which impacts delivery reliability.
Delivery reliability	Logistic Performance	+	An increase in delivery reliability increases logistic performance (Mentzer & Konrad, 1991).	An improvement in delivery reliability positively impacts logistic performance by ensuring consistent fulfilment of delivery requirements
Costs	Logistic Performance	-	An increase in costs negatively affects logistic performance (Mentzer & Konrad, 1991).	An increase in operational costs for Company X leads to a negative impact on logistic performance.
Lead time	Logistic performance	-	An increase in lead time negatively affects logistic performance (Mentzer & Konrad, 1991).	An increase in lead time can lead to a decrease in customer satisfaction, negatively impacting the logistic performance of Company X

Appendix 6: Causal Loop Diagram

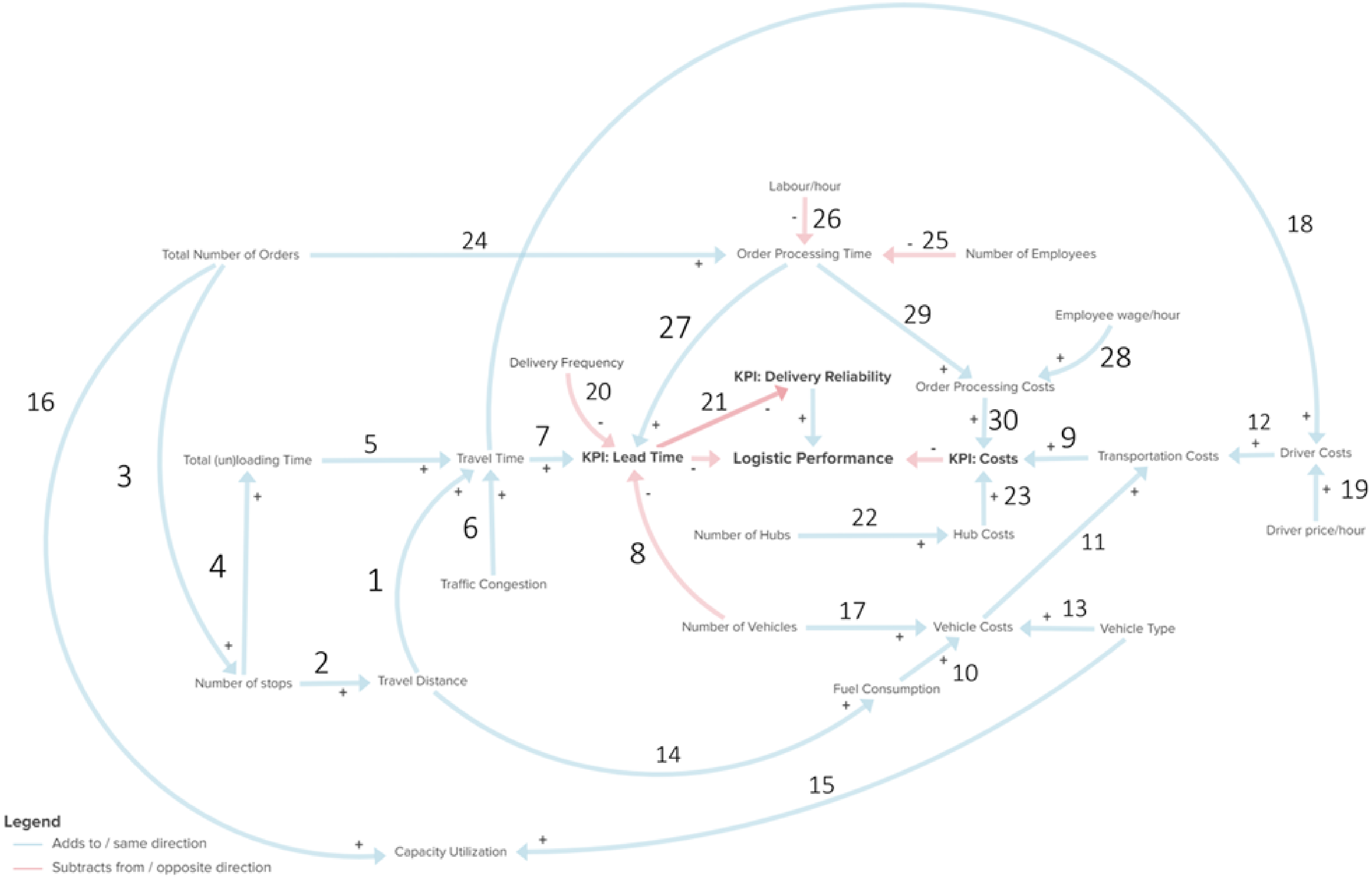


Figure 24, Causal Loop Diagram full size

Appendix 7: Explanation Causal Loop Diagram

Transportation

Transportation has effect on both the KPIs **costs** and **lead time**. The **travel time** is the time it takes to collect and deliver the products from the suppliers and to the customers. This travel time is influenced by multiple variables. First the **travel distance**, the total distance that is travelled when collecting and delivering the products from suppliers and customers (1). The travel time and distance are both influenced by the **number of stops** required for collecting and delivering products from suppliers and customers, with more stops generally leading to longer distances and times (2) (Mentzer & Konrad, 1991). The frequency of stops at customers is determined by the **number of orders** received for the particular delivery day (3). At every stop, the vehicle has to be **loaded and unloaded** (4), contributing to the overall travel time (5). Furthermore**, traffic congestion** during product collection and delivery can further extend travel duration as vehicles may experience delays in navigating through congested areas, leading to increased travel time (6) (Mentzer & Konrad, 1991). The total travel time affects the main KPI lead time because it directly impacts the time taken to deliver products (7). Increasing the **number of vehicles** can reduce the lead time by distributing the workload across multiple vehicles, thereby decreasing the time required for collecting and delivering (8).

Transportation costs are the costs associated with collecting and delivering the products from suppliers and to customers, and directly impacts total costs (9). These costs are composed of **vehicle costs**, which include expenses related to vehicle maintenance, fuel, and depreciation (10)(11), and **driver costs**, primarily consisting of wages for drivers (12). The costs of the vehicle are associated with the **vehicle type** (13), as each vehicle has unique specifications affecting **fuel consumption** and capacity. Fuel consumption refers to the amount of fuel consumed per unit of distance travelled (14), while capacity refers to the maximum load the vehicle can accommodate, which impacts **capacity utilization** (15). Capacity utilization is also impacted by the number of orders that are received, with more orders resulting in higher capacity utilization (16).

Vehicle costs increases when the number of vehicles increases (17). Driver costs are influenced by travel time since drivers are on an hourly basis (18), therefore the costs are calculated based on their **wage/hour** (19) (Mentzer & Konrad, 1991).

Increasing **delivery frequency** reduces lead time due to more frequent deliveries. However, if the volume remains constant, this can lead to higher transportation costs per product due to increased vehicle operations (20) (Krämer, 2010). Increased lead time leads to reduced **delivery reliability** because longer lead times can result in missed delivery deadlines (21) (Handfield & Pannesi, 1992).

Warehousing and order processing

As explained, the hub of X serves as consolidation point of products where the products that are collected from suppliers are processed. The **number of hubs** can influence the lead time both positively and negatively. Firstly, having more hubs distributed strategically can reduce the distance between the hubs and the customers, thereby decreasing lead time. However, an excessive number of hubs may increase complexity and transit times between hubs, potentially offsetting the benefits. Additionally, more hubs lead to more **hub costs**, which encompass fixed expenses related to each hub's operation (22), which impacts total costs (23) (Campbell, De Miranda, De Camargo, & O'Kelly, 2015).

Order processing has effect on both the main KPIs lead time and costs. The **order processing time** depends on the volume of orders received and the **number of employees** that are available. Increased order volume typically results in longer processing times (24) but increasing the number of employees can boost order processing capacity, leading to shorter processing times (25). Processing time also decreases when **labour/hour** increases (26); labour/hour refers to the quantity of crates processed by each employee per hour. Order processing time has a direct impact on the lead time (27). The **order processing costs** are composed of the total order process time multiplied by the **wage/hour of employees** (28)(29) and impacts total costs (30) (Mentzer & Konrad, 1991).

Appendix 8: Calculation of input parameters

Avg. B2B customers:

X have been operating in the hub since February 1^{st,} 2024, Therefore there is not a lot of data available. However, the actual number of customers from week 5 to week 13 is available and incorporated in the model. The starting point of the simulation will be on February 1st, 2024, starting with 4x B2B customers.

X expects to grow on average two B2B customers per month over the period of four years. Consequently, by the end of the volume increase scenario, the average weekly customer count reaches 162 (Company X, 2024).

Avg. B2C customers:

X have been operating in the hub since February 1st of 2024, therefore there is not a lot of data available. However, the actual number of customers from week 5 to 13 is available and incorporated in the model. The starting point of the simulation will be on February 1st, 2024, starting with 26.3x B2C customers.

X expects to grow on average 11 B2C customers per month over a period of four years. Consequently, by the end of the volume increase scenario, the average weekly customer count reaches 601 (Company X, 2024).

Delivery days B2B:

X currently have two delivery days for B2B customers, on Tuesday and Friday. Therefore, the number of delivery days is two (Manager & Manager, 2024).

Delivery days B2C:

X currently have one delivery day for B2C customers, on Thursday. Therefore, the number of delivery days is one (Manager & Manager, 2024).

Standard deviation B2B:

Because B2B customers are acquired more stably, and once acquired frequently place orders on a weekly basis, the standard deviation will be two in the model

Standard deviation B2C:

The standard deviation of the number of B2C customers is calculated over the period from February 1st until May 12th. The standard deviation over this period was 10.5.

Avg. order quantity B2B customer:

On average, a B2B customer orders products worth approximately six crates per order (Company X, 2024).

Avg. order quantity B2C customer:

On average, a B2C customer orders products worth approximately 1.5 crates per order (Company X, 2024).

Number of Renaults:

X uses one Renault vehicle (Manager & Manager, 2024).

Number of Mercedes':

X uses one Mercedes vehicle (Manager & Manager, 2024).

Fixed costs Renault:

The Renault vehicle used by X is leased, entailing fixed costs totalling €77x per week (Manager & Manager, 2024).

Fixed costs Mercedes:

The Mercedes vehicle used by X is leased, entailing fixed costs totalling €108x per week (Manager & Manager, 2024).

Vehicle capacity of Renault:

The capacity of the Renault vehicle is 100 crates (Manager & Manager, 2024).

Vehicle capacity of Mercedes:

The capacity of the Mercedes vehicle Is 163 crates (Manager & Manager, 2024).

Fuel consumption Renault:

The average price per kilometre due to fuel consumption for the Mercedes is €0.13 (Manager & Manager, 2024).

Fuel consumption Mercedes:

The average price per kilometre due to fuel consumption for the Mercedes is €0.12 (Manager & Manager, 2024).

Avg. time per extra trip:

The average duration of an extra trip is approximately one hour. An additional trip is scheduled when the driver cannot accommodate all the products in one trip due to capacity constraints. Once the capacity limit is reached, the driver returns to the hub to load or unload the products. The entire process, including driving back to the hub and returning to the destination, typically takes one hour. This is an judgmental parameter estimation made by the general manager of X.

Driver wage:

The average hourly wage for the drivers from February 1st to March 31st is €5x.

Bus (un)loading time per stop:

The bus (un)loading time per stop is the time it takes to load and unload the vehicle at location at the suppliers and customers. On average, this process takes around 8 minutes, which is an judgmental parameter estimation made by the general and operational manager of X (Manager & Manager, 2024).

Number of stops inbound:

The number of stops inbound refers to the number of stops X makes at suppliers to gather all the products. X make around 32 inbound stops at suppliers for a delivery window (Manager & Manager, 2024).

Avg. time per stop:

The average time per stop, refers to the duration between consecutive stops along the routes driven by X's drivers. The number is calculated by reviewing old routes driven by X, the routes are stored in the app “Circuit”. This app calculates the fastest route by all the stops and is used by X. Table 25 displays information regarding these routes, including the number of stops and total time. This data enables the calculation of average time between stops. Based on this table, which is supplemented after the sensitivity analysis, the average time per stop is 16.87 minutes.

Avg. km per stop:

The average km per stop, refers to the distance between consecutive stops along the routes driven by X's drivers. The number is calculated by reviewing old routes driven by X, the routes are stored in the app “Circuit.” Table 25 displays information regarding the routes, including the number of stops and total distance. This data enables the calculation of average distance between stops. Based on this table, which is supplemented after the sensitivity analysis, the average distance per stop is 12.2 kilometres.

Table 25, Historical data Circuit

Route	**Stops**	**Time (minutes)**	**Kilometres (km)**	**Avg. Time per stop**	**Avg. km per stop**
1	9	168	130.3	18.67	14.48
2	7	92	63.4	13.14	9.06
3	9	127	75.5	14.11	8.39
4	6	113	80.8	18.83	13.47
5	10	138	74.2	13.80	7.42
6	6	148	134.7	24.67	22.45
7	7	132	97.1	18.86	13.87
8	10	167	36.1	16.70	3.61
9	8	86	39.9	10.75	4.99
10	6	114	117.5	19.00	19.58
11	18	275	254.9	15.28	14.16
12	9	168	130.3	18.67	14.48
13	10	326	210.3	32.60	21.03
14	7	92	63.4	13.14	9.06
15	9	127	75.5	14.11	8.39
16	6	69	33.3	11.50	5.55
17	12	171	1566	14.25	13.05
18	16	249	243.07	15.56	15.19
Average	9.17	153.44	112.05	16.87	12.12

Table 26, Traffic congestion

Free flow speed of <50km/h		Free flow speed of > 80km/h	
Moving avg. 1h	Moving avg. 3h	Moving avg. 1h	Moving avg. 3h
17.8 seconds	15.6 seconds	5.4 seconds	4.3 seconds

Traffic congestion:

Traffic congestion refers to the extra time that a trip takes due to traffic. The delay in seconds per kilometre is presented in table 26 (Christidis & Rivas, 2012). Because X drive a lot on both 50 km/h and 80 km/h roads, to calculate the traffic congestion per/km, the average of the four numbers is taken, which results in a delay of 10.775 seconds per km.

Avg. customers per pick up point:

The average number of customers per pickup point represents the number of customers who collect their products from a specific pickup location. As X expands, it anticipates an increase in the number of pickup points. Currently, the model projects an average of 10 customers per pickup point (Company X, 2024)

Hub (un)loading time:

The hub unloading time refers to the time it takes to unload the vehicle after collecting products from suppliers. The hub loading time refers to the time it takes to load the vehicle after order processing. This takes around 15 minutes, which is an judgemental parameter estimation made by the general manager of X (Mount, 2011) (Manager & Manager, 2024).

Max time inbound + order processing:

The max time inbound + order processing refers to the maximum time the first day of a delivery window of two days can take. On the first day of the delivery window the orders have to be collected and processed. Currently the driver starts collecting products at 8:00 AM, and X want to be finished with order processing at max 10:00 PM. Therefore, the max time for inbound + order processing is 14 hours (Manager & Manager, 2024).

Order process speed employee

The order process speed of an employee refers to the number of orders an employee on average processes per hour. Based on data provided by X, a calculation is made to find the average order process speed per employee. In table 27 below, different days where order processing took place are shown. Based on this information it can be stated that the average order process speed per employee per hour is around 10.2 crates per hour, however after the sensitivity analysis, in discussion with the operational manager, this is raised to 11.

Table 27, Order process speed

Day	Hours	Crates	Crates/hour
1	10.9	117.0	10.7
2	13.74	145.2	10.6
3	10.25	126.4	12.3
4	21.42	179.8	8.4
5	22.17	210.0	9.5
6	13.25	128.8	9.7

Number of employees hub:

The number of employees refers to the number of employees that are working simultaneously in the hub to process the orders. Typically, five employees are employed at the hub. Consequently, this value is utilized as the input parameter in the base case (Manager & Manager, 2024).

Hub employee wage:

The wage per hour for the hub employees is on average €4x over the period of February 1st, 2024, until March 31st.

Hub fixed costs:

The hub fixed costs refer to the monthly costs associated with the use of the hub. This mostly includes rent. The hub fixed costs are €2.6x per week (Company X, 2024).

Max time delivery B2B:

The maximum delivery time for B2B refers to the second day of the two-day delivery window. X begins deliveries at 8:00 AM and aims to complete them by 5:00 PM, aligning with the preferred delivery window of their B2B customers. Therefore, the maximum delivery time is 9 hours (Manager & Manager, 2024).

Max time delivery B2C:
The maximum delivery time for B2C refers to the second day of the two-day delivery window. X begins deliveries at 8:00 AM and aims to complete them by 8:00 PM. B2C products are delivered to pick up points, which are partners of Company X, allowing for later delivery times. Thus, the maximum delivery time is 12 hours (Manager & Manager, 2024)

Appendix 9: Simulation model

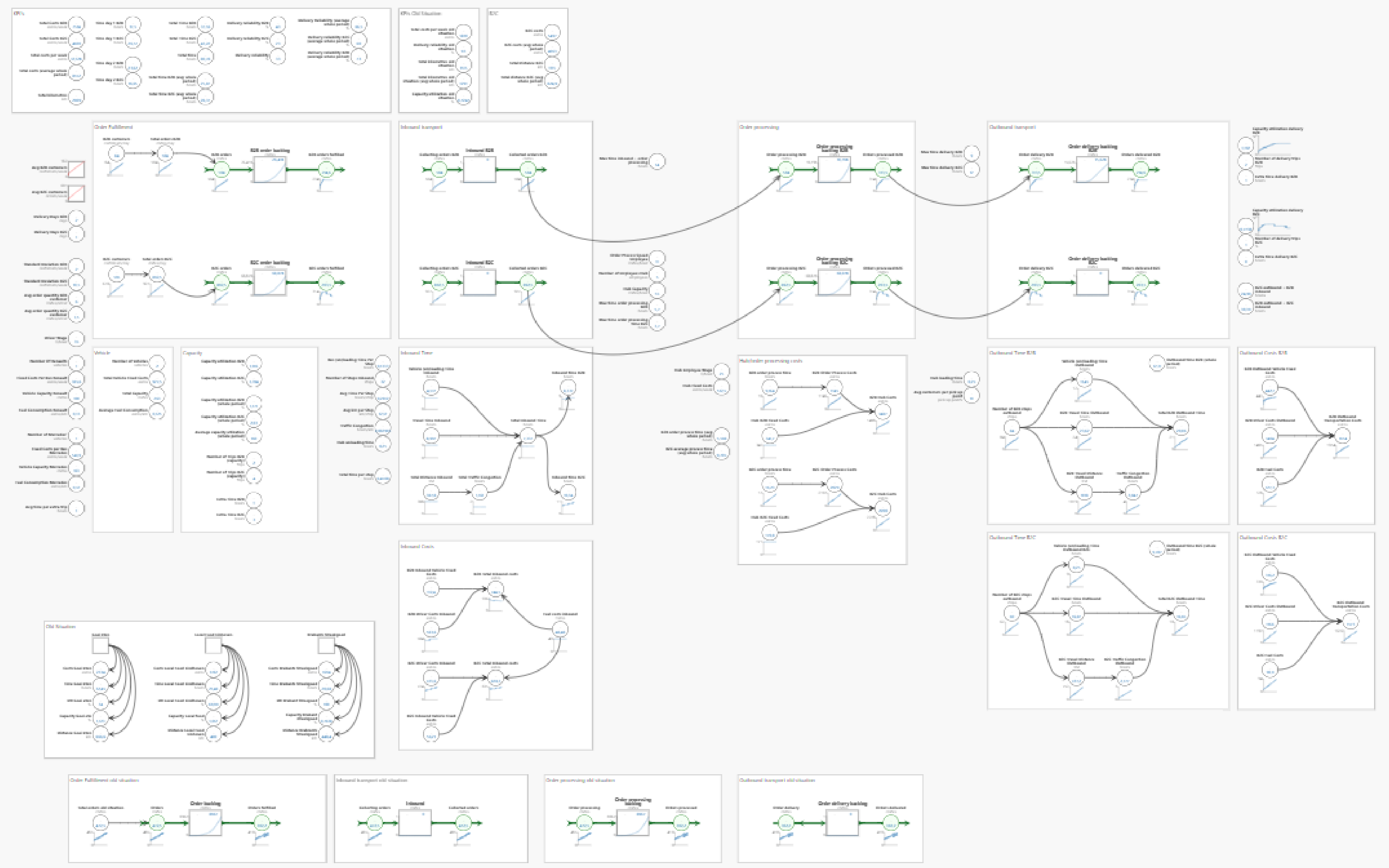
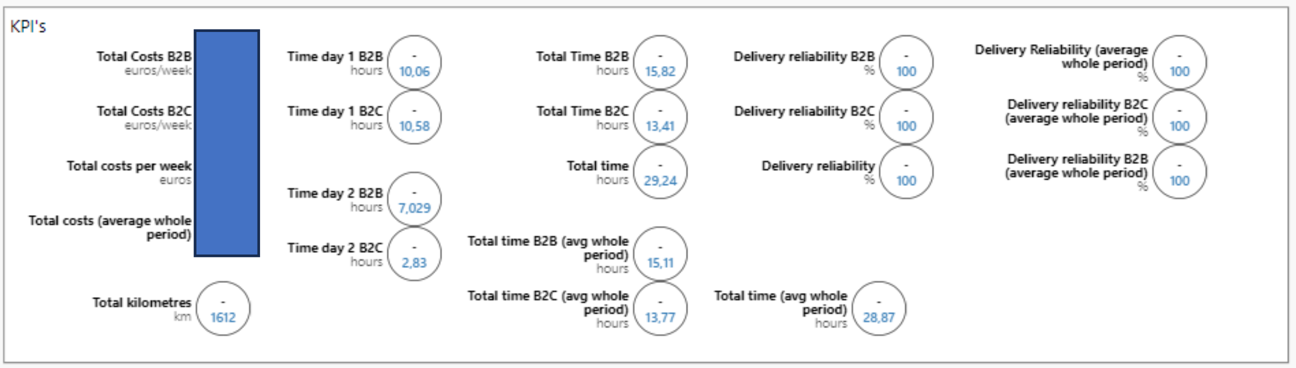


Figure 25, Simulation model

Appendix 10: Description of simulation model

In this Appendix, the simulation model is displayed. Due to its size, it is divided into several screenshots. The formulas for the independent variables are presented below the screenshots.

