Research into the potential effects of a receiver-led consolidation policy on costs, CO2 emissions and vehicle movements

A case study for the logistics service provider PostNL

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Faculty of Technology, Policy and Management
Master of Engineering and Policy Analysis

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Master Thesis
August 2020

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A case study for the logistics service provider PostNL

Master thesis submitted to Delft University of Technology in partial fulfilment of the requirements for the degree of Master of Science in Engineering and Policy Analysis, to be defended publicly on 17th of August 2020

by
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Project duration:	February 10, 2020 – August 17, 2020	
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Preface

Dear reader,

In front of you lies the thesis that concludes my Master Of Science in Engineering and Policy Analysis at the TU Delft. This project started on the 10th of February 2020 with an interesting internship at PostNL. Here, I was welcomed with open arms. Every member of the team as well as other PostNL employees have assisted me throughout my time there. Their insights have helped me create this report.

Therefore, I would like to thank Jordy Kol for supporting and guiding me throughout my internship at PostNL. Furthermore, I would like to thank Lisa van der Gaag for helping me gain insight in the current processes of PostNL and providing me with the data. I would like to thank the members of my graduation committee for all the feedback and guidance in finishing this thesis. I would like to thank Martijn Warnier for all his time and effort he put in guiding me trough this project. His feedback has helped me create the thesis as is. Furthermore, I would like to thank Marcel Ludema and Lóri Tavasszy for their critical comments during the official meetings. Due to these I have looked with a more critical view at certain aspects of my thesis.

Finally, I would like to thank my family and friends for their support, encouragements and occasionally reviewing parts of my thesis.

Vera Meulblok

August, 2020

Executive summary

The efficiency of a logistic service provider's network can be improved by implementing a receiver-led consolidation policy. This policy means that shipments destined to the same location are consolidated in one truck. The literature states that by doing this the costs, CO2 emissions and number of vehicle movements can be reduced. However, consolidating shipments towards hospitals is complex due to the fact that medication is a highly regulated product and non-regulated products are also needed at the hospitals.

Furthermore, from the stakeholder analysis, it became apparent that such receiver-led consolidation policy is also favourable for hospitals. The efficiency of the operating practices in the logistics department in hospitals can be improved by reducing the number of deliveries.

However, from the literature became apparent that the knowledge on the effects of a receiver-led consolidation technique implemented in a logistics service provider's network is still lacking. Especially on how receiver-led consolidation can improve the efficiency of a logistic service provider's network and how this effects the other stakeholders. This problem is stated in the following main research question:

What is the impact of receiver-led consolidation alternatives in the PostNL supply chain with respect to trade-offs between costs, CO2 emissions and vehicle movements between PostNL and other stakeholders?

In order to find an answer to this research question, a case study for the logistics service provider PostNL is carried out. PostNL has several networks that delivers shipments. However, mostly the Cargo, Pharma&Care and Mikropakket network deliver shipments to hospitals. It appeared that these three networks barely work together which results in overlap between destination addresses. This means that two or more networks can

make a delivery to a certain address on the exact same date. Furthermore, the Pharma&Care network is meant for large deliveries. However, it sometimes occurs that this networks makes a stop for just one or two colli. This is an expensive stop in comparison to the Mikropakket network.

Therefore, a conceptual model of the current data-processing system of PostNL is created. After brainstorm sessions and discussions with PostNL employees, it became apparent that many bottlenecks originate from this process. Therefore, a discrete event simulation model is created that captures this model.

Furthermore, two design alternatives have been proposed to improve the efficiency in the current system. The two design alternatives that have been created are: (1) integrating the processes of different networks and (2) implementing a smart planning process which controls the data sets of all networks. In the first alternative, all shipments are checked on a pre-defined list. If the destination address is present on this list, the shipments are redirected to the Pharma&Care network. Otherwise, the shipments continue in their original process. The second alternative, consolidates all shipments of all networks in a certain network, based on their characteristics.

These design alternatives have also been implemented in a discrete event simulation model. The data obtained from postnl has been used to measure the effects of the design alternatives on the current system. When analysing the results obtained from the simulation model, it can be seen that the overlap, number of stops, operating costs and CO2 emissions have been reduced in both design alternatives compared to the current system. The second design alternative yields the highest benefits. However, this alternative is expected to be more difficult to implement in the current system of PostNL.

Moreover, the analysis of the output data has also shown positive outcomes for the other two core stakeholders (hospitals and suppliers of end-products). According to the stakeholder analysis, the outcomes of the second design alternative are more favorable.

To conclude, implementing a receiver-led consolidation policy in a logistics service provider network yields many benefits with respect to the efficiency. The overlap between networks on destination addresses, the number of stops, the operating costs and the CO2 emissions are reduced. Since, the second design alternative scores highest on all aspects, it is recommended to PostNL that this alternative is implemented. This way, all shipments are consolidated over the three networks and the efficiency of the logistics service providers network is improved the most.

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Chapter 1

Introduction

During the last couple of years, many studies have emphasized the importance of supply chain management (SCM) for companies (Elmuti et al., 2013). Supply chain management is introduced to gain cost advantages, reduce cycle time and lead to higher performances without compromising on quality (Elmuti et al., 2013). The internal, as well as the external performance of the supply chain, can be improved substantially by integrating information and goods throughout the entire supply chain (De Vries and Huijsman, 2011). An improvement of a companies' supply chain is required due to the competitive and demanding market. Therefore, there has been an increasing interest in outsourcing the logistic processes. This way, companies can focus more on their core competencies instead of the logistics processes (Liu and Papageorgiou, 2013).

The commercial sector has already applied logistic tools to improve the supply chain. However, the logistics in the healthcare sector is behind the commercial sector (Kwon et al., 2016). Since technologies have advanced quickly in the pharmaceutical industry, outsourcing logistics is highly favorable in order to keep up with the developments in this industry, reduce the operating costs, improve in responding to changes, increase the service level, and share risks (El Mokrini et al., 2016).

However, consolidating shipments towards hospitals is a complex process due to the fact that medication is a highly regulated product (Garattini et al., 2007). Medication has unique demands and supply, and there are several regulations regarding the transportation of certain medication. This leads to difficulties when consolidating the supply chain of medication with other types products (Jaberidoost et al., 2013; Janjevic et al., 2013). Making outsourcing logistics in the pharmaceutical sector complex (El Mokrini et al., 2016; Ouzayd et al., 2010).

Another complexity lies in the fact that there are several stakeholders involved in the healthcare supply chain, i.e. suppliers, wholesalers, distributors, customers, information service providers and regulatory agencies (Singh et al., 2016). Over the years, there seems to be a more interdependent relationship between the stakeholders, and therefore the relationships between stakeholders have become more valuable (Cachon, 2003; Harland et al., 2007; Hussain et al., 2018). However, in the healthcare sector there seems to be a lack of cooperation between supply chain partners, despite the serious results in competitive advantages and cost reduction (Jaberidoost et al., 2013; Koh et al., 2003; Narayana et al., 2014). Kwon et al. (2016) state that it is probably due to the lack of trust between the stakeholders. This is one of the major barriers of implementing a cost-effective and standardized process in the healthcare industry.