KPI's:



KPI's

Total Costs B2B euros/week
Total Costs B2C euros/week
Total costs per week euros
Total costs (average whole period)
Total kilometres km - 1612

Time day 1 B2B hours - 10,06
Time day 1 B2C hours - 10,58
Time day 2 B2B hours - 7,029
Time day 2 B2C hours - 2,83

Total Time B2B hours - 15,82
Total Time B2C hours - 13,41
Total time hours - 29,24
Total time B2B (avg whole period) hours - 15,11
Total time B2C (avg whole period) hours - 13,77

Delivery reliability B2B % - 100
Delivery reliability B2C % - 100
Delivery reliability % - 100
Total time (avg whole period) hours - 28,87

Delivery Reliability (average whole period) % - 100
Delivery reliability B2C (average whole period) % - 100
Delivery reliability B2B (average whole period) % - 100

Figure 26, KPIs

This dashboard displays the relevant KPIs for this study. There is a distinction between the KPIs: some are calculated over the entire simulation period, while others are based on specific moments in time. To clarify, KPIs calculated over the whole period are marked with "(avg. whole period)" after their names.

Total costs B2B:

if "B2B customers" = 0

then ("Total Vehicle Fixed Costs" + "Hub Fixed Costs")/2

else

(("B2B Driver Costs Inbound" + "B2B Driver Costs Outbound" + "B2B Order Process Costs" + "Fuel costs inbound" + "B2B Fuel Costs") * "Delivery Days B2B") + "Hub B2B Fixed Costs" + "B2B Inbound Vehicle Fixed Costs" + "B2B Outbound Vehicle Fixed Costs"

Total costs B2C:

if "B2C customers" = 0

then ("Total Vehicle Fixed Costs" + "Hub Fixed Costs")/2

else

(("B2C Driver Costs Inbound" + "B2C Driver Costs Outbound" + "B2C Order Process Costs" + "Fuel costs inbound" + "B2C Fuel Costs") * "Delivery Days B2C") + "Hub B2C Fixed Costs" + "B2C Inbound Vehicle Fixed Costs" + "B2C Outbound Vehicle Fixed Costs"

Total costs per week:
"Total Costs B2B" + "Total Costs B2C"

Total costs (average whole period):
moving_avg(“Total costs per week", 256)

Total kilometres:
("Total Distance Inbound"* "Delivery Days B2C") +("Total Distance Inbound" * "Delivery Days B2B") + "B2B Travel Distance Outbound" + "B2C Travel Distance Outbound"

Time day 1 B2B:
"Inbound time B2B" + "B2B order process time"

Time day 1 B2C:
"Inbound time B2C" + "B2C order process time"

Time day 2 B2B:
"B2B Travel Time Outbound"

Time day 2 B2C:
"B2C Travel Time Outbound"

Total Time B2B:
"Inbound time B2B" + "B2B order process time" + "Total B2B Outbound Time"

Total Time B2C:
"Inbound time B2C" + "B2C order process time" + "Total B2C Outbound Time"

Total Time:

"Total Time B2B" + "Total Time B2C"

Total time B2B (avg. whole period):

moving_avg ("Total Time B2B", 256)

Total time B2C (avg. whole period):

moving_avg ("Total Time B2C", 256)

Delivery reliability B2B:

(("B2B orders fulfilled"/"B2B orders") *100)

Delivery reliability B2C:

(("B2C orders fulfilled"/ "B2C orders") * 100)

Delivery reliability:

(("Delivery reliability B2C" + "Delivery reliability B2B") /2)

Delivery Reliability (average whole period):

("Delivery reliability B2B (average whole period)"+"Delivery reliability B2C (average whole period)") /2

Delivery reliability B2C (average whole period):

round(moving_avg(("B2C orders fulfilled"/"B2C orders") , 256) , 2) *100

Delivery reliability B2B (average whole period)

round(moving_avg(("B2B orders fulfilled"/"B2B orders") , 256) , 2) * 100

KPI’s old and bundled situation:

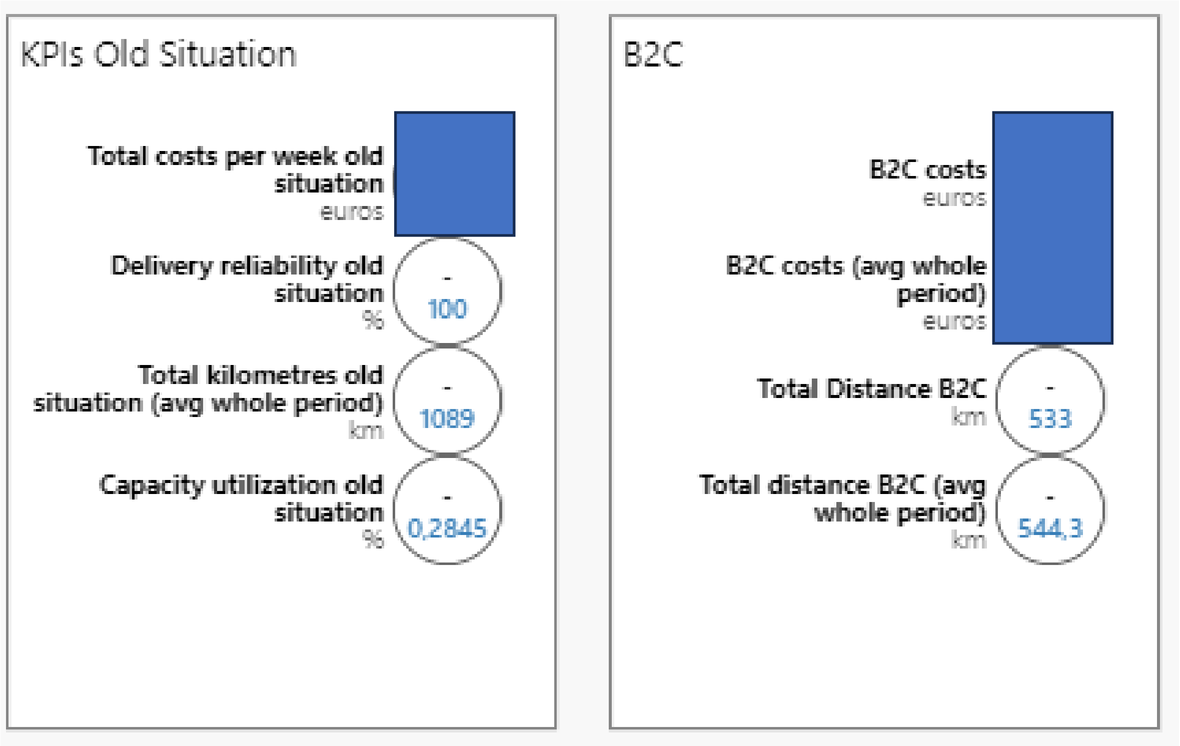


Figure 27, KPIs old situation and bundled

This dashboard shows the KPI’s of the old situation on the left, and the bundled situation of the three B2C initiatives on the right.

Total costs per week old situation:

"Costs Initiative 3" + "Costs Initiative 1" + "Costs Initiative 2"

Delivery reliability old situation:

moving_avg(("DR Initiative 1" + "DR Initiative 3" + "DR Initiative 2") /3 , 256)

Total kilometres old situation:

"Distance Initiative 3" + "Distance Initiative 2" + "Distance Initiative 1"

Total kilometres old situation (avg. whole period):

moving_avg("Total kilometres old situation", 256)

Capacity utilization old situation:

("Capacity Initiative 1" + "Capacity Initiative 3" + "Capacity initiative 2") /4

B2C costs:

if "B2C customers" = 0

then ("Total Vehicle Fixed Costs" + "Hub Fixed Costs")/2

else

(("B2C Driver Costs Inbound" + "B2C Driver Costs Outbound"

+ "B2C Order Process Costs" + "Fuel costs inbound" + "B2C Fuel Costs") * "Delivery Days B2C") + "Hub Fixed Costs" + "Total Vehicle Fixed Costs"

B2C costs (avg. whole period):

Moving_avg(“B2C costs”, 256)

Total Distance B2C:

("Total Distance Inbound"* "Delivery Days B2C") + "B2C Travel Distance Outbound"

Total distance B2C (avg. whole period):

moving_avg("Total Distance B2C", 256)

Order fulfilment:

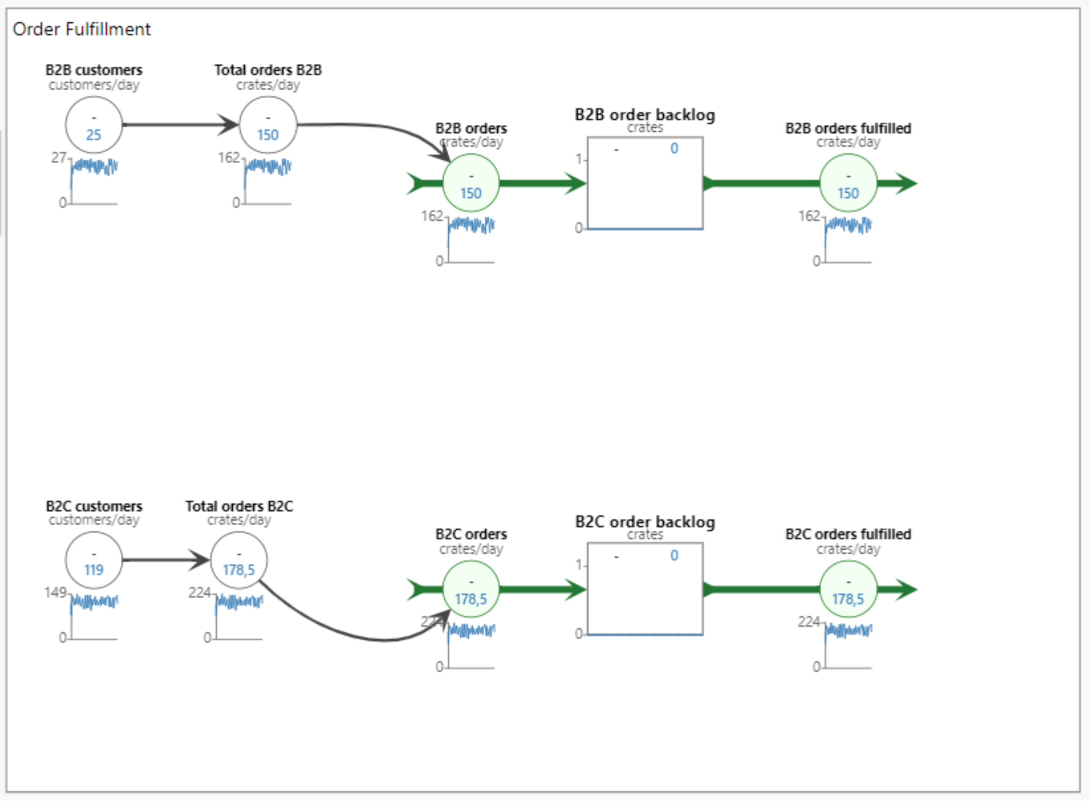


Figure 28, Order fulfilment

This screenshot displays the order fulfilment rate of X for a specific week.

B2B customers:

ceil(rand_gaussian("Avg. B2B customers"("time") / "Delivery Days B2B", "Standard Deviation B2B"))

Total orders B2B:

"B2B customers"*"Avg. order quantity B2B customer"

B2B orders fulfilled:

"Orders delivered B2B"

B2C customers:

ceil(rand_gaussian("Avg. B2C customers" ("time") / "Delivery Days B2C", "Standard Deviation B2C"))

Total orders B2C:

"B2C customers"*"Avg. order quantity B2C customer"

B2C orders:

"Total orders B2C"

B2C orders fulfilled:

"Orders delivered B2C"

Inbound transport:

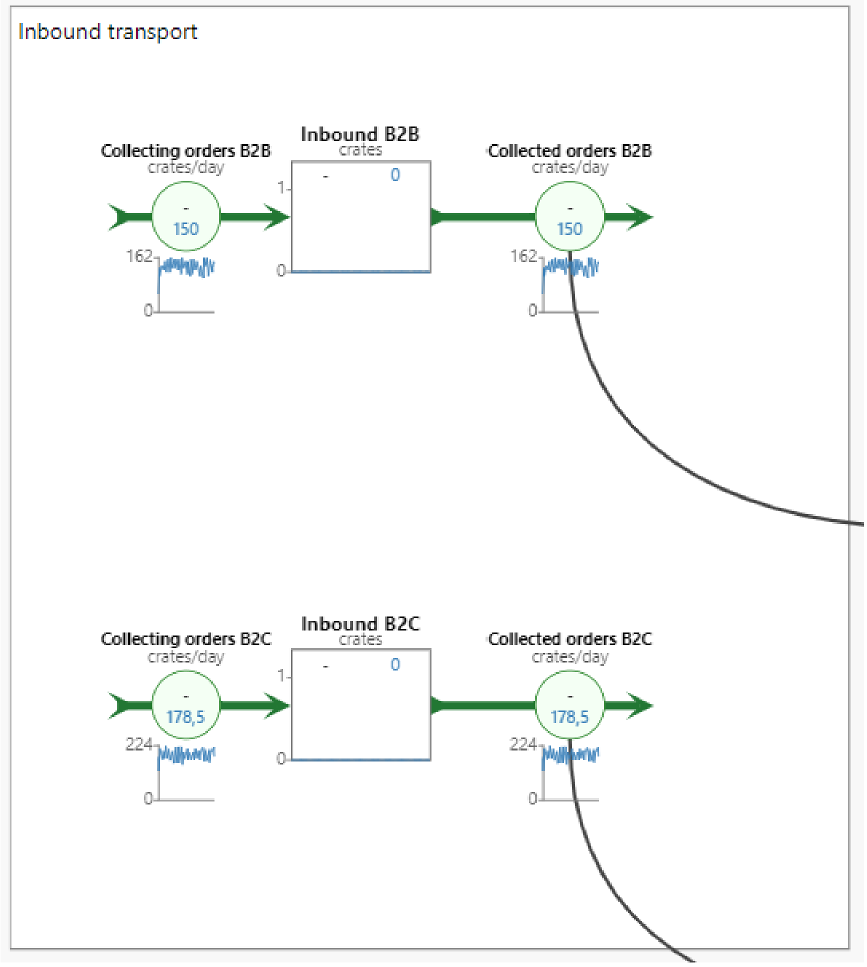


Figure 29, Inbound transport

This screenshot indicates whether all the orders scheduled for collection within a specific week have been successfully collected.

Collecting orders B2B:

```
if "Number of Vehicles" = 0
or "Delivery Days B2B" = 0
then 0
else  "Total orders B2B"
```

Collected orders B2B:

```
if "Inbound time B2B" < "Max time inbound + order processing"
then "Collecting orders B2B"
else (("Max time inbound + order processing" - ("Hub unloading time" * "Number of Vehicles") ) / ("Total time per stop" + "Avg. time per extra trip"))* "Total Capacity"
```

Collecting orders B2C:

```
if "Number of Vehicles" = 0
or "Delivery Days B2C" = 0
then 0
else "Total orders B2C"
```

Collected orders B2C:

```
if "Inbound time B2C" < "Max time inbound + order processing"
then "Collecting orders B2C"
else (("Max time inbound + order processing" - ("Hub unloading time" * "Number of Vehicles") ) / ("Total time per stop" + "Avg. time per extra trip")) * "Total Capacity"
```

Order processing:

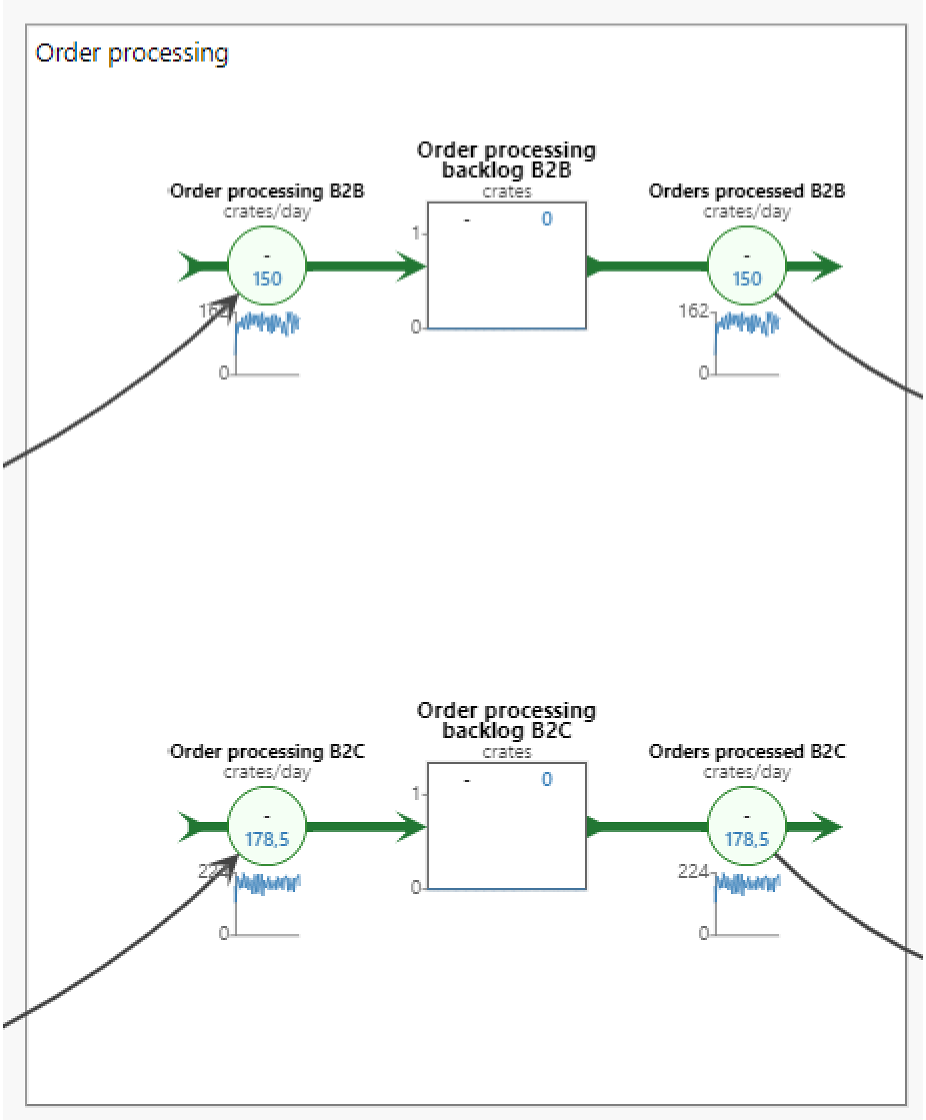


Figure 30, Order processing

This screenshot illustrates the order processing workflow at X and indicates whether all required orders have been successfully processed.

Order processing B2B :

if "Number of Employees Hub" = 0

then 0

else "Collected orders B2B"

Orders processed B2B :

if ("Total orders B2B" / "Hub Capacity") < "Max time order processing B2B" then "Order processing B2B"

else "Max time order processing B2B" * "Hub Capacity"

Order processing B2C:

if "Number of Employees Hub" = 0

then 0

else "Collected orders B2C"

Orders processed B2C :

if ("Total orders B2C" / "Hub Capacity") < "Max time order processing time B2C"

then "Order processing B2C"

else "Max time order processing time B2C" * "Hub Capacity"

Max time order processing B2B:

round(if "Max time inbound + order processing" - "Inbound time B2B" < 0

then 0

else "Max time inbound + order processing" - "Inbound time B2B", 1)

Max time order processing time B2C:

round(if "Max time inbound + order processing" - "Inbound time B2C" < 0

then 0

else "Max time inbound + order processing" - "Inbound time B2C" , 1)

Outbound transport:

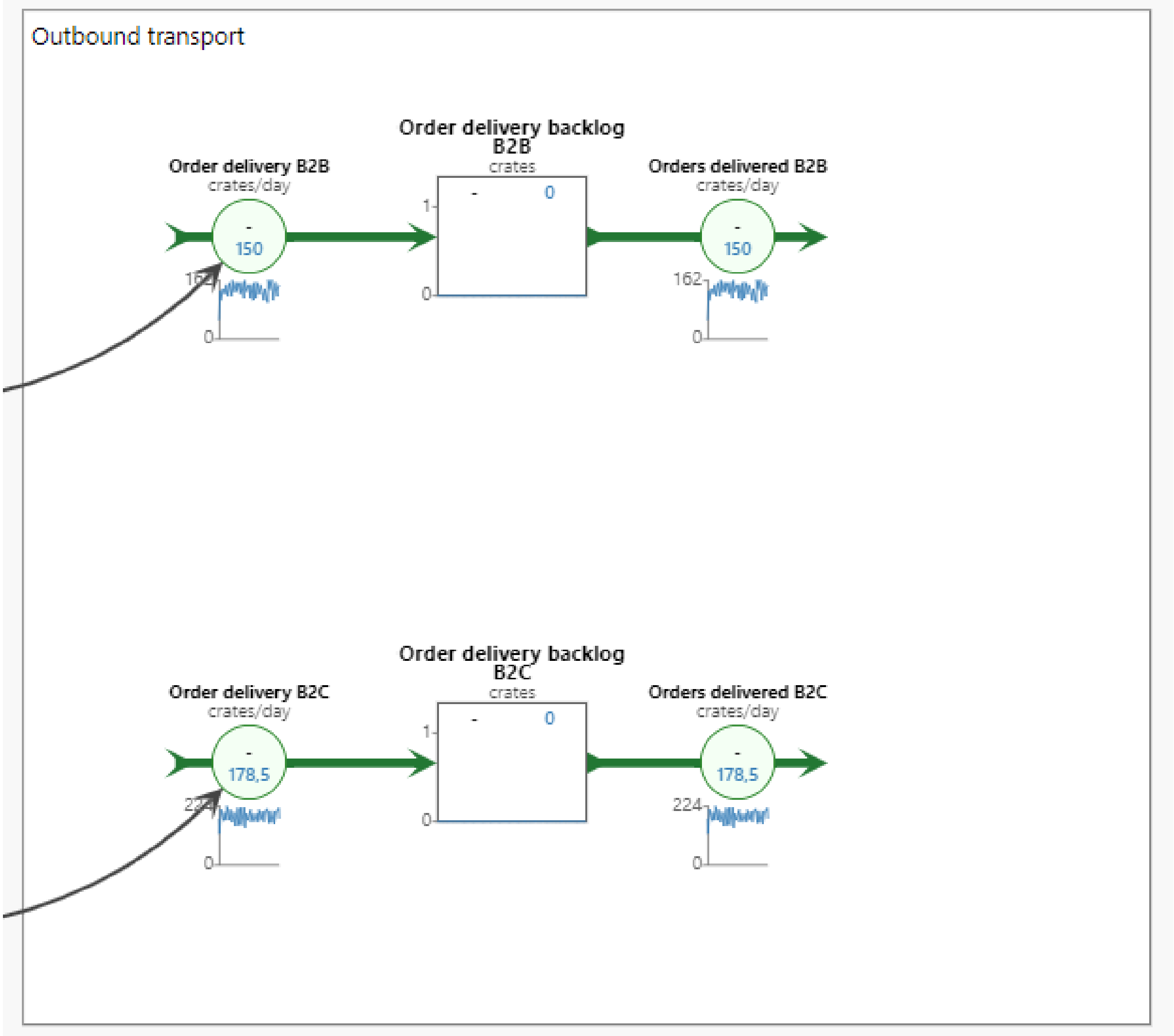


Figure 31, Outbound transport

This screenshot displays the outbound transportation process at X and confirms whether all scheduled deliveries have been completed. It also shows capacity utilization and any additional time required as a result.

Order delivery B2B:

if "Orders processed B2B" < "Total orders B2B"
then "Max time order processing B2B" * "Hub Capacity"
else "Orders processed B2B"

Orders delivered B2B:

if "Total B2B Outbound Time" < "Max time delivery B2B"

or "Order delivery B2B" = 0
then "Order delivery B2B"
else min("Order delivery B2B", (("Max time delivery B2B" - ("Hub loading time" * "Number of Vehicles")) / (((ceil(("Total Capacity" / "Avg. order quantity B2B customer")) * "Total time per stop" + "Avg. time per extra trip") / "Number of Vehicles")) * "Total Capacity")

Order delivery B2C:
if "Orders processed B2C" < "Total orders B2C"
then "Max time order processing time B2C" * "Hub Capacity"
else "Orders processed B2C"

Orders delivered B2C:
if "Total B2C Outbound Time" < "Max time delivery B2C"
or "Order delivery B2C" = 0
then "Order delivery B2C"
else
min("Order delivery B2C", (("Max time delivery B2C" - ("Hub loading time" * "Number of Vehicles")) / (((ceil(("Total Capacity"/("Avg. order quantity B2C customer" * "Avg. customers per pick up point"))) * "Total time per stop" + "Avg. time per extra trip") / "Number of Vehicles")) * "Total Capacity"))

Capacity utilization delivery B2B:
"Order delivery B2B"/ "Total Capacity"

Number of delivery trips B2B:
ceil("Capacity utilization delivery B2B")

Extra time delivery B2B:
if "Number of delivery trips B2B" = 0
then 0
else ("Number of delivery trips B2B" -1) * "Avg. time per extra trip"

Capacity utilization delivery B2C:

"Order delivery B2C"/ "Total Capacity"

Number of delivery trips B2C:

ceil("Capacity utilization delivery B2C")

Extra time delivery B2C:

if "Number of delivery trips B2C" = 0

then 0

else ("Number of delivery trips B2C" -1) * "Avg. time per extra trip"

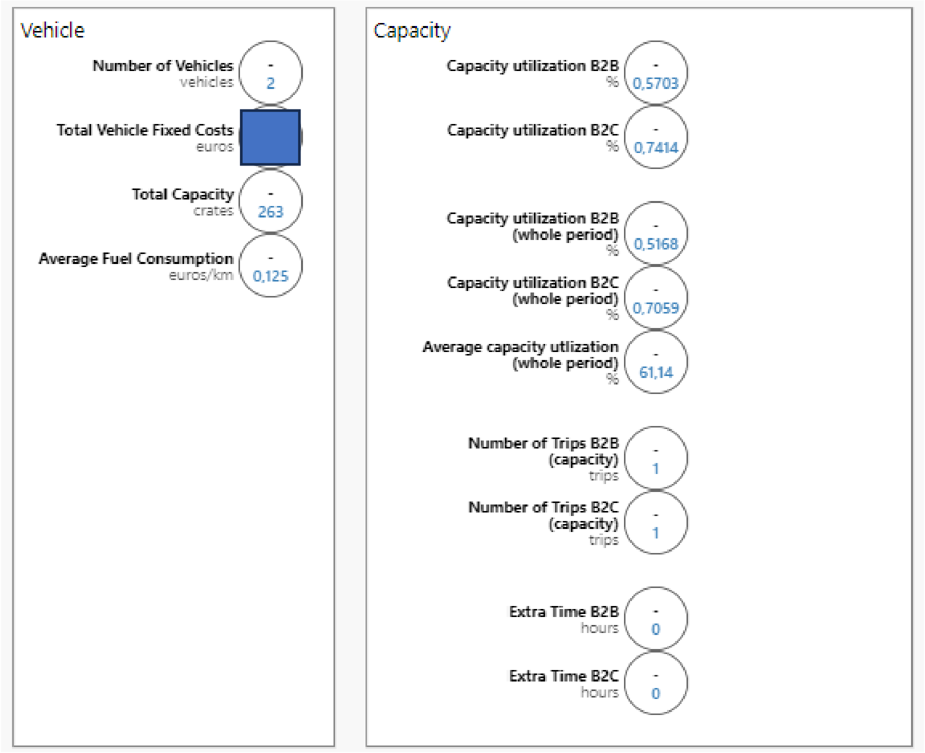
B2C outbound + B2B inbound

round("Inbound time B2B" +"Total B2C Outbound Time", 2)

B2B outbound + B2C inbound:

round("Inbound time B2C" + "Total B2B Outbound Time", 2)

Vehicle and inbound capacity:



Vehicle

Number of Vehicles	vehicles	2
Total Vehicle Fixed Costs	euros	
Total Capacity	crates	263
Average Fuel Consumption	euros/km	0,125

Capacity

Capacity utilization B2B	%	0,5703
Capacity utilization B2C	%	0,7414
Capacity utilization B2B (whole period)	%	0,5168
Capacity utilization B2C (whole period)	%	0,7059
Average capacity utlization (whole period)	%	61,14
Number of Trips B2B (capacity)	trips	1
Number of Trips B2C (capacity)	trips	1
Extra Time B2B	hours	0
Extra Time B2C	hours	0

Figure 32, vehicle specifications and inbound capacity utilization

This screenshot provides vehicle-related information, including inbound transport capacity utilization, and highlights any additional time required as a result.

Number of Vehicles:
"Number of Mercedes"' + "Number Of Renaults"

Total Vehicle Fixed Costs:
("Fixed Costs Per Bus Renault" * "Number Of Renaults") + ("Fixed Costs per Bus Mercedes" * "Number of Mercedes"')

Total Capacity:
("Number Of Renaults" * "Vehicle Capacity Renault") + ("Number of Mercedes"' * "Vehicle Capacity Mercedes")

Average Fuel Consumption:
("Fuel Consumption Mercedes" +"Fuel Consumption Renault") / 2

Capacity utilization B2B:
"Total orders B2B"/"Total Capacity"

Capacity utilization B2C:
"Total orders B2C"/ "Total Capacity"

Capacity utilization B2B (whole period):
moving_avg("Capacity utilization B2B", 256)

Capacity utilization B2C (whole period):
moving_avg("Capacity utilization B2C", 256)

Average capacity utilization (whole period):
round(moving_avg(("Capacity utilization B2B"+"Capacity utilization B2C")/2, 256) * 100)

Number of Trips B2B (capacity):

ceil("B2B orders" / "Total Capacity")

Number of Trips B2C (capacity):

ceil("B2C orders" /"Total Capacity")

Extra Time B2B:

if "Number of Trips B2B (capacity)" = 0

then 0

else ("Number of Trips B2B (capacity)" -1) * "Avg. time per extra trip"

Extra Time B2C:

if "Number of Trips B2C (capacity)" = 0

then 0

else ("Number of Trips B2C (capacity)"-1) * "Avg. time per extra trip"

Inbound time:

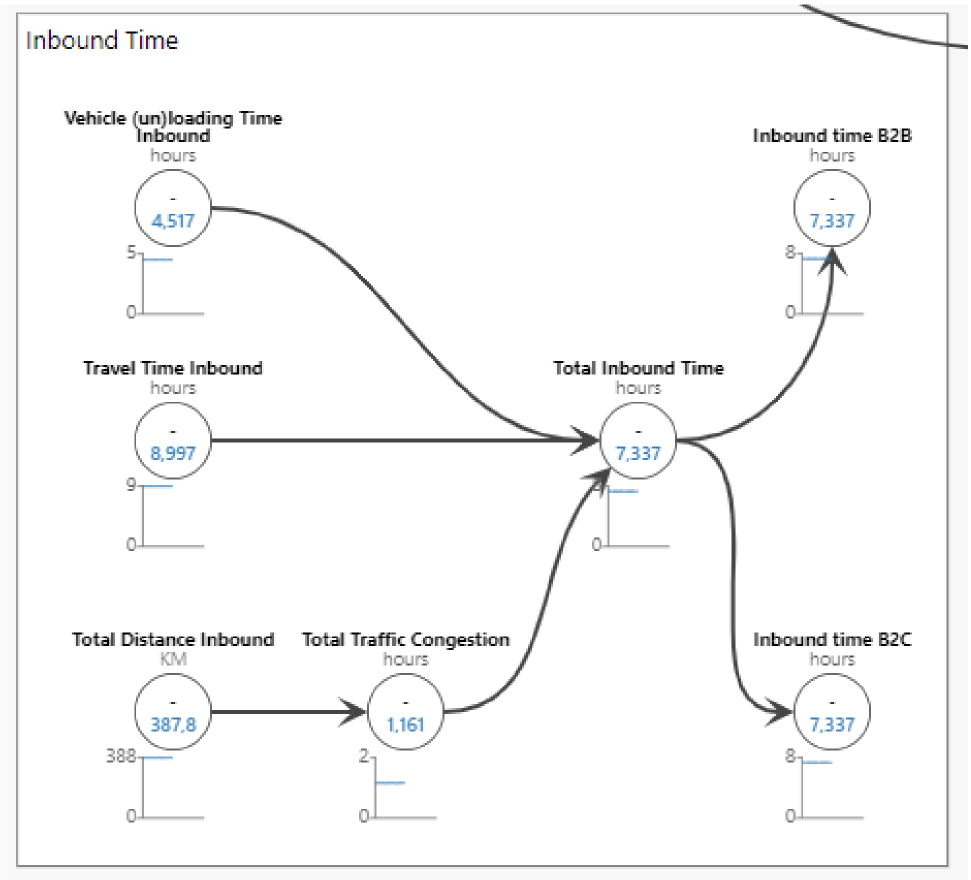


Figure 33, Inbound lead time

This screenshot illustrates the inbound transport time for both the B2B and B2C processes at X.

Vehicle (un)loading Time Inbound:
"Bus (un)loading Time Per Stop"*"Number of Stops Inbound" + "Hub unloading time"

Travel Time Inbound:
"Number of Stops Inbound" * "Avg. Time Per Stop"

Total Distance Inbound:
"Avg. km per Stop" * "Number of Stops Inbound"

Total Traffic Congestion:
"Total Distance Inbound" * "Traffic Congestion"

Total Inbound Time:
("Vehicle (un)loading Time Inbound" + "Travel Time Inbound" + "Total Traffic Congestion") / "Number of Vehicles"

Inbound time B2B:
if "B2B customers" = 0
then 0
else "Extra Time B2B" + "Total Inbound Time"

Inbound time B2C:
if "B2C customers" = 0
then 0
else "Extra Time B2C" + "Total Inbound Time"

Inbound costs:

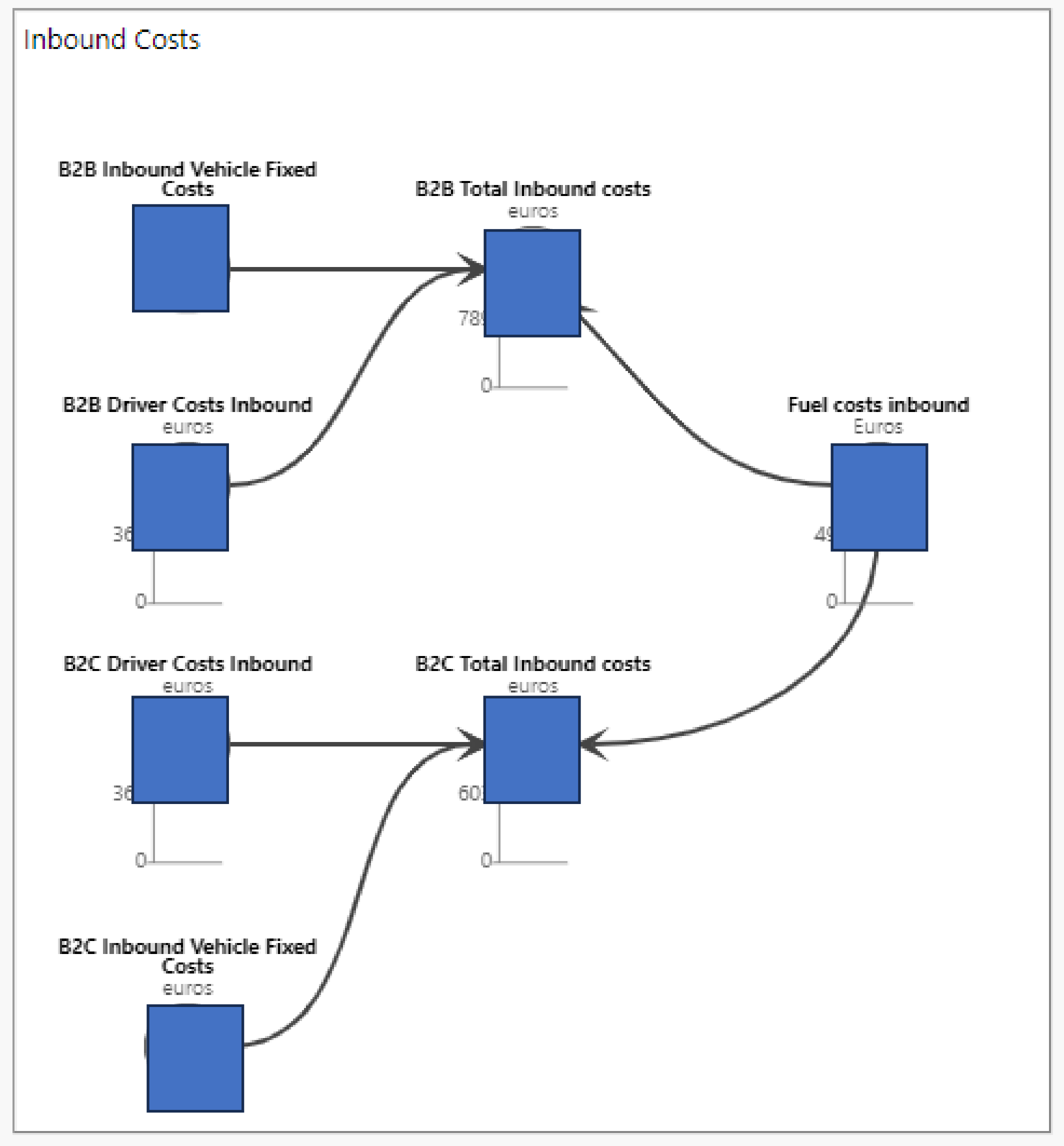


Figure 34, Inbound costs

This screenshot displays the costs associated with inbound transport.