1.1 Research objective

This research focuses on the distribution of shipments from supplier of end-product towards hospitals, via a logistics service provider. The stakeholders that are involved have different visions with respect to an improved supply chain. For example, the hospitals mainly want to focus on reducing the number of shipments delivered during the day (Aljohani and Thompson, 2019; Jola, 2018). Meanwhile the suppliers do not want to change their operating systems and mainly want to reduce the transportation costs (El Mokrini et al., 2016; Mokrini et al., 2015). The carrier has to keep in mind both points of view when improving the supply chain's efficiency with regard to the operating costs, CO2 emission and number of deliveries (Aljohani and Thompson, 2018; Holguín-Veras and Sánchez-Díaz, 2016).

In order to improve the efficiency of the supply chain of a logistics service providers, the supply chain management technique called "consolidation" is introduced. The consolidation of goods means that products from different suppliers are loaded in one vehicle and transported towards the receiver instead of shipping all products in different vehicles. This process takes place in consolidation centers. These centers are often located close to the delivery areas and receive multiple goods from several suppliers (Janjevic et al., 2013). Especially when trying to reduce the number of vehicle movements, the receiver-led consolidation technique yields the highest result (Aljohani and Thompson, 2018, 2019). By implementing this consolidation technique, the performance of a logistics service provider with respect to the efficiency could improve, which leads to a reduction in costs, CO2 emission and the number of vehicle movements (Aljohani and Thompson, 2018).

The logistics service provider PostNL distributes medication, but also medical disposables and other non-food products towards hospitals. Currently, the products with similar characteristics are consolidated. However, products with different characteristics are not consolidated. Therefore, a case study is conducted for the logistics service provider PostNL to create insight in the collaboration possibilities between networks in order to consolidate different types of products and propose alternatives to improve the efficiency of the supply chain.

1.2 Social, EPA and scientific relevance

1.2.1 Societal relevance

This research performs a case study for the logistics service provider PostNL. One of the new goals of PostNL is to reduce its carbon footprint. This can be done by consolidating shipments that are sent over the different networks of PostNL. This research has a societal relevance because (1) it creates insight in the effects of consolidating shipments on costs, CO2 emissions and the number of vehicle movements, and (2) it creates insight in the perspectives of other stakeholders that are involved.

The insights gathered from these two points lead to more effective, tailor made design alternatives in implementing a receiver-led consolidation technique, which can possibly reduce the operating costs, reduce the amount of CO2 emitted and reduce the number of vehicle movements. Indirectly, consolidating shipments leads to less congestion in urban areas, less air- and noise pollution. Furthermore, by creating insight in the perspectives of other stakeholders, the best way of communicating the changes in the operating practices can be found.

1.2.2 EPA relevance

This research is relevant as a master thesis subject in the Engineering and Policy Analysis (EPA) program studied by the researcher. This subject relates to the reduction of air and noise pollution which is translated in one of the sustainable development goals. There is an increasing interest in sustainable cities and communities and many companies and organisations try to contribute to this. With the help of this research, more insight is created in how to improve the supply chains of a logistics service provider which contributes to more environmentally friendly operations.

1.2.3 Scientific relevance

This research also has a scientific relevance. This research provides insight in the different product flows towards hospitals and their characteristics. Due to the difference in product characteristics, consolidation of these shipments proves to be difficult. This research develops knowledge on the possibilities of consolidating shipments of different networks in several stages to investigate its effect on the carbon footprint, operating costs and vehicle movements. The scientific relevance mainly lies in the fact that, to the best knowledge of the researcher, discrete event simulation models have not yet been used to analyse the effect of a receiver-led consolidation technique. Furthermore, there seems to be a lack of academic knowledge with respect to the effects of implementing a receiver-led consolidation policy.

1.3 Report structure

The structure of this report is as follows: chapter 2 contains an extensive literature review on the important elements in supply chain management. In chapter 3, the main questions of this research are presented and the respective research methods are explained. A short description of the case study is given in chapter 4. Chapter 5 elaborates on the stakeholders that are involved in this case and explains the current system of PostNL. From this, the conceptual model is presented in chapter 6. Chapter 7 presents the design alternatives that are proposed to improve the efficiency of the current PostNL system. Chapter 8 describes how the simulation model is verified and validated. In chapter 9, the outcomes of the simulation runs are analysed and evaluated. The discussion is presented in chapter 10. Finally, the conclusion and recommendations are discussed in chapter 11.

Chapter 2

Literature review on the characteristics of consolidation

The supply chain of the healthcare sector is no ordinary supply chain, due to its specific characteristics of the products as explained in section 2.1. Since this research focuses on the consolidation of shipments in different networks of a logistics service provider, a brief explanation about this technique is given in section 2.2. In the past few years, a lot of research has been done with respect to the improvement of supply chains. Section 2.3 gives a brief overview of the research method that is most common. Finally, section 2.4 elaborates on the knowledge gap presented by the literature.

2.1 Product characteristics

Hospitals need different types of products, such as incontinence products, medical disposables and facility goods. These products originate from different suppliers, but all need to be transported towards hospitals (Ouzayd et al., 2010). These products are often lightweight products that are transported on pallets. Moreover, these products do not have any real restrictions with regard to the transportation thereof, while medication is a highly regulated product (Camp et al., 2011). Generally, medication needs to be transported under strict conditions. Medication needs a temperature controlled environment, but other conditions should also be taken into account, e.g. humidity level, light, oxygen, shocks, pressure, vibrations and X-rays. These conditions need to be monitored carefully in order to maintain the quality of the product (Ammann, 2011).

Cold chain medicines are medicines that require a temperature-controlled environment to maintain their quality. A cold chain can be described as an uninterrupted storage and distribution of products while maintaining a required temperature in a certain range (Bhatnagar et al., 2017). If the temperature range is breached for over 15 minutes, the quality and effectiveness of the product diminishes (Ammann, 2011; Bhatnagar et al., 2017; Coleiro, 2012).

Furthermore, the products considered in this research are finished products. This means that the value of the product now has the highest value in the whole supply chain due to the costs that have already been made. These are production, storage, and delivery costs, but also costs related to marketing, sales and other aspects (Ammann, 2011;

Subzwari and Nasir, 2015). During all these stages, it is important that the products stay in the required temperature ranges to maintain their quality (FanJun and ZhaoJiong, 2011).

During the transportation of these products, the distributor has to adhere to the guidelines on Good Distribution Practice (GDP) of medicinal products published by the European Union. These guidelines state that before a distributor is allowed to distribute such products, an authorisation is mandatory. These guidelines consist of requirements with respect to maintaining the quality of the system, competent personnel, owning adequate premises and equipment, good documentation of the system to prevent errors, handling complaints of returned or falsified medication, describing clearly the activities that are outsourced, self-inspections to monitor implementation of GDP and requirements of the transportation of the goods (Union, 2013).