Fuel costs inbound:

"Average Fuel Consumption" * "Total Distance Inbound"

B2B Inbound Vehicle Fixed Costs:

((("Delivery Days B2B" / ("Delivery Days B2B" + "Delivery Days B2C")) * "Total Distance Inbound") / ("Total Distance Inbound" + "B2C Travel Distance Outbound" + "B2B Travel Distance Outbound")) * "Total Vehicle Fixed Costs"

B2B Driver Costs Inbound:

("Driver Wage"* "Inbound time B2B") * "Number of Vehicles"

B2B Total Inbound costs:

"B2B Inbound Vehicle Fixed Costs" + "B2B Driver Costs Inbound" + "Fuel costs inbound"

B2C Driver Costs Inbound:

("Inbound time B2C" * "Driver Wage") * "Number of Vehicles"

B2C Inbound Vehicle Fixed Costs:

((("Delivery Days B2C" / ("Delivery Days B2B" + "Delivery Days B2C")) * "Total Distance Inbound") / ("Total Distance Inbound" + "B2C Travel Distance Outbound" + "B2B Travel Distance Outbound")) * "Total Vehicle Fixed Costs"

B2C Total Inbound costs:

"B2C Inbound Vehicle Fixed Costs" + "B2C Driver Costs Inbound" + "Fuel costs inbound"

Order processing costs:

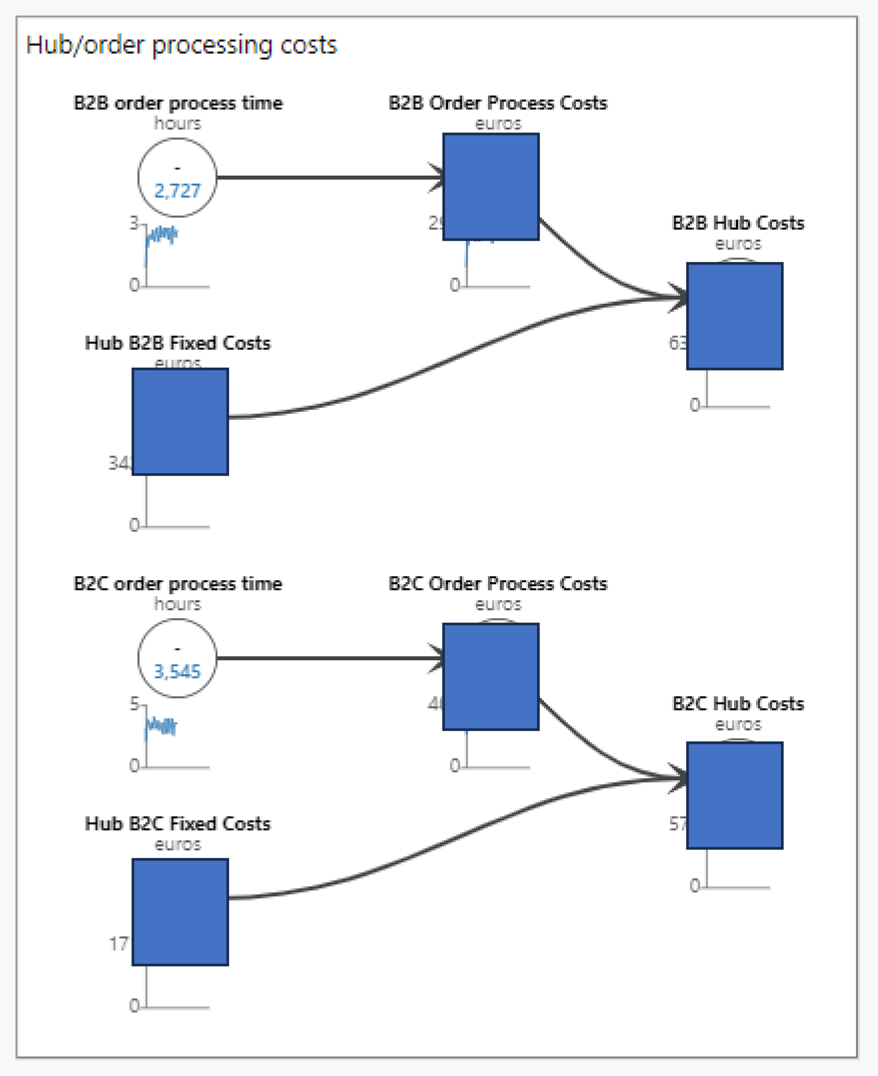


Figure 35, Order processing costs

This screenshot shows the order processing time for both the B2B and B2C processes, along with the costs associated with order processing.

B2B order process time:

"B2B orders" / "Hub Capacity"

B2B Order Process Costs:

"Hub Employee Wage" * "B2B order process time" * "Number of Employees Hub"

Hub B2B Fixed Costs:

"Hub Fixed Costs" * ("Delivery Days B2B" / ("Delivery Days B2B" + "Delivery Days B2C"))

B2B Hub Costs:

"Hub B2B Fixed Costs" + "B2B Order Process Costs"

B2C Order Process Time:

round("B2C orders"/ "Hub Capacity",2)

B2C Order Process Costs:

"B2C order process time" * "Hub Employee Wage" * "Number of Employees Hub"

Hub B2C Fixed Costs:

"Hub Fixed Costs" * ("Delivery Days B2C" / ("Delivery Days B2B" + "Delivery Days B2C"))

B2C Hub Costs:

"B2C Order Process Costs" + "Hub B2C Fixed Costs

B2B order process time (avg. whole period):

moving_avg("B2B order process time", 256)

B2C average process time (avg. whole period):

moving_avg("B2C order process time", 256)

Outbound time and costs B2B:

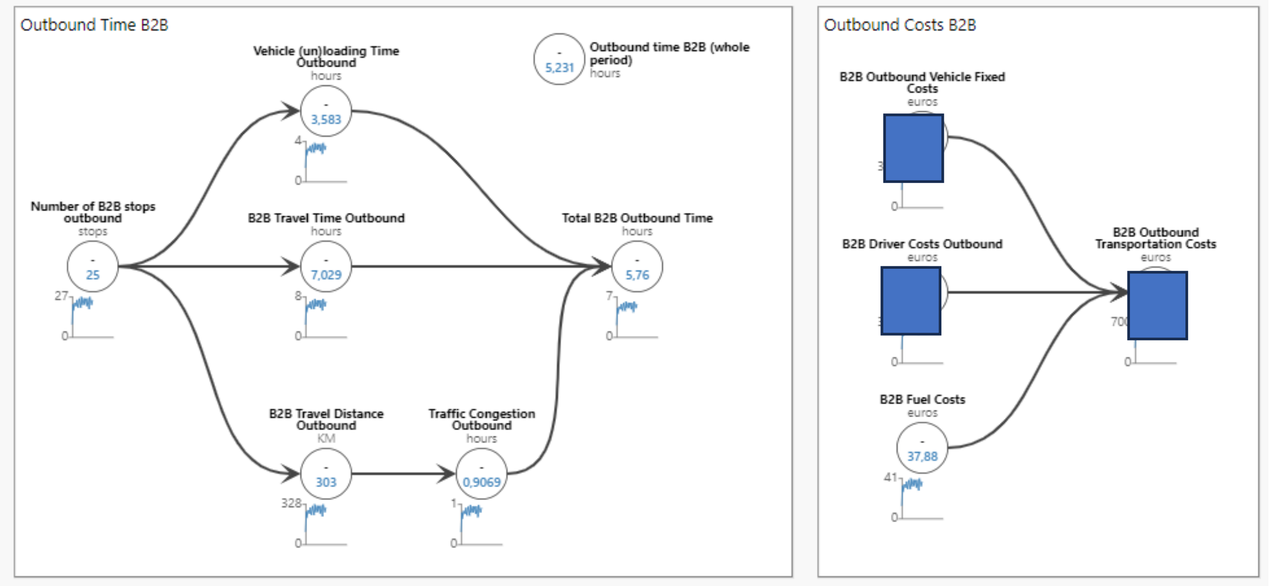


Figure 36, B2B outbound time and costs

This screenshot displays the outbound delivery time for B2B customers and the associated costs.

Number of B2B stops outbound:

"B2B customers"

Vehicle (un)loading Time Outbound:

"Number of B2B stops outbound" * "Bus (un)loading Time Per Stop" + "Hub loading time"

B2B Travel Time Outbound:

"Number of B2B stops outbound" * "Avg. Time Per Stop"

B2B Travel Distance Outbound:

"Avg. km per Stop" * "Number of B2B stops outbound"

Total B2B Outbound Time:

if "B2B customers" = 0

then 0

else: (("B2B Travel Time Outbound" +"Traffic Congestion Outbound" +"Vehicle (un)loading Time Outbound") / "Number of Vehicles") + "Extra Time B2B"

Outbound time B2B (whole period):

moving_avg("Total B2B Outbound Time", 256)

B2B Outbound Vehicle Fixed Costs:

(("B2B Travel Distance Outbound") / ("Total Distance Inbound" + "B2C Travel Distance Outbound" + "B2B Travel Distance Outbound")) * "Total Vehicle Fixed Costs"

B2B Driver Costs Outbound:

("Total B2B Outbound Time" * "Driver Wage") * "Number of Vehicles"

B2B Fuel Costs:

"Average Fuel Consumption" * "B2B Travel Distance Outbound"

B2B Outbound Transportation Costs:

"B2B Driver Costs Outbound" + "B2B Outbound Vehicle Fixed Costs" + "B2B Fuel Costs"

Outbound time and costs B2C:

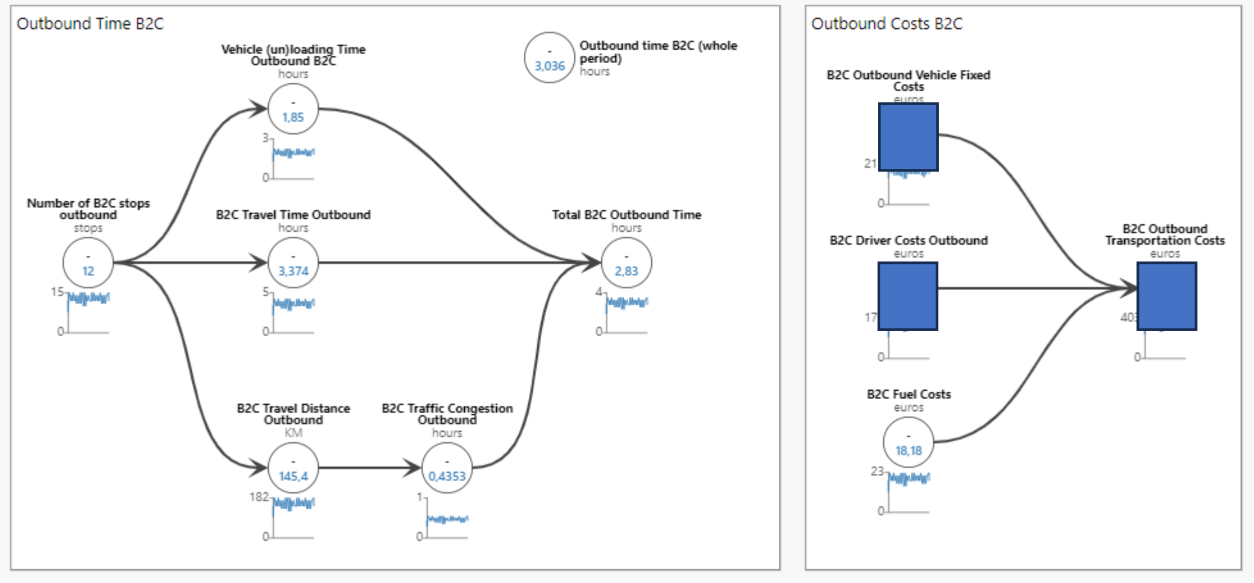


Figure 37, B2C outbound time and costs

This screenshot displays the outbound delivery time for B2C customers and the associated costs.

Number of B2C stops outbound:

ceil("B2C customers"/"Avg. customers per pick up point")

Vehicle (un)loading Time Outbound B2C:

"Number of B2C stops outbound" * "Bus (un)loading Time Per Stop" + "Hub loading time"

B2C Travel Time Outbound:

"Avg. Time Per Stop" * "Number of B2C stops outbound"

B2C Travel Distance Outbound:

"Avg. km per Stop" * "Number of B2C stops outbound"

B2C Traffic Congestion Outbound:

"B2C Travel Distance Outbound" * "Traffic Congestion"

Total B2C Outbound Time:

round(if "B2C customers" = 0
then 0
else (("B2C Travel Time Outbound" + "B2C Traffic Congestion Outbound" + "Vehicle (un)loading Time Outbound B2C") / "Number of Vehicles") + "Extra Time B2C" , 2)

Outbound time B2C (whole period):

moving_avg("Total B2C Outbound Time", 256)

B2C Outbound Vehicle Fixed Costs:

("B2C Travel Distance Outbound" / ("Total Distance Inbound" + "B2C Travel Distance Outbound" + "B2B Travel Distance Outbound")) * "Total Vehicle Fixed Costs"

B2C Driver Costs Outbound:

("Total B2C Outbound Time" * "Driver Wage") * "Number of Vehicles"

B2C Fuel Costs:

"Average Fuel Consumption" * "B2C Travel Distance Outbound"

B2C Outbound Transportation Costs:

"B2C Driver Costs Outbound" + "B2C Outbound Vehicle Fixed Costs" + "B2C Fuel Costs"

Old situation values

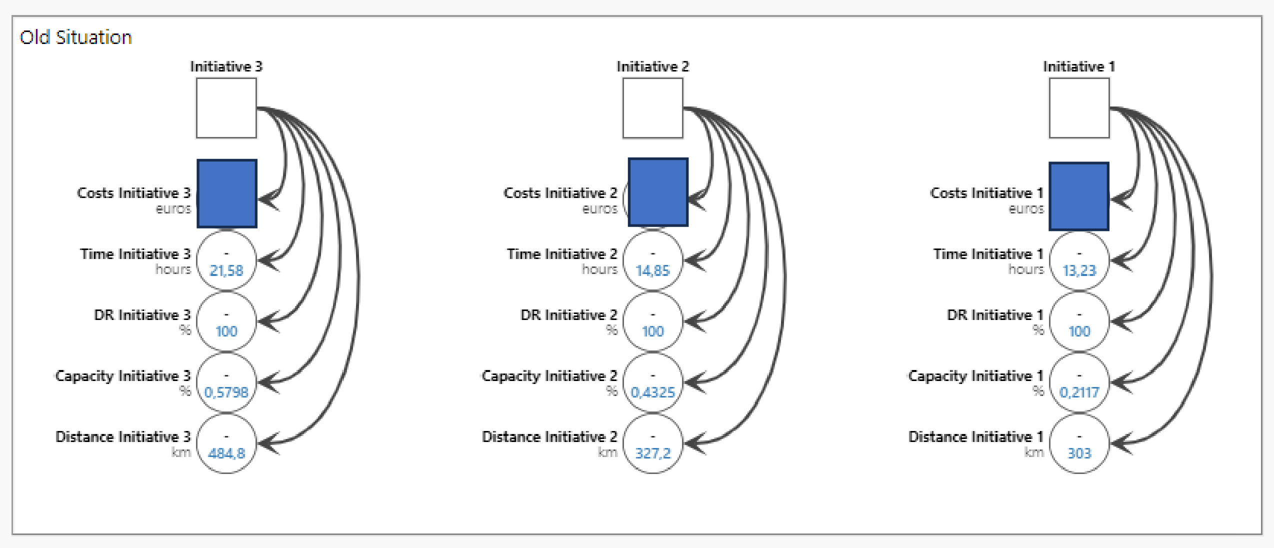


Figure 38, Values old situation

The screenshot displays values imported from the sub-models.

Order fulfilment old situation

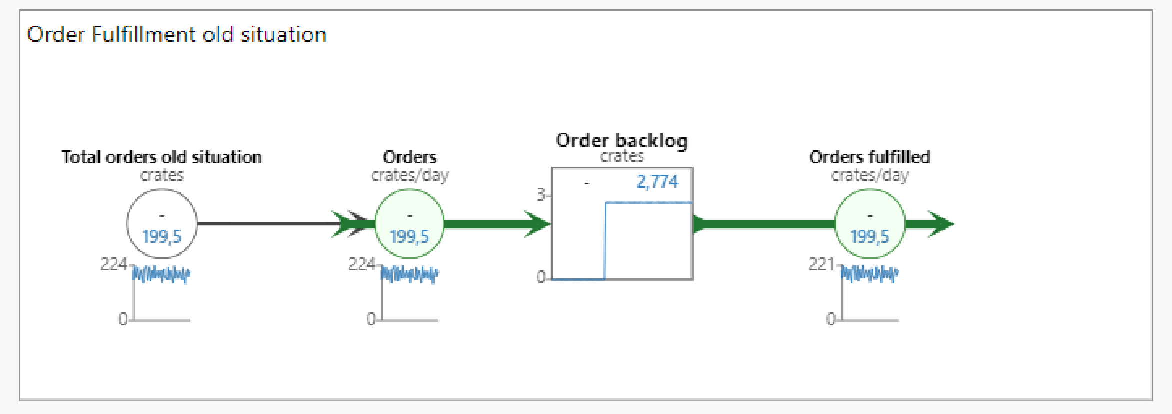


Figure 39, Order fulfilment old situation

This screenshot shows the combined order fulfilment rates for the three initiatives in the previous situation.

Total orders old situation:

"Initiative 1"->"Total orders" + "Initiative 3"->"Total orders" + "Initiative 2"->"Total orders"

Orders:

"Total orders old situation"

Orders fulfilled:

"Initiative 1"->"Orders delivered" + "Initiative 3"->"Orders delivered" + "Initiative 2"->"Orders delivered"

Inbound transport old situation:

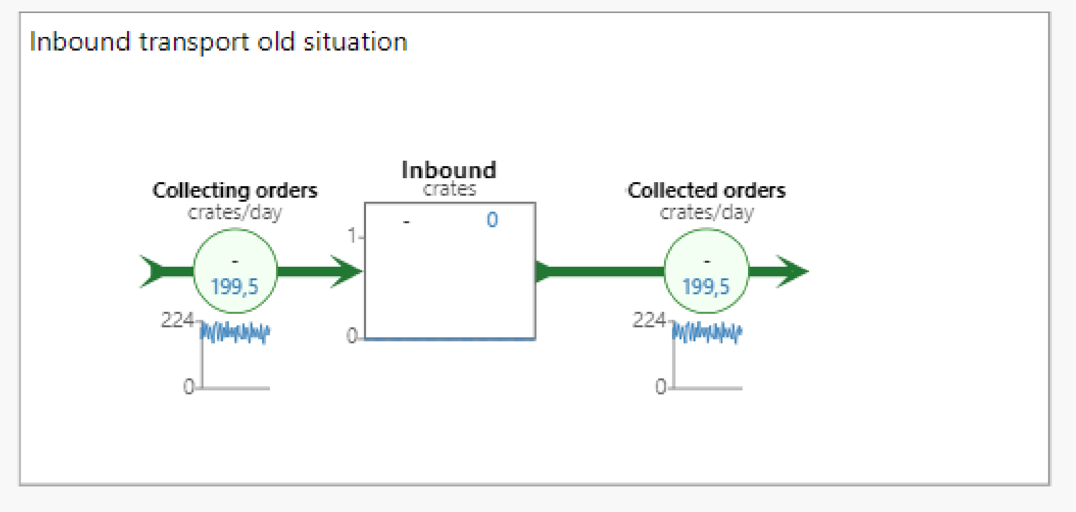


Figure 40, Inbound transport old situation

This screenshot indicates whether all the orders scheduled for collection within a specific week have been successfully collected in the previous situation of the three initiatives combined.

Collecting orders:

"Total orders old situation"

Collected orders:

"Initiative 1"->"Collected orders" + "Initiative 3"->"Collected orders" + "Initiative 2"->"Collected orders"

Order processing old situation:

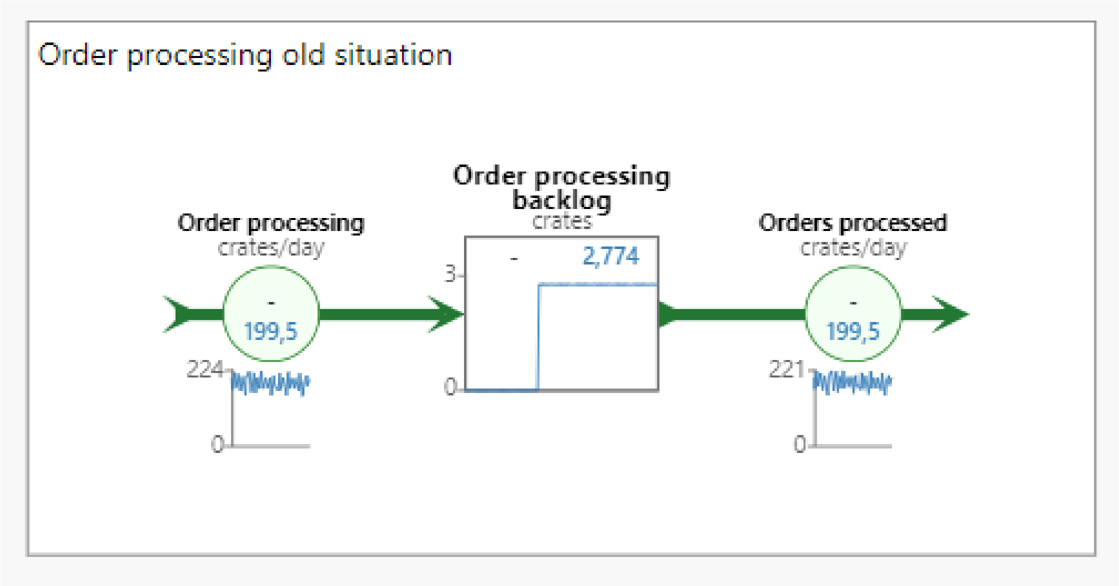


Figure 41, Order processing old situation

This screenshot illustrates the order processing workflow at X and indicates whether all required orders have been successfully processed in the previous situation of the three initiatives combined.

Order processing:

"Initiative 1"->"Order processing" + "Initiative 3"->"Order processing" + "Initiative 2"->"Order processing"

Orders processed:

"Initiative 1"->"Orders processed" + "Initiative 3"->"Orders processed" + "Initiative 2"->"Orders processed"

Outbound transport old situation:

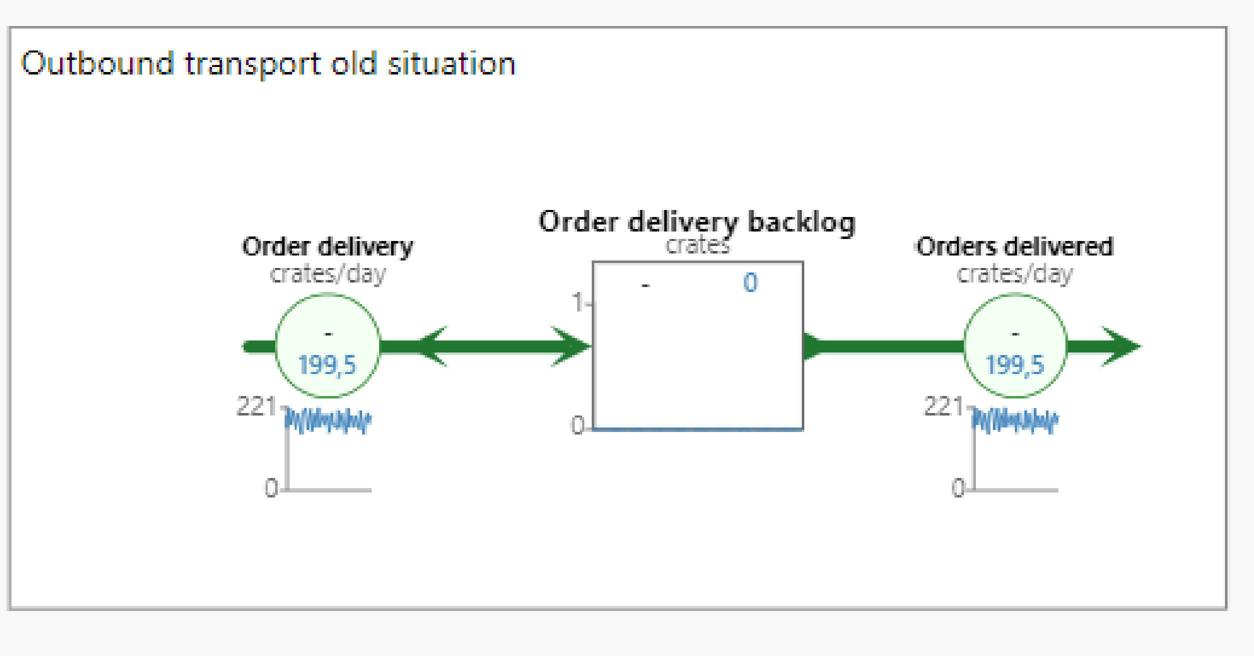


Figure 42, Outbound transport old situation

This screenshot displays the outbound transportation process at X and confirms whether all scheduled deliveries have been completed, in the previous situation of the three initiatives combined.

Order delivery:

"Initiative 1"->"Order delivery" + "Initiative 3"->"Order delivery" + "Initiative 2"->"Order delivery"

Orders delivered:

"Initiative 1"->"Orders delivered" + "Initiative 3"->"Orders delivered" + "Initiative 2"->"Orders delivered"

Appendix 11: Sub-model

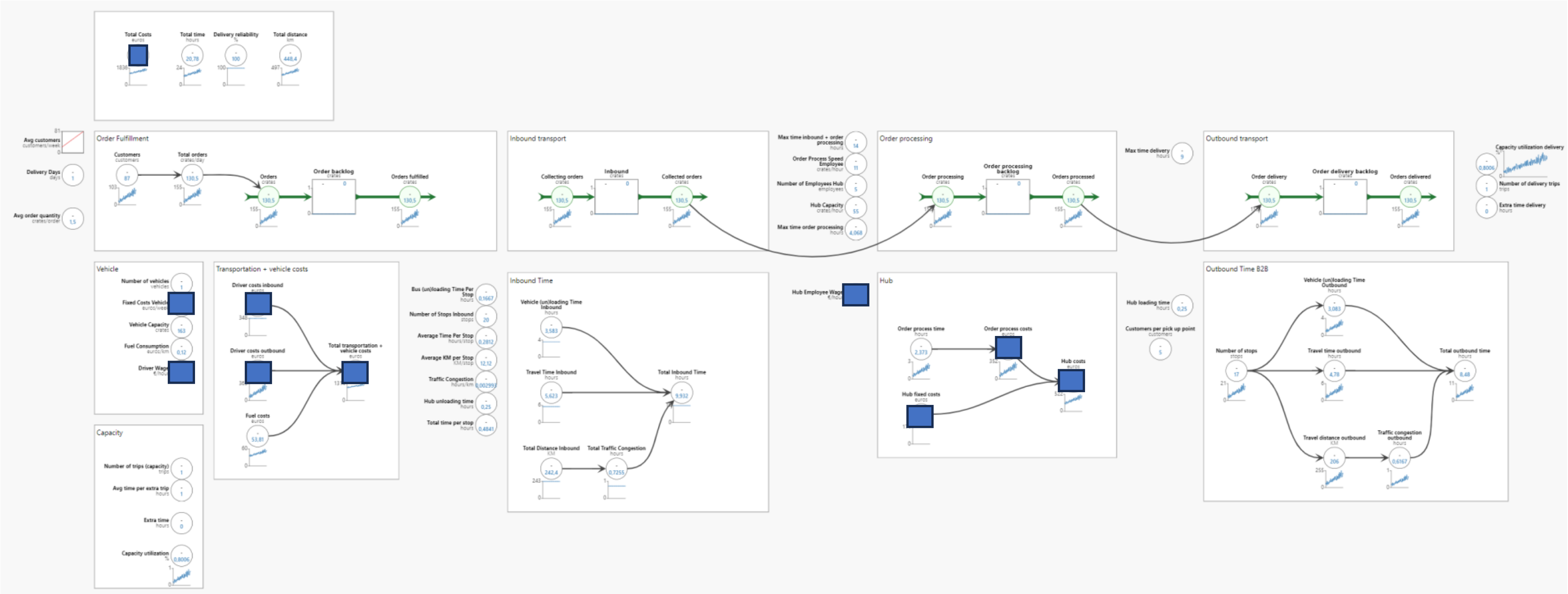


Figure 43, Sub-model

This screenshot displays the sub-model for "Initiative 1." The other models are identical, differing only in their input variables. Detailed, zoomed-in images are provided on the following pages.

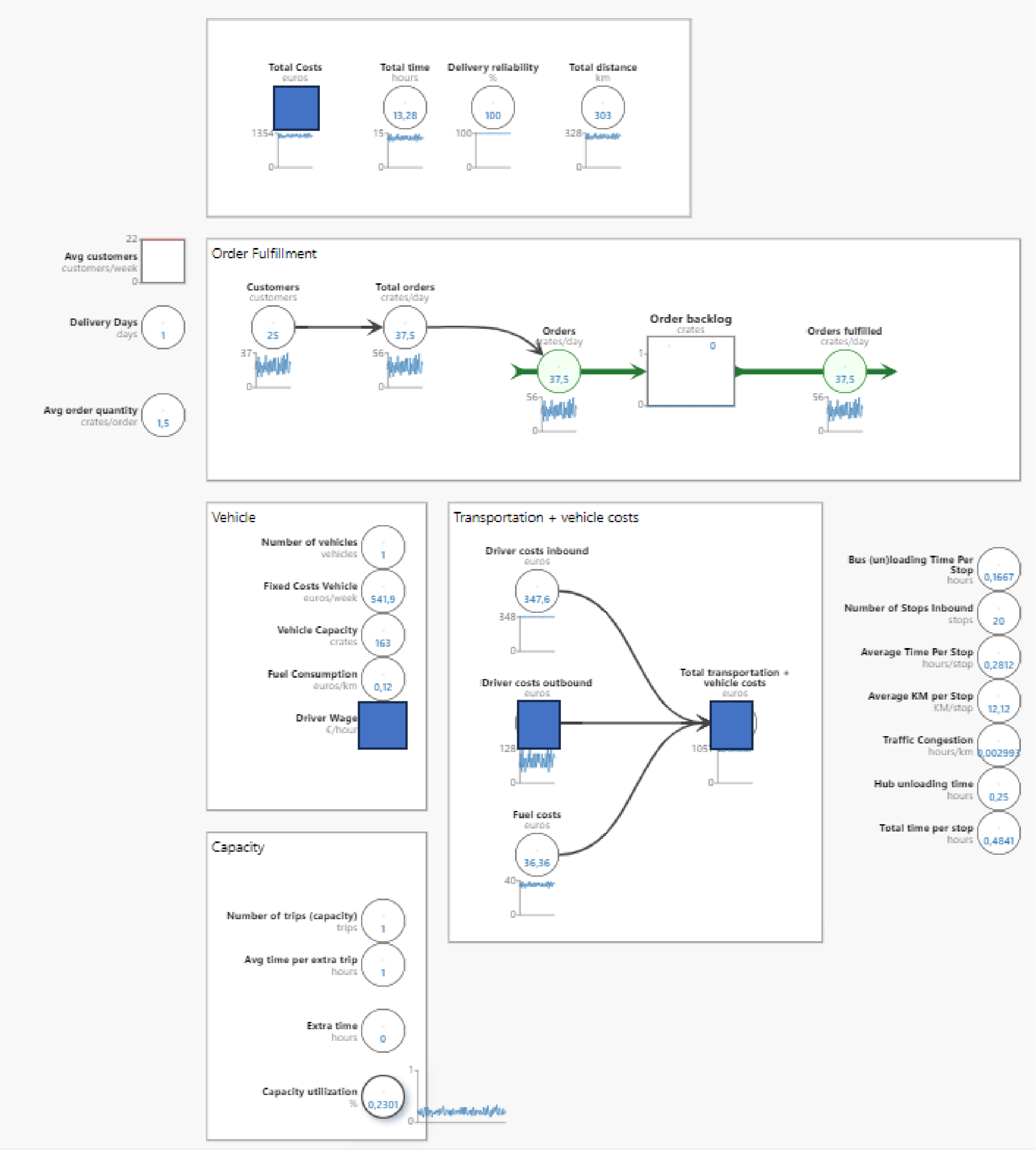


Figure 44, Sub-model screenshot 1

Figure 44 displays the order fulfilment process, including vehicle information and transportation costs. Figure 45 illustrates the inbound transport process and order processing procedures.

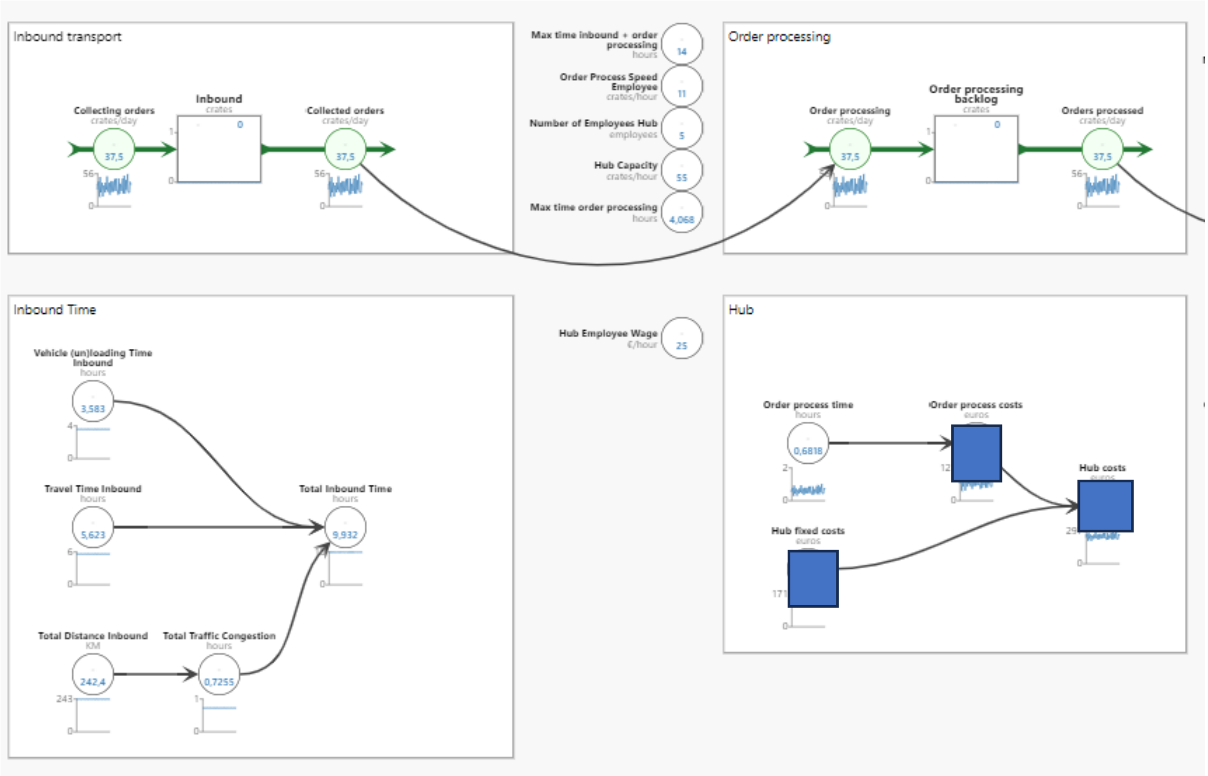


Figure 45, Sub-model screenshot 2

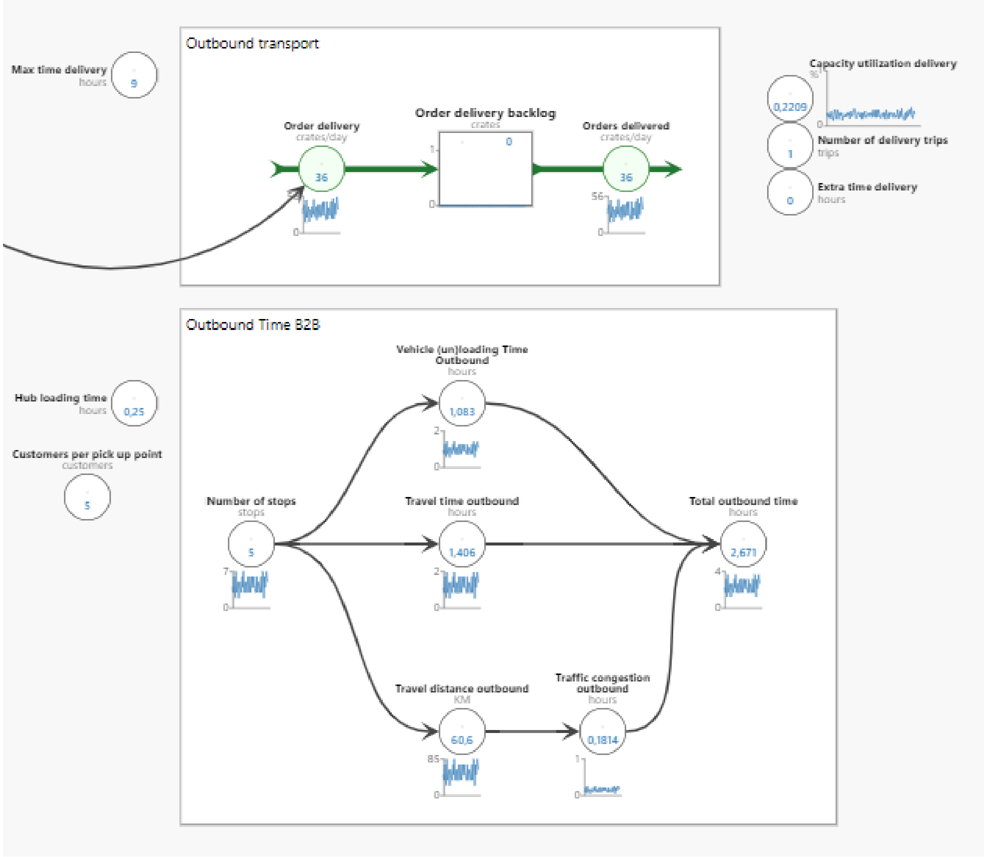


Figure 46, Sub-model screenshot 3

Figure 46 shows the outbound transport process.