Moreover, the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) provides conditions to which carriers need to comply. These conditions consist of packing and tank provisions, consignment procedures, requirements for the construction and testing of packaging, provisions concerning the conditions of carriage, loading, unloading and handling, and requirements for the vehicle crews, equipment, operation and documentation (Unece, 2019).

2.2 Consolidation

As mentioned in chapter 1, the consolidation of goods means that different products from different origins, but with the same destination are loaded in one vehicle and then transported to the receiver (Janjevic et al., 2013). This means that the number of deliveries at a destination can be reduced without changing the number of goods ordered by the customer. By combining the different products that are destined to the same location, the number of operating vehicles can be reduced due to fully loaded vehicles. However, section 2.1 elaborated on the different product types that need to be transported to the hospitals. When consolidating these items, different aspects need to be kept in mind (Ammann, 2011). When considering consolidating products, two types of consolidation orientations are possible, i.e. origin-centered consolidation and destination-centered consolidation (Holguín-Veras and Sánchez-Díaz, 2016). Origin-centered consolidation maximizes the efficiency of a supply chain by using the different assets in the most efficient way. Destination-centered consolidation combines the products from different suppliers that are destined to the same location (Holguín-Veras et al., 2016). The two consolidation programs, carrier-led consolidation and receiver-led consolidation, are discussed next in sections 2.2.1 and 2.2.2, respectively.

2.2.1 Carrier-led consolidation

The efficiency of carriers' operations can be improved by consolidating the goods. These shipments can be consolidated in different locations. The location that is chosen by the carrier is the most convenient location where the costs and lead times are smallest. The carriers only focus on their own gains (Janjevic et al., 2013). The goods can be consolidated in a prearranged location, a terminal of another carrier, or in an Urban Consolidation Center (UCC) (Holguín-Veras et al., 2016).

UCCs are facilities that are located at the border of a city. Suppliers deliver their products to the centers where they are consolidated into one vehicle and delivered in the city. UCCs try to decrease the total travelled distance of a product, and reduce the number of vehicles in the city (Aljohani and Thompson, 2019). To conclude, in the carrier-led consolidation technique, there is only a focus on the gains of the carriers. This means, that the most favorable location is chosen to consolidate their products without considering the receivers. This results in a cost reduction for the carriers (Aljohani and Thompson, 2019).

2.2.2 Receiver-led consolidation

In the past, there was mainly a focus on the carriers to improve the last mile delivery, by coordinating the different shipments going into the city. The last mile delivery can be described as the final stage of the delivery from warehouse to receiver (Wang et al., 2016). Lately the focus has shifted to the receivers, since receivers are the primary customers in the supply chain (Aljohani and Thompson, 2019). Furthermore, receivers are often located in dense areas, where pollution and congestion are big problems. Therefore, receivers are more focused on sustainability to improve the living conditions (Aljohani and Thompson, 2018).

Furthermore, this receiver-led consolidation method consists of two initiatives. In the first method, the number of deliveries are reduced by consolidating the products destined to the receiver (Estrada and Roca-Riu, 2017; Holguín-Veras et al., 2016). This method tries to encourage the different suppliers to deliver their products to a consolidation center where the products are loaded according to the receivers' benefit. This way, associated negative effects like pollution and congestion can be reduced (Holguín-Veras and Sánchez-Díaz, 2016). The second approach focuses on a delivery service plan for large companies to coordinate the deliveries to receivers (Jaller et al., 2015). This helps improve operating practices of companies that transport many goods to many receivers. A delivery service plan aims to reduce the number of deliveries and improves the efficiency of the supply chain (Holguín-Veras et al., 2016).

2.2.3 Effects of consolidation

Up to 20 percent of the typical hospital's operating budget is spent on supply chain costs (McKone-Sweet et al., 2005; Narayana et al., 2014). These operating costs can be reduced by two to eight percent with the help of an efficiently managed healthcare supply chain (Ben-Daya et al., 2008). Moreover, Ballot and Fontane (2010) state that there is a potential saving of at least 25% of CO2 emissions when optimizing the supply chain using consolidation. Furthermore, consolidation can help reduce the freight kilometers, and lessen local environmental and traffic problems in urban areas (Janjevic et al., 2013; Verlinde et al., 2012).

Moreover, consolidating shipments in one vehicle and making sure the vehicles are fully loaded, results in a reduction of the number of deliveries to the receiver (Aljohani and

Thompson, 2019; Allen et al., 2012; Conway et al., 2011). This way, the receivers are less often disturbed by the deliveries, which result in an increase in productivity. However, it is unknown if receivers are interested in such a consolidation program (Holguín-Veras et al., 2016).

2.3 Supply chain modeling and simulating

Several mathematical models and tools have been created that have contributed to the understanding of logistic operating processes. Information and communication technologies helped companies to control flows of goods in a more integrated way (De Vries and Huijsman, 2011; Dezdar and Sulaiman, 2009). Some of these tools have only been developed for certain companies. Often, these modeling tools are based on other simulation languages. These modeling languages mainly focus on the representation of the physical interactions between the stakeholders. This way, a simulation model can be used as a mean for communication in the supply chain design (Zee and Vorst, 2005).

In many cases, discrete event simulation modeling is chosen as the decision tool in supply chain management (Tako and Robinson, 2015; Zee and Vorst, 2005). Discrete event simulation models allow for modeling at an individual level. This results in a high running time. However, the model can be constructed in a way which resembles the reality (Caro et al., 2010; Nyhuis et al., 2005). This allows for testing different scenarios (Caro et al., 2010).

2.4 Summary of the literature review and knowledge gaps

Different products with different characteristics are needed in hospitals. These are products like incontinence products, medical disposables, facility goods and medication (Ouzayd et al., 2010). During the transportation of these products, the carrier has to adhere to the ADR and GDP regulations (Unece, 2019; Union, 2013). When a carrier is able to adhere to these regulations, the products can be consolidated in two ways (Aljohani and Thompson, 2019). The first method mainly focuses on the benefits for the carriers, while the second method (receiver-led consolidation) mainly focuses on the gains of the receivers (Aljohani and Thompson, 2018). The consolidation of goods can be described as combining products destined to the same location (Janjevic et al., 2013). This results in a reduction in operating costs, a reduction in CO2 emission and a reduction in the number of vehicle movements (Aljohani and Thompson, 2019). The effects of consolidating shipments has been researched many times (Holguín-Veras and Sánchez-Díaz, 2016). Often, mathematical tools and models have been created to contribute to a deeper understanding of the supply chain (De Vries and Huijsman, 2011).

However, there is no sufficient knowledge about the effects of implementing a receiver-led consolidation technique in a logistics service provider system and the trade-offs stakeholders need to make regarding the implementation of this technique. For example, it is unknown what trade-offs need to be considered by a hospital or supplier when collaborating with a logistics service provider.

From the literature, it became apparent that the knowledge on the effect of a receiver-led consolidation technique implemented in a logistics service provider's network is still lacking. Especially on how a receiver-led consolidation policy can improve the efficiency of a logistics service provider's network. Therefore, this research tries to create insight in the benefits and pitfalls of implementing a receiver-led consolidation technique and the trade-offs that need to be made.

Chapter 3

Research design

As discussed in section 2.4, the effects of implementing the receiver-led consolidation technique for a logistic service provider is unknown. Therefore, this research is conducted to find an answer to this. In order to find an answer to this question, a combination of qualitative and quantitative research is proposed, also known as mixed method research. When combining these two methods, it is possible to bring the different strengths of both methods together in the same research project (Morgan, 1998). Furthermore, the two techniques can contribute to different perspectives in the study of complex systems. The knowledge gained from qualitative research can help interpret the results from the quantitative research (Holguín-Veras and Sánchez-Díaz, 2016).

This chapter first elaborates on the goal of this research in section 3.1. After that the scope of this research is explained in section 3.2. Thereafter, the research method used to provide an answer to the main and sub-questions is discussed in section 3.3. Finally, the research flow diagram is presented in section 3.4.

3.1 Research goal

Several types of products in various volumes are transported separately towards hospitals, even though these shipments could be consolidated. However, why these shipments are not consolidated, how it could be improved and what the effects are on costs, CO2 emissions and number of vehicle movements is uncertain. Therefore, a case study for the logistics service provider PostNL is carried out which is explained in more detail in chapter 4. This creates insight in the current logistics network that transport these products towards hospitals. By doing this, the bottlenecks can be identified and an answer to questions like: why shipments are not consolidated, why multiple networks make a stop at the same location at the same day, how shipments with different characteristics can be consolidated, how networks can collaborate better, what the effects are on costs and CO2 emission, can be found. By creating insight in this current situation, alternatives can be proposed to improve the collaboration between the networks, reduce the number of vehicle movements, reduce the amount of CO2 emitted and reduce operating costs. To conclude, this research aims to provide a model that shows the current state of the PostNL network, but also the effects of consolidating shipments on some of the key performance indicators (KPIs), i.e. overlap, operating costs, and CO2 emissions.

3.2 Scope

Each of the networks of PostNL is its own supply chain that works individually, has its own characteristics and competencies. Different types of products are transported on these networks towards hospitals. The complete healthcare supply chain is visualised in figure 3.2.1. The healthcare supply chain is very complex. A healthcare product goes through several steps before it reaches its end-user as can be seen in this figure. The primary manufacturers produce the active ingredients of medicines. These ingredients are delivered to secondary manufacturers that process these ingredients to create the end-product. These products are then transported to distribution centers from where they are distributed to retailers or hospitals. It is also possible that the products are directly transported from the secondary manufacturer to the retailers or hospitals (Sousa et al., 2011; Zahiri et al., 2018). Once the products are finished, PostNL collects these products, distributes them to the warehouse where the shipments are sorted and finally, transports the medication and other products to hospitals, pharmacies and wholesalers. The scope of this research is the transportation of products from the supplier of end-products to hospitals. Figure 3.2.1 represents the complete pharmaceutical supply chain and the blue box indicates the scope of this research.

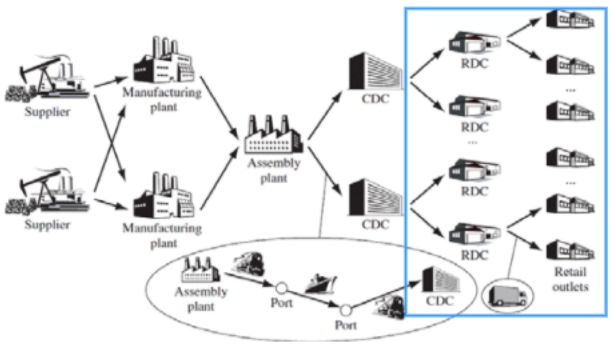


Figure 3.2.1: Scope of this research

3.3 Research method

In section 2.4 the knowledge gap is presented. From this, the following research question is drafted:

What is the impact of receiver-led consolidation alternatives in the PostNL supply chain with respect to trade-offs between costs, CO2 emissions and vehicle movements between PostNL and other stakeholders?

To answer this research question, the following sub-questions have been drafted:

1. What is the structure of the current logistics network of PostNL that transports the products from suppliers to hospitals and what are the bottlenecks?

2. How can a logistics service provider's network be captured in a quantitative model to model the effects of design alternatives?

3. What alternatives can be used to enhance the efficiency in the distribution of products from suppliers to hospitals?

The method that is used in this research is a framework for conceptual modelling proposed by Tako et al. (2010). By taking the different steps in this framework, a final design can be created. The steps taken are: initiate the study, structure the situation of interest, specify study objectives, develop a simulation model, experimentation, and implementation. These steps help to understand the system and create insight in which and how design alternatives can improve the consolidation of shipments between networks (Tako et al., 2010).

3.3.1 Sub-question 1: What is the structure of the current logistics network of PostNL that transports the products from suppliers to hospitals and what are the bottlenecks?

First a stakeholder analysis is carried out to create insight in the wishes and demands of the stakeholders involved. These requirements should be kept in mind when designing alternatives for improving the current system and when communicating the findings of this research.

Thereafter, the logistic processes of PostNL are described. In order to be able to improve the current PostNL network, a basic understanding of the current processes is necessary. This research focuses on three networks of PostNL, i.e. the Pharma&Care network, the Cargo network and the Mikropakket network. After that, the bottlenecks found in the current system of PostNL are discussed.

This sub-question is part of the first and second step in the framework; initiate study and define the system. In this phase the key activities in the system are mapped and the problems are identified.

3.3.2 Sub-question 2: How can a logistics service provider's network be captured in a quantitative model to model the effects of design alternatives?

The goal of this sub-question is to capture the system of PostNL in a simulation model. This is the third stage in the framework proposed by Tako et al. (2010). In this stage the key elements of the system are defined, as well as the study objectives, inputs and outputs of the model, and model assumptions and simplifications (Robinson, 2008). After that, a discrete event simulation model is built. The main advantages of this method are that it is commercially available, the models are easily adaptable, it is possible to analyse discrete events and the models have a high degree of acceptance. However, the application phase in creating the simulation models can be seen as a struggle (Nyhuis et al., 2005; Zee and Vorst, 2005).

3.3.3 Sub-question 3: What alternatives can be used to enhance the efficiency in the distribution of products from suppliers to hospitals?

The third sub-question aims to provide alternatives to implement the receiver-led consolidation technique to improve the current system of PostNL (Hevner et al., 2004). These alternatives are created during brainstorm sessions with the people responsible for improving the efficiency of the distribution of products towards the hospitals. Moreover, information can be gathered from literature research (Silverman, 2016).

These alternatives are implemented in the discrete event simulation model to investigate the effects on the current system. These adaptations generate different outcomes. These outcomes have their pros and cons for the stakeholders, because some parameters might be more important to stakeholders than others. By comparing the outcomes of the different parameter values for the stakeholders, trade-offs become apparent. It might be the case that not one outcome contains all the desirable parameter values. Therefore, trade-offs between criteria need to be made (Huang et al., 2011; Linkov et al., 2006).