Appendix 12: Sensitivity analysis

				KPIs				Difference in percentage					
Variable	Unit	Run	Value	Lead time B2B	Lead time B2C	Costs	Delivery reliability	Lead time B2B	Lead time B2C	Costs	Delivery reliability	Impact	Uncertainty
Avg B2B customers	Customers	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Medium
		-25%	[redacted]	13,73	13,41	[redacted]	100,00%	-15,22%	0,00%	-4,73%	0,00%		
		25%	[redacted]	17,91	13,41	[redacted]	100,00%	23,34%	0,00%	12,62%	0,00%		
Avg B2C customers	Customers	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Medium
		-25%	[redacted]	15,82	11,92	[redacted]	100,00%	0,00%	-12,50%	-3,52%	0,00%		
		25%	[redacted]	15,82	14,91	[redacted]	100,00%	0,00%	20,05%	5,45%	0,00%		
Delivery days B2B	Days	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Low
		-25%	[redacted]	18,50	13,41	[redacted]	100,00%	14,49%	0,00%	-5,30%	0,00%		
		25%	[redacted]	14,49	13,24	[redacted]	100,00%	-27,67%	-1,28%	9,64%	0,00%		
Delivery days B2C	Days	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Low
		-25%	[redacted]	15,82	15,69	[redacted]	100,00%	0,00%	14,53%	-2,14%	0,00%		
		25%	[redacted]	15,82	12,28	[redacted]	100,00%	0,00%	-27,77%	4,48%	0,00%		
Standard deviation B2B	Customers/week	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Medium
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,02%	0,00%		
		25%	[redacted]	16,16	13,41	[redacted]	100,00%	2,10%	0,00%	0,00%	0,00%		
Standard deviation B2C	Customers/week	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Medium
		-25%	[redacted]	15,82	13,70	[redacted]	100,00%	0,00%	2,12%	0,00%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	66,50%	0,00%	-2,16%	0,00%	-50,38%		
Avg order quantity B2B customer	Crates/order	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Medium	Medium
		-25%	[redacted]	15,14	13,41	[redacted]	100,00%	-4,49%	0,00%	-2,98%	0,00%		
		25%	[redacted]	16,51	13,41	[redacted]	100,00%	8,30%	0,00%	5,64%	0,00%		
Avg order quantity B2C customer	Crates/order	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Medium
		-25%	[redacted]	15,82	12,57	[redacted]	100,00%	0,00%	-6,68%	-1,97%	0,00%		
		25%	[redacted]	15,82	14,27	[redacted]	100,00%	-10,86%	6,41%	4,04%	0,00%		
Number of Renault	Vehicles	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Low
		-25%	[redacted]	17,70	14,87	[redacted]	100,00%	10,62%	9,82%	-2,29%	0,00%		
		25%	[redacted]	14,37	12,29	[redacted]	100,00%	-23,17%	-20,99%	4,40%	0,00%		
Number of Mercedes	Vehicles	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Low
		-25%	[redacted]	17,70	14,87	[redacted]	100,00%	10,62%	9,82%	-3,25%	0,00%		
		25%	[redacted]	14,37	12,29	[redacted]	100,00%	-23,17%	-20,99%	6,12%	0,00%		
Fixed costs per bus Renault	Euros/week	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	-2,29%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	4,40%	0,00%		
Fixed costs per bus Mercedes	Euros/week	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	-3,25%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	6,12%	0,00%		

Figure 47, Sensitivity analysis

Vehicle capacity Renault	Crates	Base	100,00	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
Vehicle capacity Mercedes	Crates	Base	[redacted]	15,82	13,41	[redacted]	66,50%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	64,50%	0,00%	0,00%	0,02%	-3,10%		
		25%	[redacted]	15,82	13,41	[redacted]	67,50%	0,00%	0,00%	-0,02%	4,44%		
Fuel consumption Renault	Euros/km	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	-0,66%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	1,30%	0,00%		
Fuel consumption Mercedes	Euros/km	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	10,58	[redacted]	100,00%	0,00%	-26,75%	-0,66%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	21,10%	1,30%	0,00%		
Avg time per extra trip	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Medium
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
Driver wage	Euros/hour	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	-11,57%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	18,79%	0,00%		
Bus (un)loading time per stop	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Medium	Medium
		-25%	[redacted]	14,87	12,68	[redacted]	100,00%	-6,39%	-5,76%	-3,10%	0,00%		
		25%	[redacted]	16,87	14,22	[redacted]	100,00%	11,86%	10,83%	6,11%	0,00%		
Number of stops inbound	Stops	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Medium
		-25%	[redacted]	13,99	11,56	[redacted]	100,00%	-11,57%	-16,00%	-7,70%	0,00%		
		25%	[redacted]	17,60	15,17	[redacted]	100,00%	25,80%	23,80%	13,35%	0,00%		
Avg time per stop	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Medium
		-25%	[redacted]	13,80	11,84	[redacted]	100,00%	-14,64%	-13,26%	-0,09%	0,00%		
		25%	[redacted]	17,79	14,92	[redacted]	100,00%	22,43%	20,64%	5,92%	0,00%		
Avg km per stop	Km/stop	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Medium
		-25%	[redacted]	15,57	13,22	[redacted]	100,00%	-1,61%	-1,44%	-2,21%	0,00%		
		25%	[redacted]	16,08	13,61	[redacted]	100,00%	3,17%	2,87%	4,26%	0,00%		

Traffic congestion	Hours/km	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Medium
		-25%	[redacted]	15,48	13,15	[redacted]	100,00%	-2,20%	-1,98%	-1,08%	0,00%		
		25%	[redacted]	16,17	13,68	[redacted]	100,00%	4,27%	3,87%	2,14%	0,00%		
Avg customers per pick up point	Pick up points	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Medium	Medium
		-25%	[redacted]	15,80	14,27	[redacted]	100,00%	-0,13%	6,03%	1,22%	0,00%		
		25%	[redacted]	15,80	12,92	[redacted]	100,00%	0,00%	-10,45%	-1,97%	0,00%		
Hub unloading time	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Medium
		-25%	[redacted]	15,79	13,38	[redacted]	100,00%	-0,19%	-0,22%	-0,09%	0,00%		
		25%	[redacted]	15,85	13,44	[redacted]	100,00%	0,38%	0,45%	0,21%	0,00%		
Max time inbound + order processing	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Low
		-25%	[redacted]	15,82	13,41	[redacted]	99,30%	0,00%	0,00%	0,00%	-0,70%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,70%		
Order process speed employee	Crates/hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Medium
		-25%	[redacted]	16,70	14,47	[redacted]	100,00%	5,27%	7,33%	6,12%	0,00%		
		25%	[redacted]	15,30	12,77	[redacted]	100,00%	-9,15%	-13,31%	-10,84%	0,00%		
Number of employees hub	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	High	Low
		-25%	[redacted]	16,73	14,50	[redacted]	100,00%	5,44%	7,52%	0,00%	0,00%		
		25%	[redacted]	15,28	12,77	[redacted]	100,00%	-9,49%	-13,55%	0,00%	0,00%		
Hub employee wage	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Medium	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	-5,12%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	9,31%	0,00%		
Hub fixed costs	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	-3,07%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	5,79%	0,00%		
Max time delivery B2B	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
Max time delivery B2C	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
		25%	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%		
Hub loading time	Hours	Base	[redacted]	15,82	13,41	[redacted]	100,00%	0,00%	0,00%	0,00%	0,00%	Low	Low
		-25%	[redacted]	15,79	13,38	[redacted]	100,00%	-0,19%	-0,22%	-0,09%	0,00%		
		25%	[redacted]	15,85	13,44	[redacted]	100,00%	0,38%	0,45%	0,21%	0,00%		

Appendix 13: Figures Scenario Analysis

In this Appendix the figures presented in the scenario analysis are displayed for additional clarity.

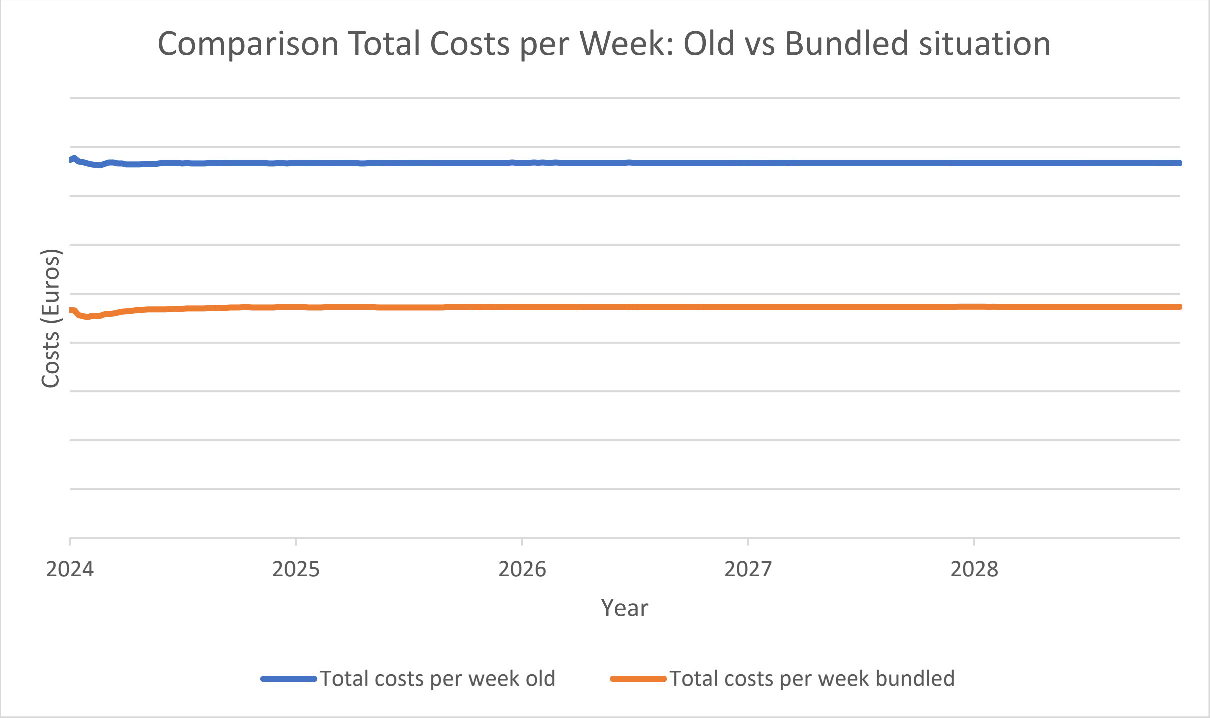


Figure 48, Comparison Total Costs per Week: Old vs Bundled situation

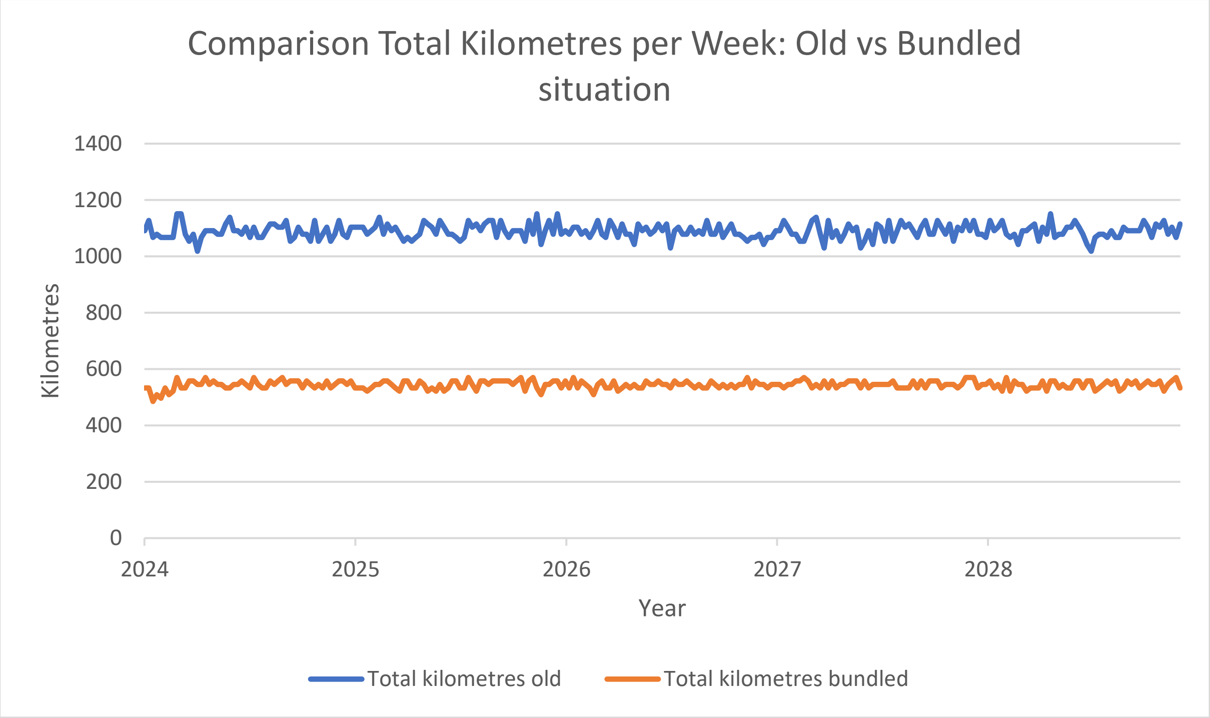


Figure 49, Comparison Total Kilometres per Week: Old vs Bundled situation

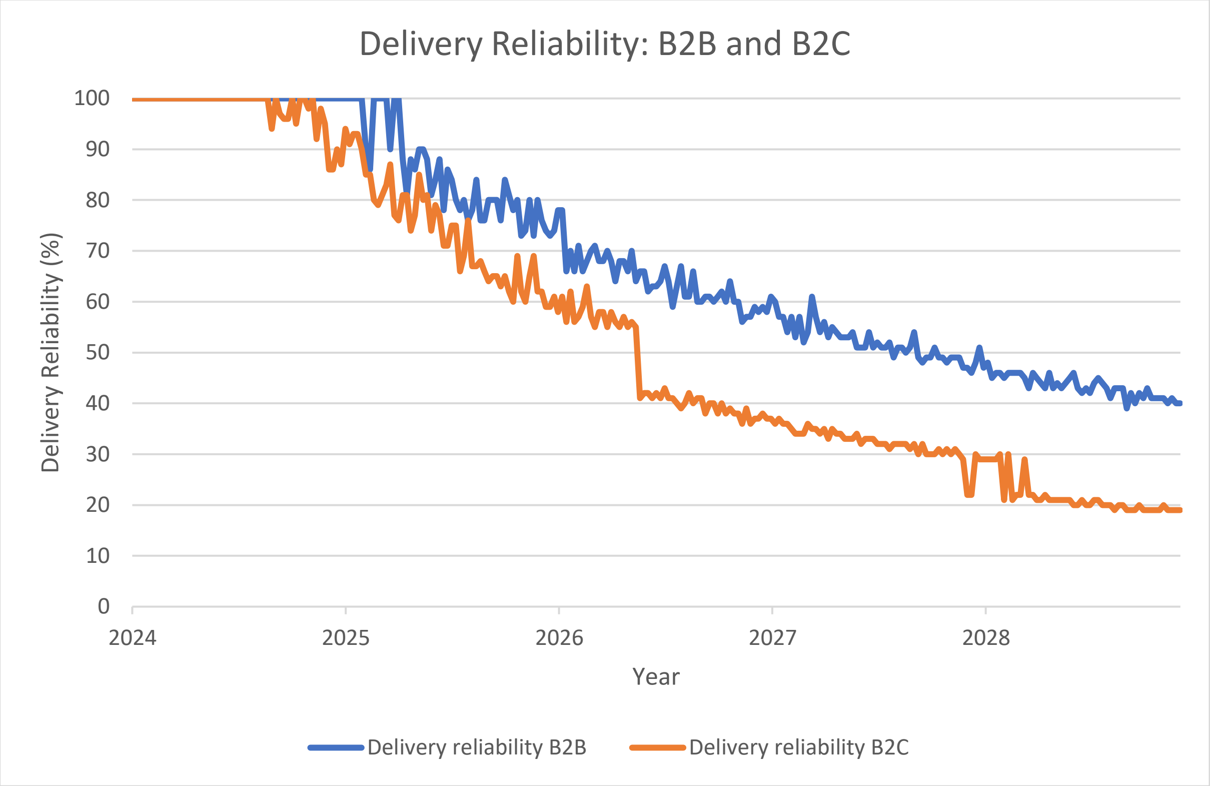


Figure 50, Delivery Reliability: B2B and B2C

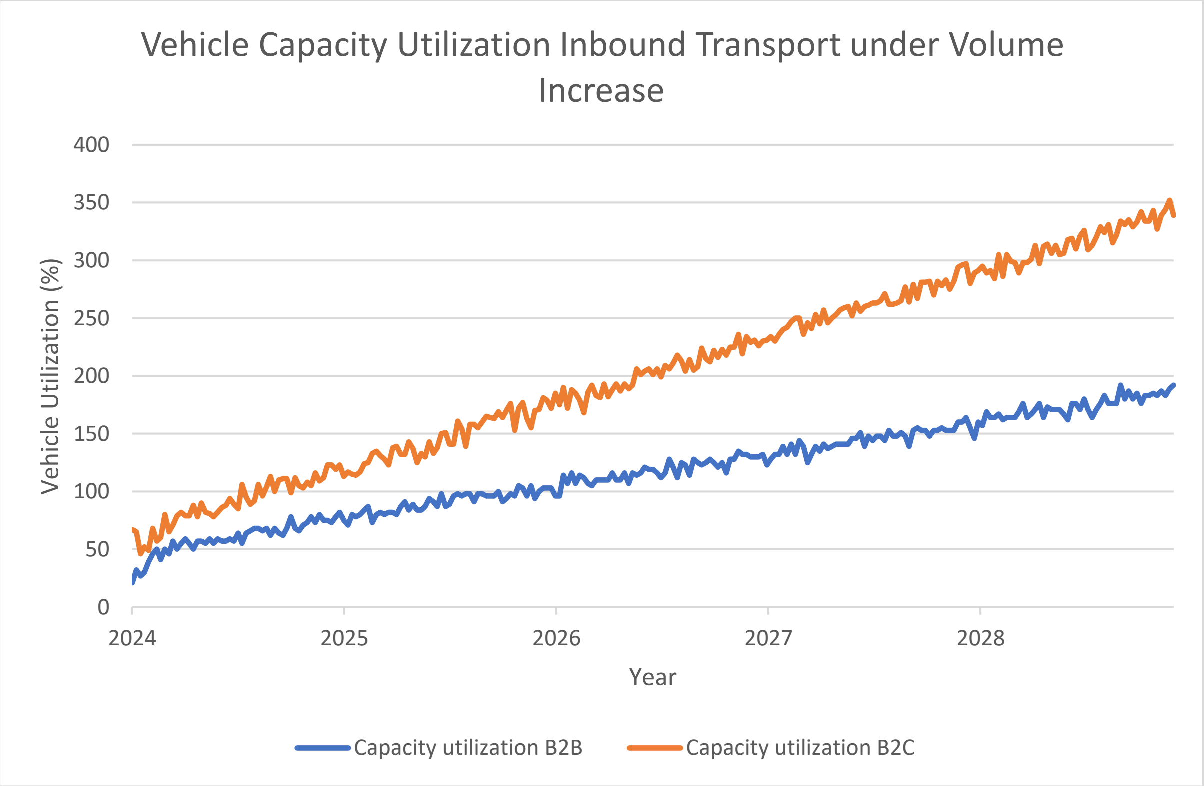


Figure 51, Vehicle Capacity Utilization Inbound Transport under Volume Increase

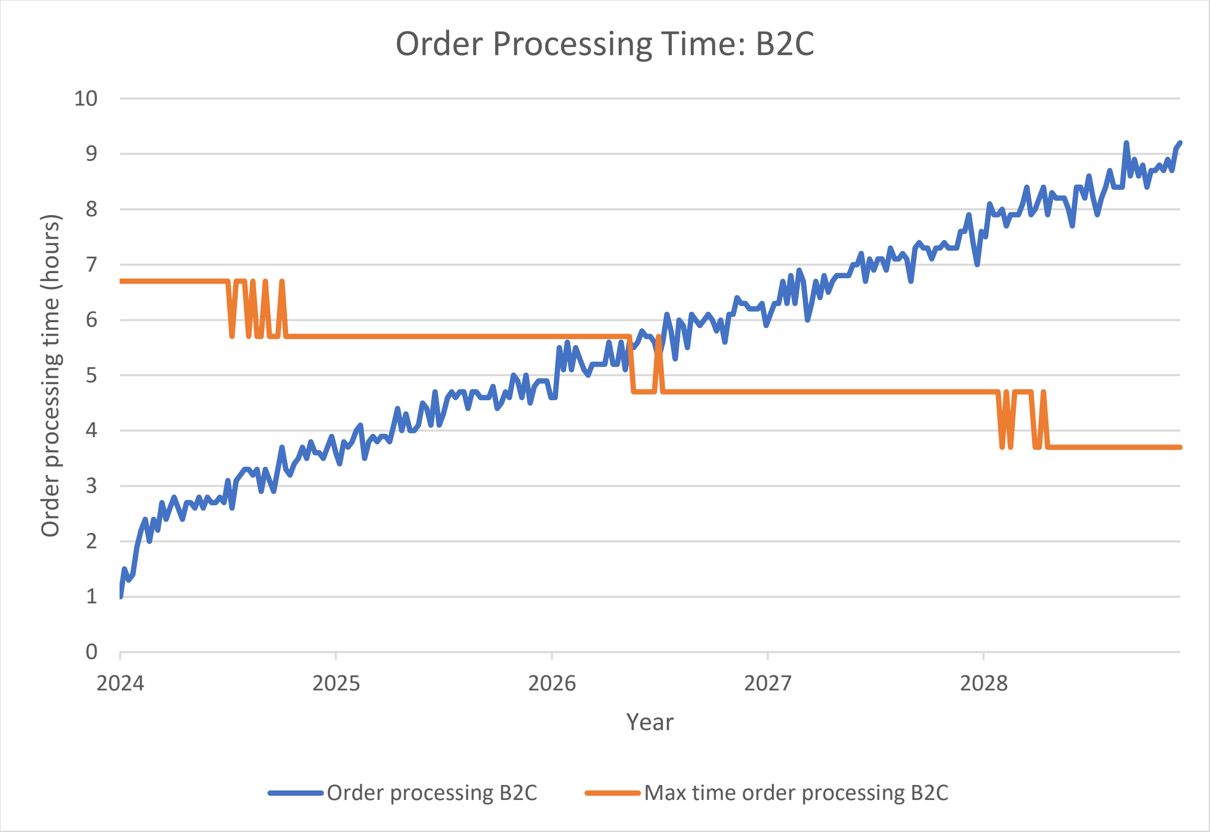


Figure 52, Order Processing Time: B2C

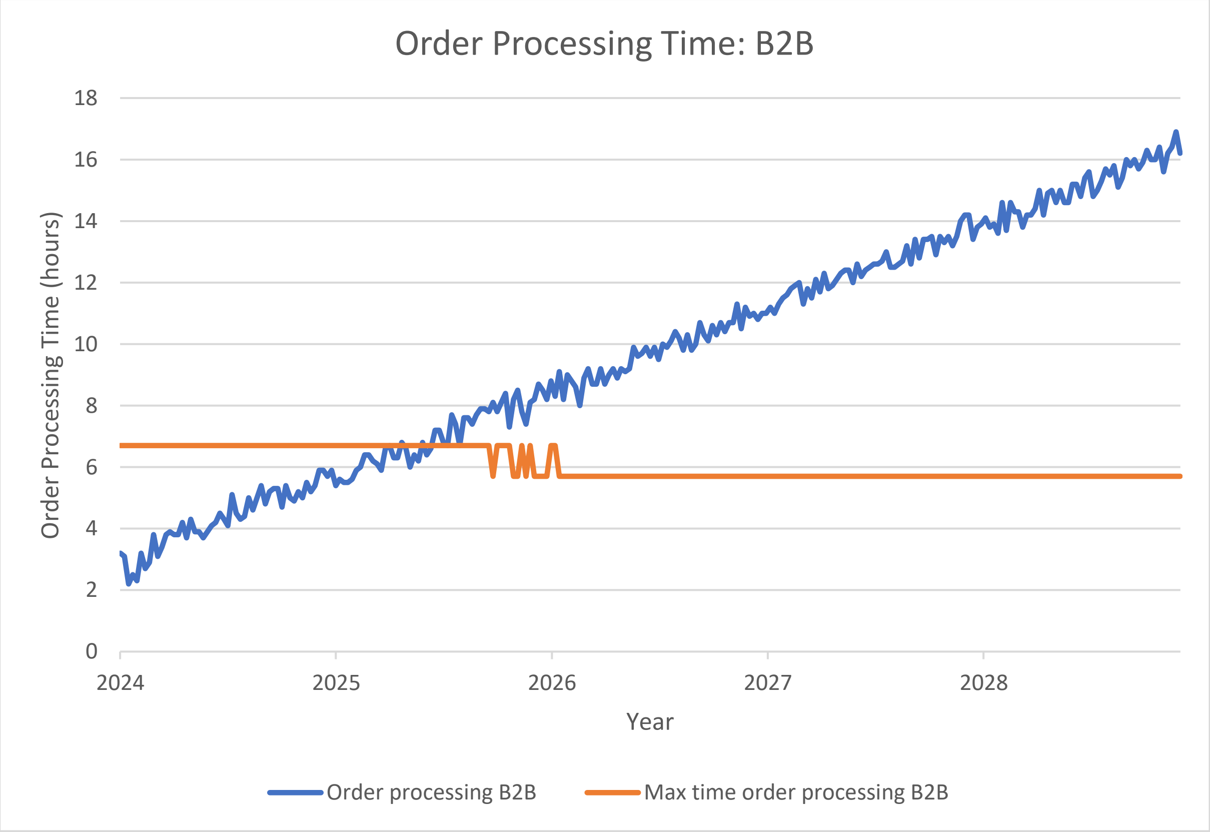


Figure 53,Order Processing Time: B2B

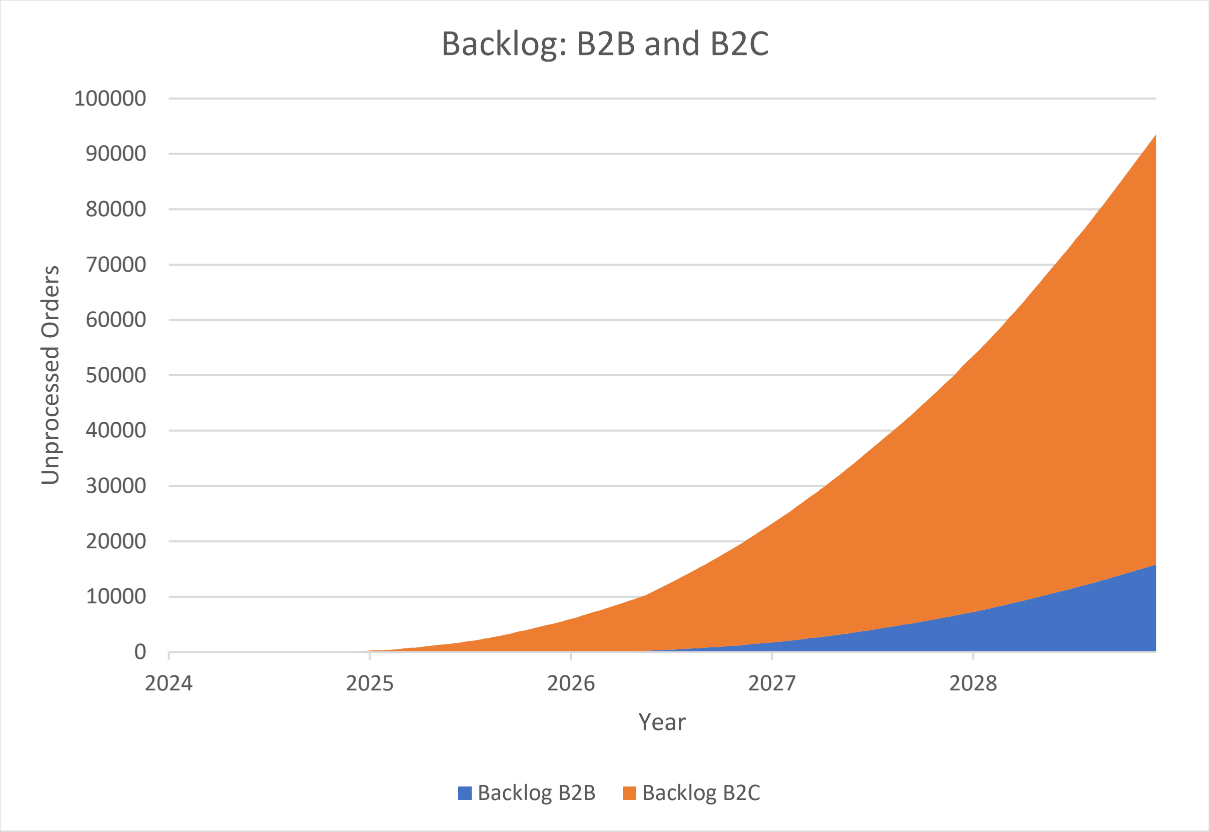


Figure 54, Backlog: B2B and B2C

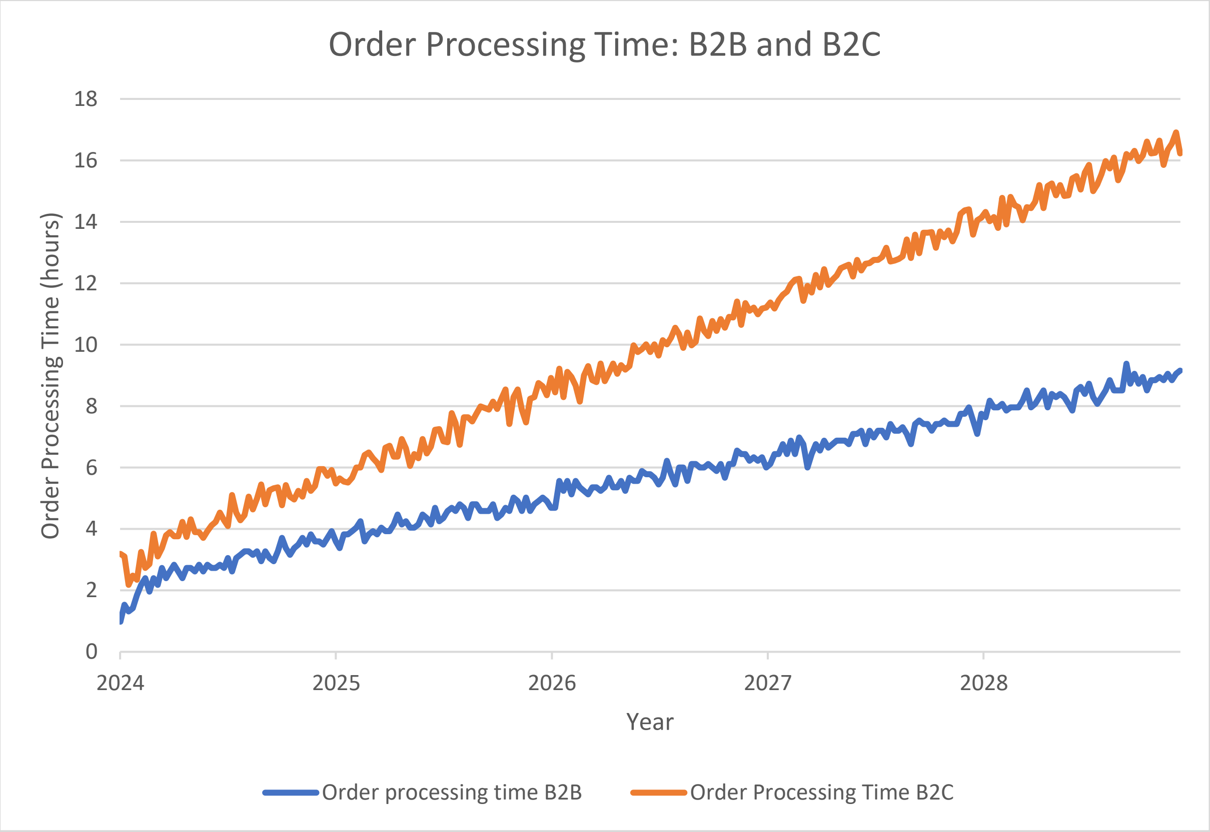


Figure 55, Order Processing Time: B2B and B2C

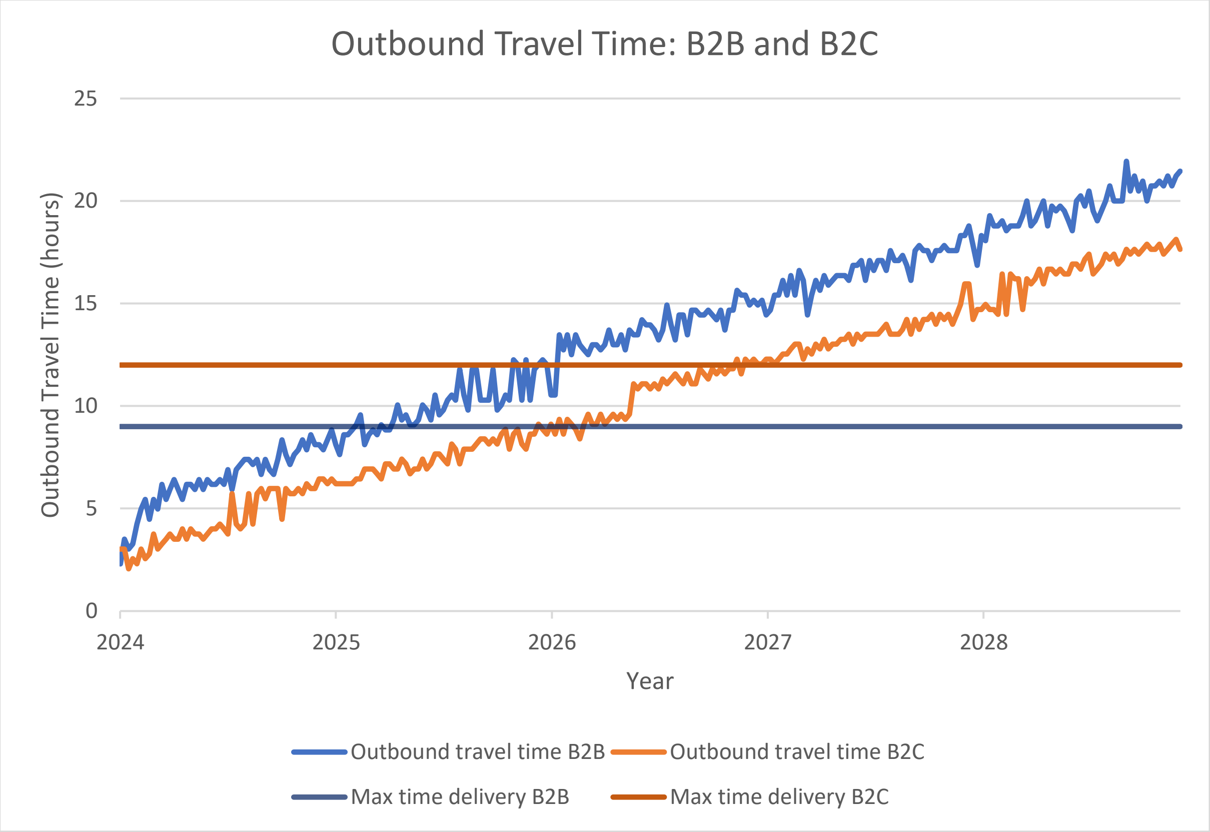


Figure 56, Outbound Travel Time: B2B and B2C

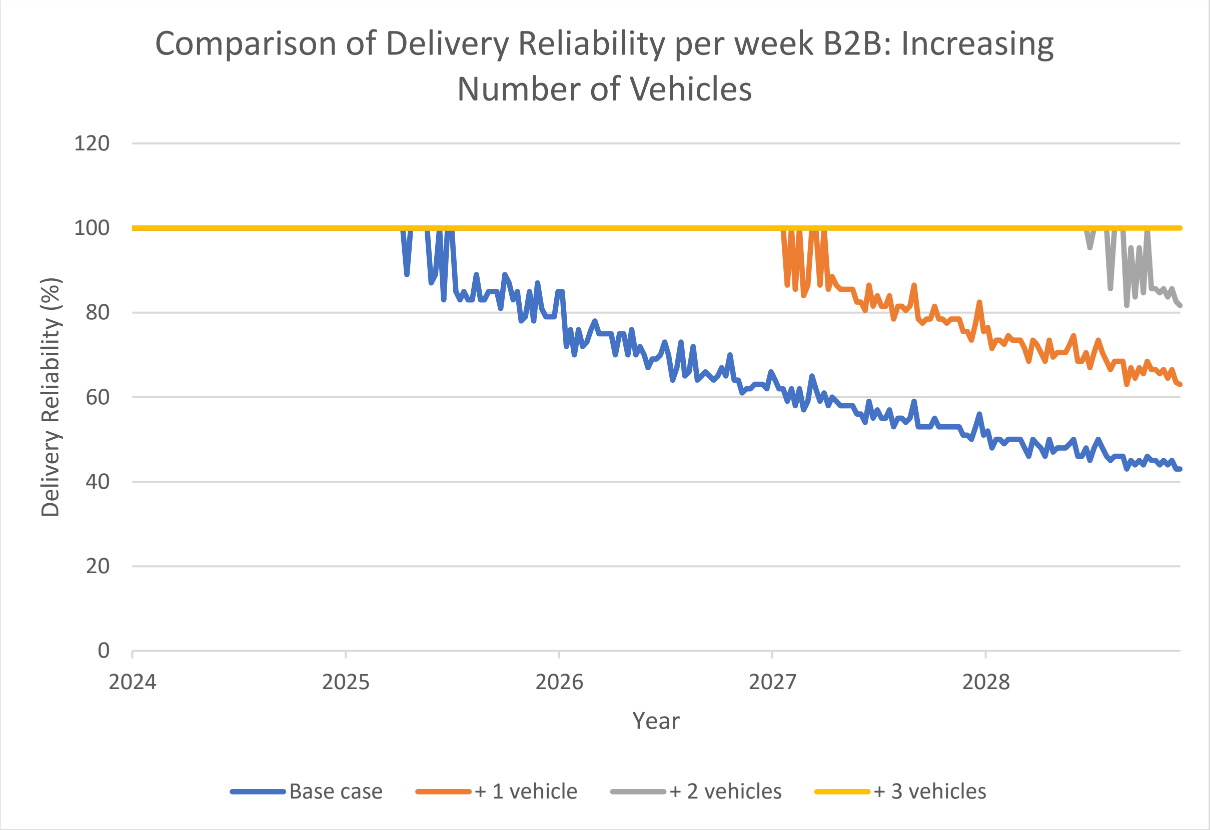


Figure 57, Comparison of Delivery Reliability per week B2B: Increasing Number of Vehicles

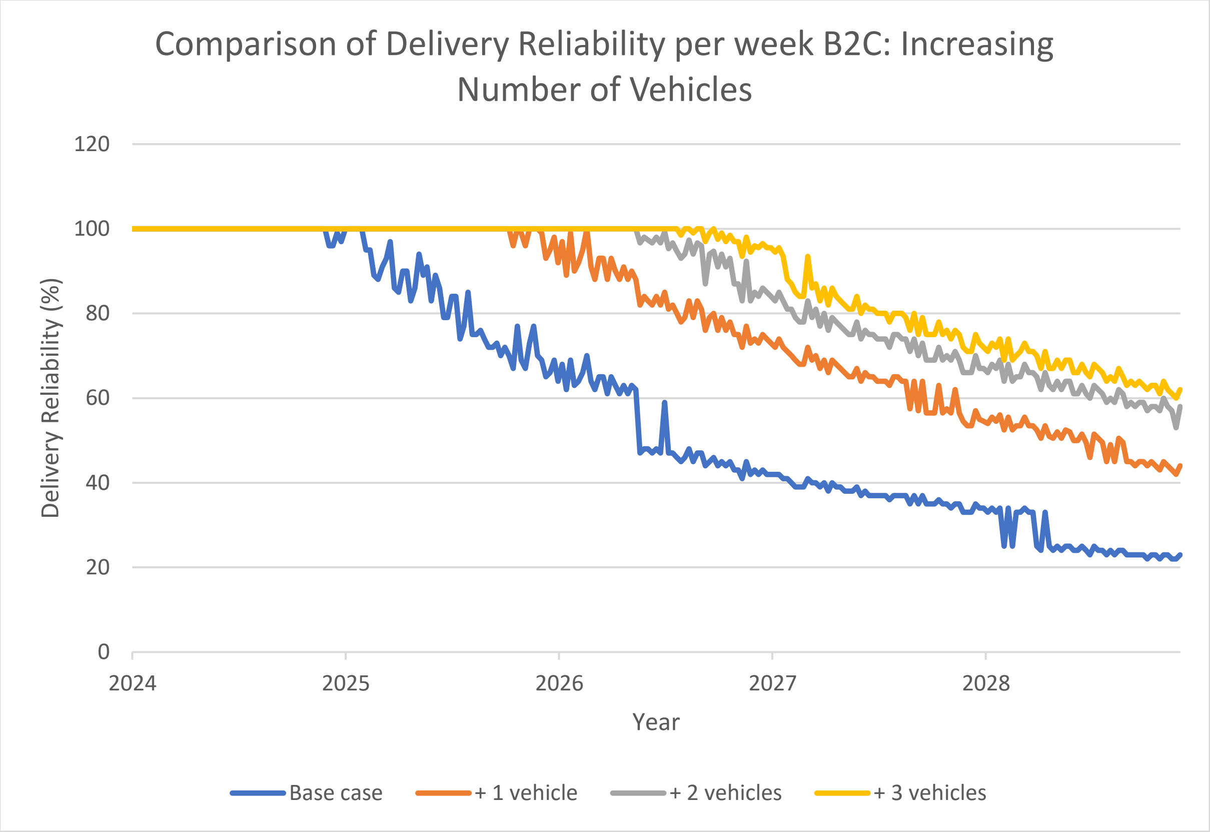


Figure 58, Comparison of Delivery Reliability per week B2C: Increasing Number of Vehicles