3.4 Research flow diagram

The three sub-questions presented provide insight in how the efficiency in the current logistics network of PostNL can be improved. The steps taken in this research are visualised in figure 3.4.1.

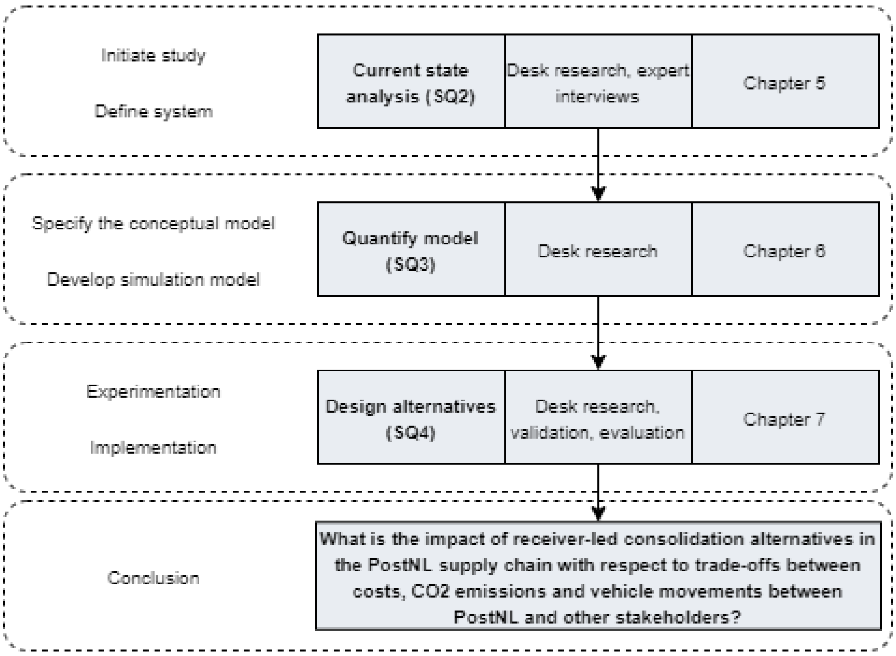


Figure 3.4.1: Research flow diagram

Chapter 4

A case study on the healthcare supply chain of PostNL

As discussed in chapters 1 and 3, a case study is carried out for the logistics service provider for PostNL. First, a short explanation of the company PostNL is provided in section 4.1. Thereafter, the characteristics of the PostNL networks are discussed in section 4.2. Finally, the case is described in more detail in section 4.3.

4.1 PostNL as a case study company

PostNL is a logistics service provider that operates in the Benelux. PostNL distributes mail and parcels, but also installs electronics in peoples homes and transports (temperature) controlled products. In the year 2019, PostNL delivered on average 6.8 million letters in the Netherlands and 900,000 parcels per day in the Benelux. They employed 46,303 people, drove around one million kilometres and went around the world by foot and bike around 1000 times. PostNL has 31 sorting centres, 11,415 letter boxes and 3,834 retail locations. Moreover, there is an increasing interest in sustainability which translates itself in 25.208 solar panels on their buildings (PostNL, 2020).

Furthermore, PostNL has several networks over which they distribute products, i.e. Mail, Cargo, Pharma&Care, @Home delivery and installation, Express, Mikropakket, night distribution and time-critical network (TCN). The Mail network distributes letters. The Cargo network transports pallets of goods. The Pharma&Care network takes care of healthcare related shipments. The Express network delivers packages within the same day. Finally, the Mikropakket network transports high-value goods (PostNL, 2020). As discussed in section 3.2, this research only focuses on the Pharma&Care, Cargo and Mikropakket network.

4.2 Characteristics of the networks

As mentioned in section 4.1, PostNL has several networks with their own characteristics. This section elaborates on the different attributes of the relevant networks in this case.

The Cargo network transports small and big shipments under GDP regulations and with ADR solutions in Europe. This network is able to distribute pallets, break bulk cargo, parcels, roll containers or even custom made solutions. Moreover, the customer receives a time frame indication of when the shipment is expected to arrive. A customer can request deliveries before 10:00, 12:00 or 14:00 o'clock.

Furthermore, the Pharma&Care network transports five times a week products related to the healthcare sector to (pharmaceutical) wholesalers, hospitals, pharmacies and general practitioners, and other medical care providers in the Benelux. These products are mostly transported on pallets. Furthermore, this network is completely specialised in dual temperature-controlled transport. This means that products can be kept in a temperature range from two to eight degrees Celsius or between 15 and 25 degrees Celsius. The hub is actively monitored and conditioned to make sure there is no temperature breach. In addition, this network is compliant to the newest GDP and ADR guidelines. The employees are trained in GDP and ADR transport. Finally, the network delivers in a set time frame and deliveries can be done within 24 hours.

Finally, the Mikropakket network delivers six days a week, high value parcels to (healthcare) customers. This network is completely designed for the transportation of single parcels (colli). These can be normal parcels, dual temperature regulated or highly secured products. This network is able to transport parcels within the temperature range of two to eight degrees Celsius, or between 15 and 25 degrees Celsius and additional security measures during delivery are possible. These deliveries are done within a time frame that is communicated via text or email to the customer. However, a customer cannot set a specific time frame in which they would like to receive the parcels.

The characteristics of these networks are summarized in table 4.2.1.

Table 4.2.1: Characteristics of the PostNL networks

Characteristics	Cargo	Pharma&Care	Mikropakket
GDP	Yes	Yes	Yes
ADR	Yes	Yes	No
Pallets	Yes	Yes	No
Roll containers	Yes	No	No
Colli	Yes	Yes	Yes
Time frame indication	Yes	Yes	Yes
Pre-defined time frame delivery	No	Yes	No
Dual temperature controlled	No	Yes	Yes
Shipment days	5 days	5 days	6 days
Security	No	No	Yes

4.3 Case study description

In the beginning of 2018, a new team was established: PostNL Health. This team focuses on the distribution of healthcare products. By doing this, the team uses different networks of PostNL to deliver all types of products. The networks most often used are the Pharma&Care, Cargo and Mikropakket network. The products transported over these networks are medication or medical disposables. However, due to the fact that several networks are used to transport these products, there is no clear overview of how many products are delivered at a certain location and which networks are being used. Therefore, it is possible that there is overlap between the networks with regard to the destination addresses. This means, that the Pharma&Care network could make a delivery to the same hospital on the same day as the Mikropakket network. This results in multiple deliveries to hospitals causing more vehicle movements which is inefficient for the receivers and PostNL.

Therefore, it would be better to consolidate shipments while taking into account the characteristics of the shipments. However, consolidating shipments proves to be difficult. The suppliers are the customers of PostNL and sign contracts with a specific network for a certain rate. Temperature controlled products sent via the Pharma&Care are more expensive than bulk cargo sent via the Cargo network. Consolidating these shipments makes that parcels are redirected to a different network where a higher rate might be in place. However, the supplier has a contract with the network for a certain rate and therefore charging a higher rate to this customer due to the benefit of PostNL does not seem fair. Therefore, other prices might need to be asked which can result in less cost savings. Ultimately, it is the choice of PostNL to redirect shipments, because they believe redirecting and consolidating improves their efficiency even though the shipments are redirected to a more "expensive" network.

Another reason that makes consolidating shipments more difficult is the fact that many suppliers see logistics as a commodity. This means that they try to find the cheapest solution for the most acceptable quality. The quality of service might be more important to certain suppliers than others.

Finally, it might be the case that the Pharma&Care network needs to make a stop for just one or two parcels. This is more expensive for this particular network than it would be for the Mikropakket network. Therefore, it has to be investigated whether certain networks make expensive stops in comparison to other networks. However, when considering to shift certain shipments to other networks, the requirements of these shipments and competencies of the networks need to be kept in mind. Therefore, this research focuses on the different networks and tries to investigate if multiple deliveries are done on the same day to the same location. And how often stops are made by the Pharma&Care network for less than five colli.

Chapter 5

Current state analysis of the PostNL network

This chapter presents the current state analysis of the PostNL network. Several networks of PostNL transport products towards hospitals, i.e. the Cargo, Pharma&Care and Mikropakket network. Insight in the current processes contributes to a deeper understanding of the networks which helps to identify key elements for the simulation model. This chapter addresses the following sub-question:

What is the structure of the current logistics network of PostNL that transports the products from suppliers to hospitals and what are the bottlenecks?

In order to get an understanding of this current system, several aspects need to be analysed. First of all, the stakeholder who are involved in this case are identified in section 5.1. To get an idea of the overall structure of the logistic network, the internal processes of PostNL are described in section 5.2. Based on these two sections, the bottlenecks are identified and discussed in section 5.3. Finally, a summary of this chapter is given in section 5.4 where th sub-question is answered.

5.1 Actor identification

Several stakeholders are involved in the pharmaceutical supply chain. These stakeholders all have different perspectives on the problem. Therefore, an actor analysis is carried out according to the method of Enserink et al. (2010) in appendix B.1. This section elaborates on the stakeholders associated with this research in order to be able to provide advice on implementing design alternatives. The stakeholder analysis contributes to a deeper understanding of the importance of certain parameters that help identify model requirements (Enserink et al., 2010).

The perspectives and interests identified in the actor analysis are summarized in table 5.1.1. This table has only incorporated the core actors (supplier, hospital and logistics service provider). On most of the criteria, these stakeholders agree with each other. However, the main focus differs per stakeholder. Hospitals mainly want to reduce the number of incoming shipments, the suppliers of end-product want to reduce the transportation costs without having to change their operating practices, and the logistics service providers would like to reduce the transportation costs and amount of

CO2 emitted.

Table 5.1.1 presents a summary of the most important criteria for the stakeholders. In the table, a plus sign is used if that particular attribute is important to that stakeholder, a minus sign if it is not important, and a zero if that criteria does not apply.

Table 5.1.1: Summary of the external stakeholder analysis. A plus sign is used when an attribute is important, a minus sign if it is not important, and a zero if that criteria does not apply.

Elements	Supplier	Receiver	Logistic service provider
Operation costs	+	+	+
GDP	+	+	0
ADR	+/-	+	0
Transport of pallet	+	+	0
Transport of break bulk cargo	+	+	0
Transport of roll containers	+	+	0
Performance of PostNL	+	+	+
Time frame	+	+	0
Number of deliveries	-	+	+

5.2 The internal processes of PostNL

As described in section 5.1, many stakeholders are involved in this research. The collaboration between these stakeholders are regarding external processes, whereas improvement possibilities lie within the internal processes of PostNL. Nevertheless, the success rate of the improvements depend on the willingness of the stakeholders to cooperate.

This section describes the internal processes of PostNL. As mentioned in section 3.2, the scope of this research reaches from the distribution of end-products from suppliers to hospitals. The different process steps taken in the PostNL network are visualised in figure 5.2.1.

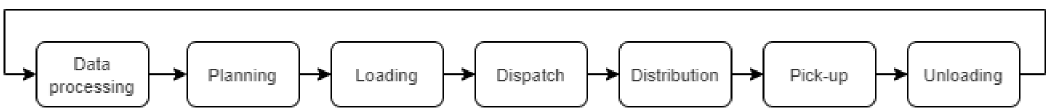


Figure 5.2.1: Internal process flow PostNL

As can be seen in figure 5.2.1, the internal processes of PostNL can be summarized in seven steps: data-processing, planning, loading, dispatch, distribution, pick-up and unloading. First of all, suppliers pre-notify shipments to a specific network of PostNL. These shipments have certain characteristics, such as a destination address, quantity, ADR and/or GDP regulated. This pre-notification is processed in the first step. After all the data from all shipments is processed, the planning department divides the shipments under the drivers and prepares the routes for the drivers. Then the shipments are loaded in the trucks or vans and they are dispatched. The drivers distribute the shipments to the receivers. When the drivers have delivered all the shipments, they pick-up new shipments from the suppliers. These shipments are then transported to the hub of PostNL and unloaded. During the unloading process, the shipments are scanned and the data from the pre-notification is processed. After this, the whole process starts over. These internal processes are discussed in more detail in appendix C.

Every network used in this research operates in a similar way, except the data-processing system differs. This process is discussed in more detail in section 6.2.

5.3 Identification of the bottlenecks

From the explanation of the current system of PostNL in section 5.2 and discussions with PostNL employees, several bottlenecks have been identified. These bottlenecks imply that the current network of PostNL does not operate is the most efficient way. These inefficiencies translate themselves to deliveries to the same locations on the same date by different networks, stops for single colli for the Pharma&Care network, high costs and a high amount of CO2 emitted.

First of all, it sometimes occurs that multiple networks make deliveries to the same location. Currently, the networks do not communicate with each other to check whether or not one of the networks have planned to make a stop at a certain destination. This results in a stop for several networks at the same location on the same day which leads to more vehicle movements, more CO2 emissions and higher costs. Based on the stakeholder analysis in section 5.1, receivers (hospitals) would like to reduce the number of deliveries during the day. This could be done by consolidating the shipments according to the receiver-led consolidation policy, as explained in section 2.2.2. This would also result in a more efficient network for PostNL, because they only have to make one stop with one network at a certain location. In order to be able to do this, shipments have to be redirected to another network. However, this rerouting often leads to physical transportation of the shipment to a different distribution center which leads to more handling costs for PostNL and probably more CO2 emissions.

Furthermore, based on empirical research, it sometimes occurs that the Pharma&Care network needs to make a stop for just one or two parcels while these parcels, in theory, needed to be transferred to the Mikropakket network. If these colli would have been redirected to the Mikropakket network, they would have been transported in a van instead of a truck. This means, that less CO2 would be emitted. Furthermore, stopping for less than five colli is highly expensive for the Pharma&Care network, while the Mikropakket network is set-up for these kind of shipments. One of the reasons these parcels are not redirected to the Mikropakket network is due to the list of wholesalers. If the shipments originated from a particular supplier, it is checked whether or not the destination address is present on the list of wholesales. If a certain address occurs on this list, parcels destined for this address are automatically sent via the Pharma&Care network, instead of checking whether or not only a single parcel is sent to this address. However, this only occurs on average eight times a week.