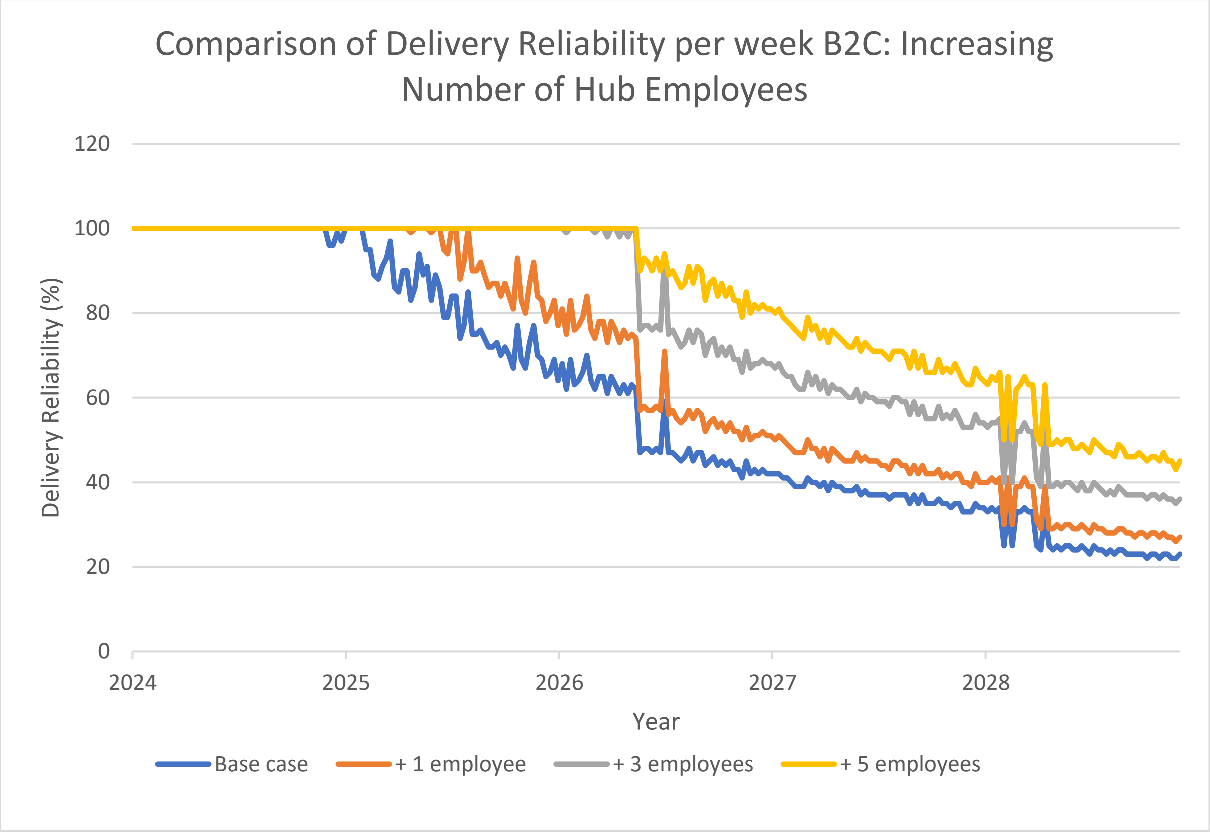


Figure 59, Comparison of Delivery Reliability per week B2C: Increasing Number of Hub Employees

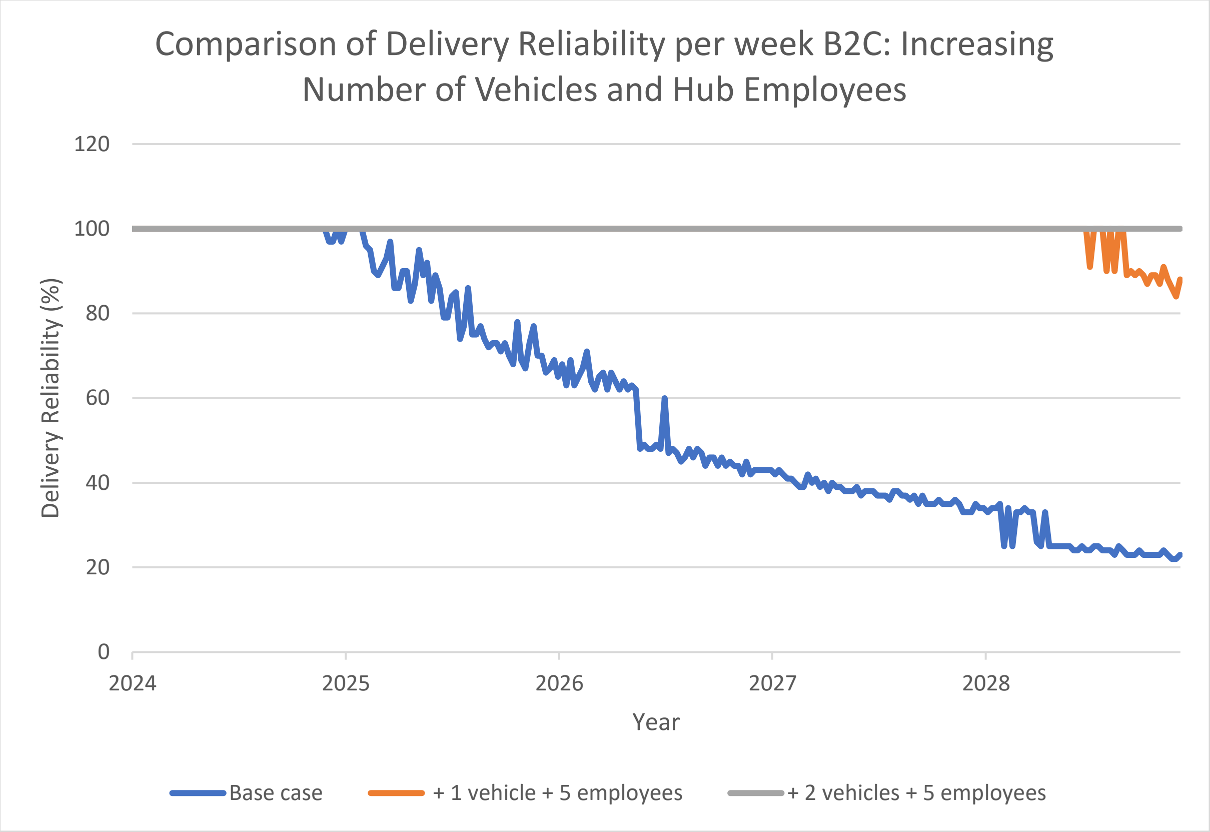


Figure 60, Comparison of Delivery Reliability per week B2C: Increasing Number of Vehicles and Hub Employees

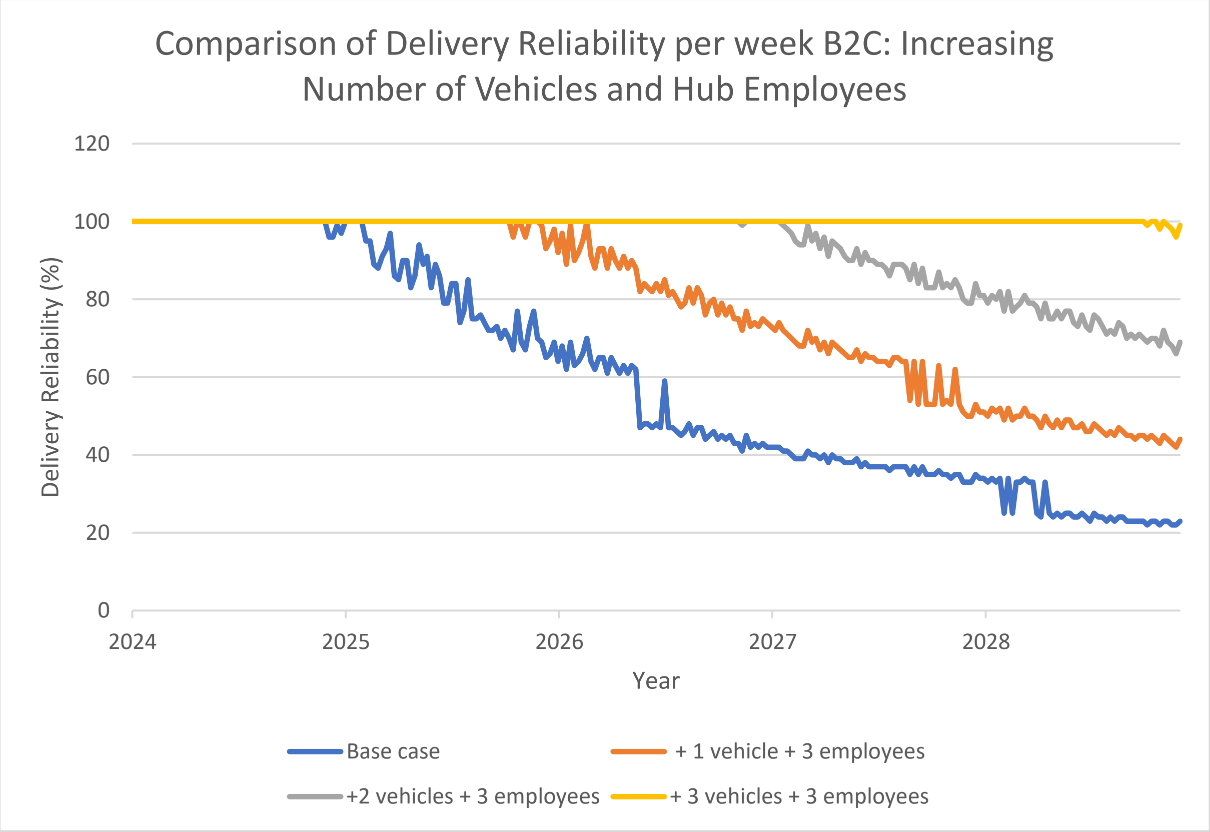


Figure 61, Comparison of Delivery Reliability per week B2C: Increasing Number of Vehicles and Hub Employee

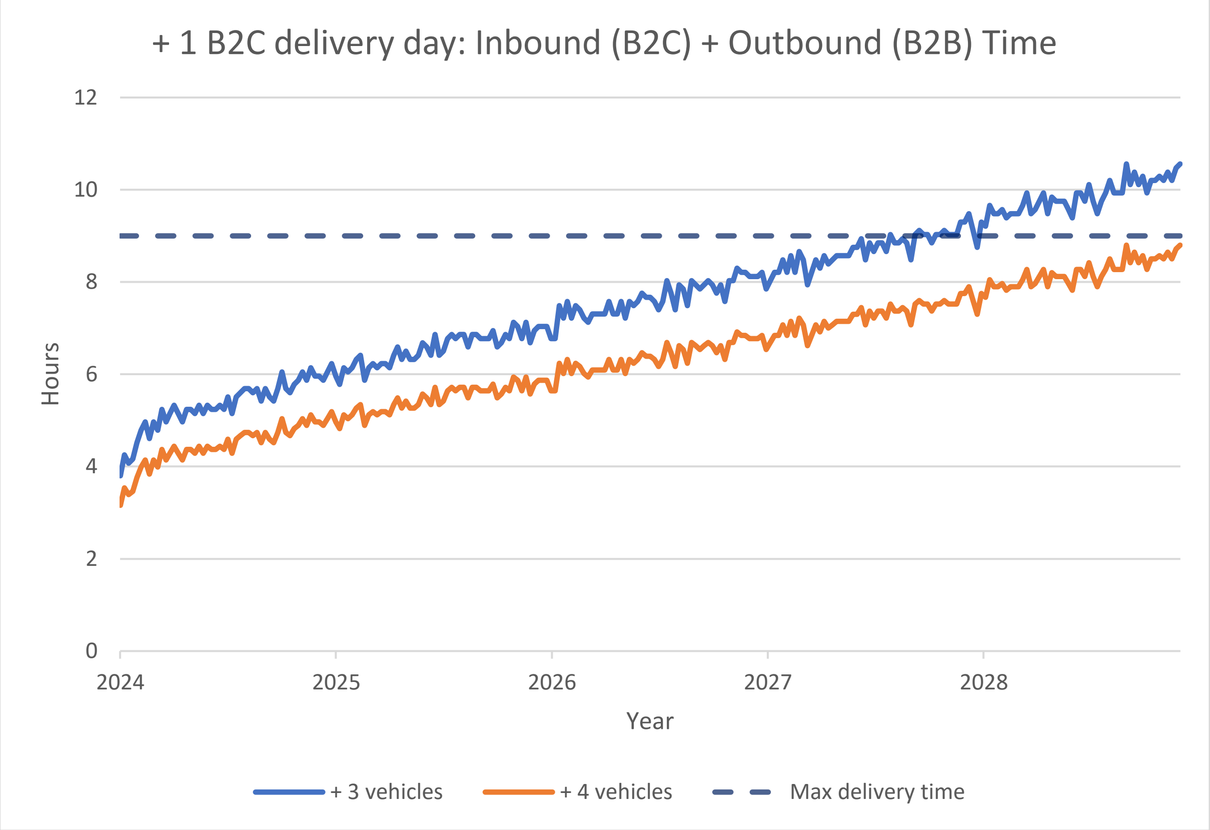


Figure 62, + 1 B2C delivery day: Inbound (B2C) + Outbound (B2B) Time

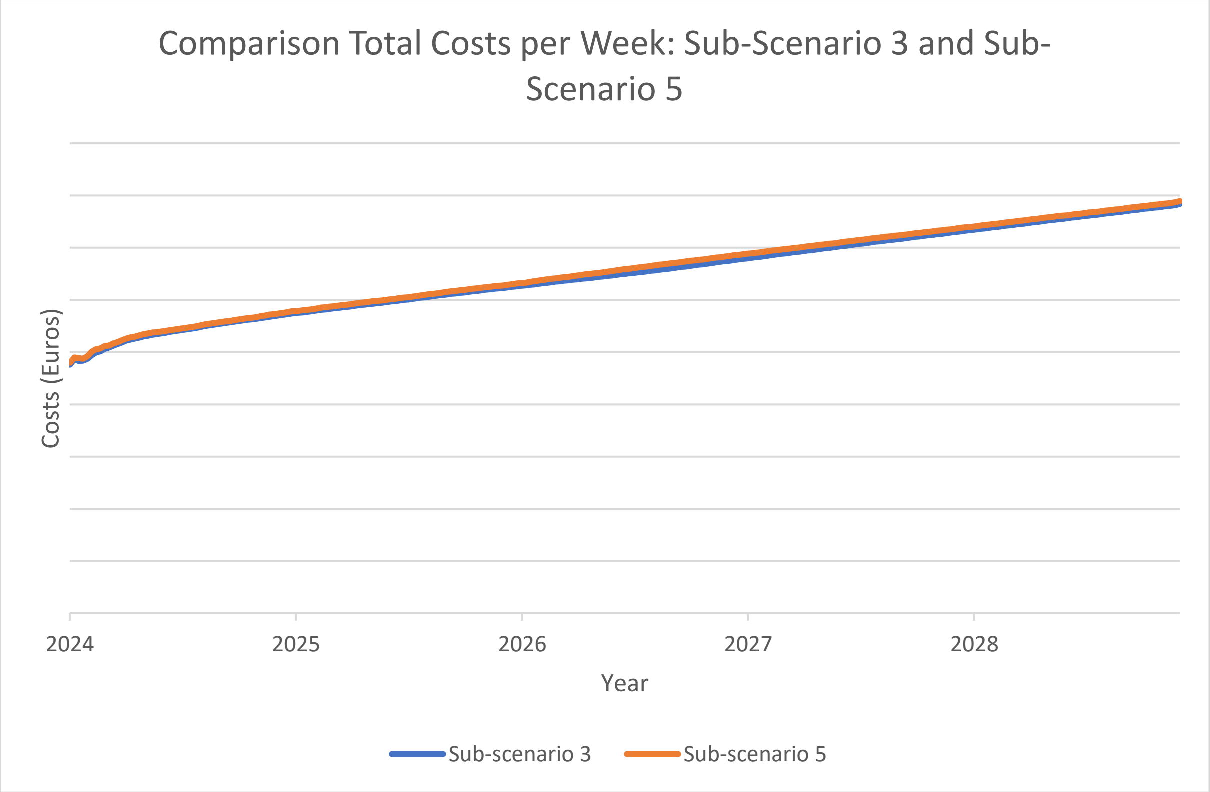


Figure 63, Comparison Total Costs per Week: Sub-Scenario 3 and Sub-Scenario 5

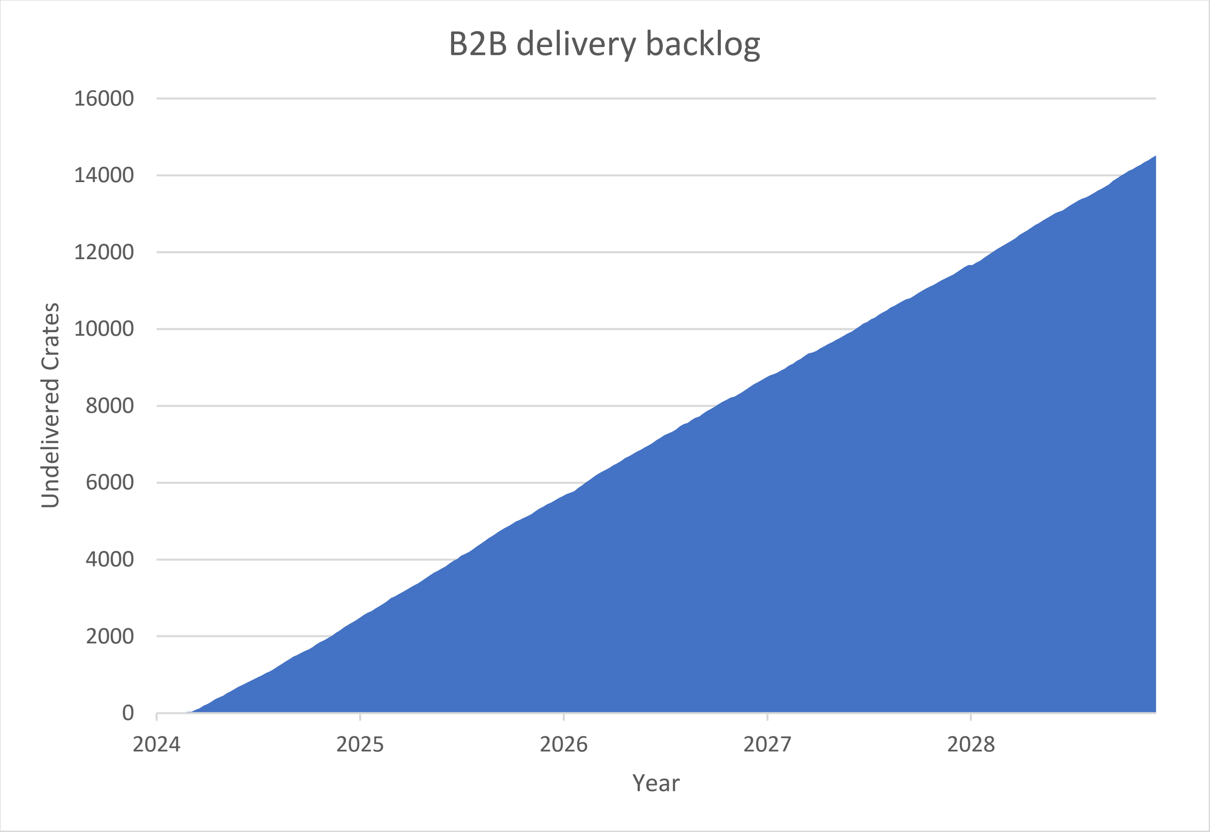


Figure 64, B2B delivery backlog