Another bottleneck arises, because the list of wholesalers is established based on a carrier-led consolidation policy (section 2.2.1). This list is set-up for suppliers who are big customers of PostNL. The list of wholesalers is developed based on common sense. It is checked if a destination is likely to receive pallets instead of colli. When this is the case, this address is put on the list of wholesalers. However, it could be the case that on certain days only one or two colli are sent to this address. It would be expected that these colli are then transported by the Mikropakket network. However, due to the fact that a shipment is first checked on the list of wholesalers and not on its quantity, inefficiencies can arise. Combining this with the non-updated list of wholesalers, stops for single parcels could be made by the Pharma&Care network which result in higher costs and higher levels of CO2 emissions.

Moreover, the list of wholesalers is not updated frequently. This means that if a shipping profile of a certain customer changes, it is not always incorporated in the PostNL system. This alteration could mean that the shipping profile changes from pallets to colli or from deliveries on multiple days to deliveries on only some days of the week. However, it is not checked if this profile changes and what the effects are on the network.

5.4 Summary of the current state analysis

This chapter elaborated on the sub-question:

What is the structure of the current logistics network of PostNL that transport the products from suppliers to hospitals and what are the bottlenecks?

Based on the actor identification in section 5.1, it became apparent that the most important stakeholders for PostNL in this case are the suppliers of end-products and the hospitals. These stakeholders have the greatest impact on design changes in the current system of PostNL.

After the actor identification, the internal processes of PostNL were discussed. The complete process consists of: (1) data-processing, (2) planning, (3) loading, (4) dispatch, (5) distribution, (6) pick-up, and (7) unloading. Sub-processes two to seven are similar in the Pharma&Care, Cargo and Mikropakket network, while the first process differs. Within this process collaboration between networks occur. In order to make sure more shipments are consolidated, these networks need to collaborate more. This can be done by improving the first sub-process.

Most bottlenecks have been identified in the first sub-process. These bottlenecks occur in the form of deliveries to the same destinations on the same day and expensive stops for the Pharma&Care network compared to the Mikropakket network. These inefficiencies can be explained by the current list of wholesalers and a lack of collaboration between the networks.

Chapter 6

Model conceptualisation

Conceptual modeling can be seen as the abstraction of a simulation model from the part of the real world it is representing (Robinson, 2012). A conceptual model can be defined as: "a non-software specific description of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model" (Robinson, 2008). In this chapter the conceptual model of the logistics service provider's network PostNL is specified and an explanation of how the simulation model is set-up is provided. This chapter addresses the following sub-question:

How can a logistics service provider network be captured in a quantitative model to model the effects of design alternatives?

First the model requirements are discussed in section 6.1. Thereafter, the conceptual model is explained in section 6.2. Section 6.3 discusses how the conceptual model is implemented in the simulation software Simio. Finally, section 6.4 provides a summary of this chapter.

6.1 Model objectives

Based on the stakeholder analysis performed in section 5.1 and appendix B.1, the explanation of the current system of PostNL given in section 5.2 and the identified bottlenecks described in section 5.3, it can be concluded that the main problems within the PostNL network are related to the lack of collaboration between the networks. Currently, the networks consolidate shipments towards receivers. However, shipments between networks are not consolidated, even though the literature study and stakeholder analysis have identified a need for this. Due to this, inefficiencies appear in the form of deliveries to the same address by multiple networks and expensive stops for the Pharma&Care network. Furthermore, more vehicles movements are generated which cause higher operating costs and more CO2 emissions.

In order to capture these problems in the model, a conceptual model of the data-processing system has been created. The consolidation of shipments should occur in this phase. Therefore, it has been decided to only focus on this part of the PostNL network.

Without knowing the purpose of the model, an incorrect simplification of reality can be created (Robinson, 2012). Therefore, the following model objectives are formulated:

- Improve the efficiency of the operating practices of the logistics service provider PostNL
- Create insights in the collaboration possibilities between the different networks
- Reduce CO2 emissions
- Reduce operating costs
- Reduce the overlap in delivery destinations between networks

With the help of these objectives, a model of the current system can be created. By keeping in mind the different model objectives, the outcomes of the model can be measured which helps identify the performance of the system.

6.2 Conceptual model

As discussed in section 5.2, collaboration between networks appears in the data-processing step. Therefore, this research focuses on this sub-process. Within this process, the shipments are being directed to a network based on certain criteria. The current data-processing phase in the PostNL network is visualised in figure 6.2.1.

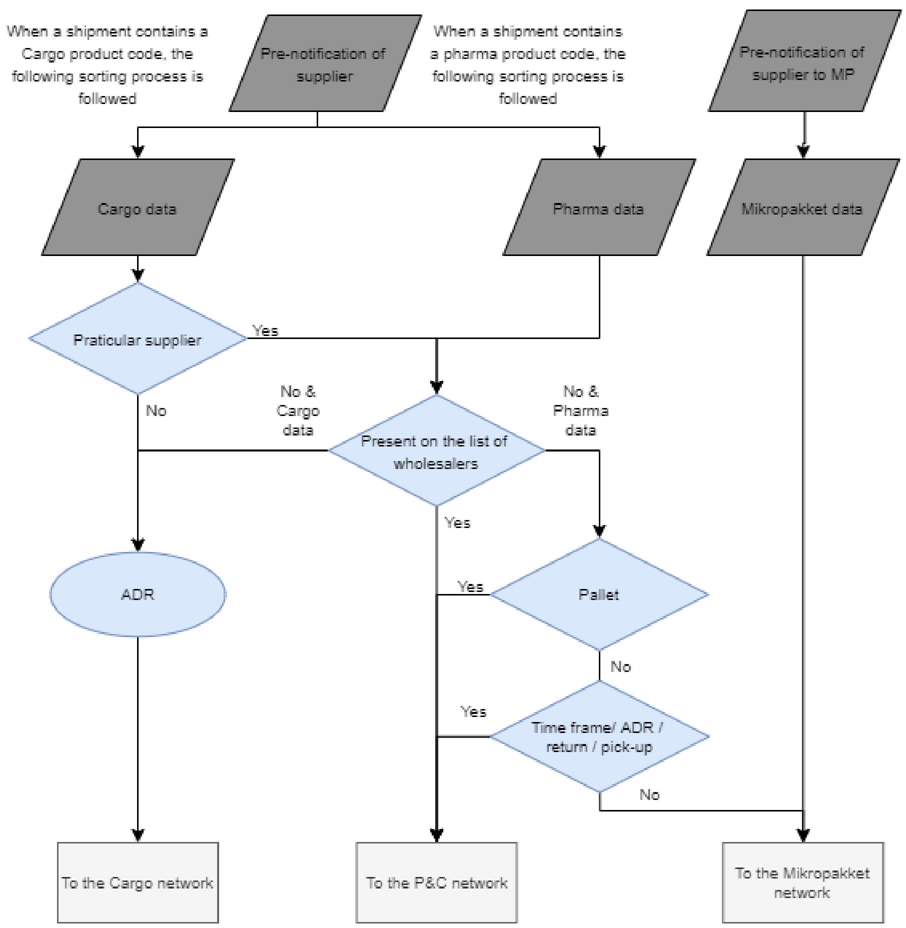


Figure 6.2.1: Current data-processing system in the PostNL network

As can be seen in figure 6.2.1, the sorting process consists of multiple phases that differ between the networks. The first step is the same for all three network. The data-processing step starts when a supplier pre-notifies PostNL that they have a delivery ready for pick-up. This shipment receives a product code. This product code depends on the network the shipment is pre-notified to. After this, the different processes are discussed next.

Data-processing in the Cargo network
As visualised in figure 6.2.1, shipments pre-notified to the Cargo network follow several decision steps. The first decision checks whether or not shipments originate from V WR, Eurodis or Pharma&Care Belgium. If they do, the delivery addresses of the shipments are checked on the list of wholesalers. [redacted]

This list contains multiple addresses where it is likely that a high volume of goods is distributed to. When the delivery address is present on this list, shipments are redirected to the Pharma&Care network. If the destination addresses of the shipments are not present on the list of wholesalers, the shipments are sent to the ADR check.

[redacted]

Furthermore, if shipments do not originate from VWR, Eurodis or Pharma&Care Belgium, the shipments are also sent to the ADR check. Here, it is checked if the shipments need ADR regulated transport. This characteristic is saved in the pre-notification data from the supplier. If the shipments need an ADR regulated delivery, the shipments are sent via the Cargo network, otherwise the shipments are redirected to the "Pakketten" network. However, the "Pakketten" network is not included in this research, as explained in section 6.2.2.

Data-processing in the Pharma&Care network
When a shipment has a Pharma product code, three decision steps need to be made: (1) list of wholesalers check, (2) pallet shipment and (3) time frame, ADR, return or pick-up drive. If the answer to these steps is "Yes", the shipment is sent via the Pharma&Care network. If the answer is "No", the shipment is sent via the Mikropakket network. These parcels are then physically transferred to the depot of the Mikropakket network.

The resources necessary to perform these processes are the list of wholesalers and the data-processing program. The control factors within these processes are the characteristics of the shipments. Especially, the destination address, the shipment size, requirement for ADR regulated shipment, requirement for a time sensitive delivery, and whether the shipment is a return or a pick-up shipment.

Data-processing in the Mikropakket network
The data-processing phase in the Mikropakket network is completely different from the Cargo and Pharma&Care network. Within the data-processing phase in the Mikropakket network, the shipments are pre-notified and no additional checks need to be done. Within this network, the shipments are not redirected to a different network. This network does, however, receive parcels from the Pharma&Care network.

6.2.1 Input and output variables

This section elaborates on the in- and output variables of the model. Input variables are items that need to be transformed to achieve the model objectives. The output variables are the factors that show whether the model objectives are reached, and if not, what needs to be done to achieve the objectives (Robinson, 2012).

In this research, the input variables are the shipments that are pre-notified by the suppliers to PostNL. These shipments have the following characteristics: a destination, a delivery time, a size, a temperature demand, an ADR demand, and a supplier.

The output of the model are shipments sorted by network. These shipments have the same characteristics as when they entered the system. However, the sorting process might decide to redirect a shipment to a different network. The output of the data can be used for further analysis. Based on this output, the number of shipments redirected to a certain network, the overlap between delivery destinations between the networks, the number of stops per network, the operational costs and the amount of CO_2 emitted, can be calculated.

As discussed in section 6.2, the list of wholesalers is needed in order to sort shipments in the Pharma&Care network and some of the shipments in the Cargo network. This list remains constant during the simulation run, as well as the list of senders needed to be checked in the Cargo network. These lists are pre-defined by PostNL.

6.2.2 Model assumptions and simplifications

If there are uncertainties or certain beliefs about the real world, model assumptions are made. This means that not every aspect of the real world can be incorporated in the model. Furthermore, simplifications make sure the model is developed in a more easy way and to improve transparency (Robinson, 2012). This section elaborates on these assumptions and simplifications.

Several assumptions and simplifications had to be made in this case. These are presented in table 6.2.1.

Table 6.2.1: Assumptions made of the system for the use of the simulation model

Assumptions & simplifications	Explanation
The pre-notification data is complete.	It often occurs that this data is not complete. However, how often and why this happens is unknown. Therefore, it is assumed that the data is complete.
There are four types of shipments: colli, pallet, roll container or other.	These four types are handled in the PostNL network and are therefore included.
Sorting errors are excluded.	It sometimes occurs that parcels are sorted incorrectly. However, these errors happen around twice a month and have therefore minimal effect on the overall process.
Seasonal and other long term trends are not included.	Seasonal and long term trends could influence the amount of parcels sorted each day. However, in this case, the demand is rather stable over the year.
The time needed for the data processing phase is not taken into account.	The speed of the data processing phase depends on several aspects. The goal of this research is to calculate operating costs, amount of CO2 emitted and overlap between networks which is barely influenced by the speed of this process.
The Pakketten network is not included in the model.	This network is not included, because the volume of shipments sent to hospitals is rather small.

6.3 Simulation model

This section elaborates on the implementation of the conceptual model in the simulation software. Section 6.3.1 elaborates on the chosen simulation software. After that, section 6.3.2 explains how the input data is prepared. Finally, section 6.3.3 elaborates on how the model is built in the simulation software.

6.3.1 Model environment

As mentioned in section 2.3, several mathematical models and tools have been created to simulate logistic operations (De Vries and Huijsman, 2011). The methods most often used are continuous modelling, discrete event modelling, or a hybrid form (Tako and Robinson, 2015). A discrete event simulation (DES) model is a modelling technique which is widely used as a decision support tool in logistics and supply chain management (Tako and Robinson, 2015). Using such a model, the detailed operations of the supply chain can be studied under uncertainty and the expected performance measures can be evaluated (Behdani, 2012). In the past, many DES models have been presented to study the supply chain and evaluate the expected performance measures (Günal and Pidd, 2010).

Therefore, the conceptual model presented in section 6.2 is implemented in the simulation software Simio. Simio is a simulation software that allows for modeling discrete event simulations. The different process step can be modelled and visualised. Since the researcher is already acquainted with this software, the logistic processes of PostNL are simulated using Simio.

6.3.2 Input data preparation

When considering the input data of the simulation model, no assumptions about variables need to be made. This is due to the fact that a case study for the logistics service provider PostNL is performed in this research and a lot of data is available. The real pre-notification data of the Cargo, Pharma&Care and Mikropakket network are used. Data of the first two months of the year 2020 has been chosen to be analysed. This particular period is chosen due to the fact that shipments were sent to different destinations by all networks and overlap between destinations is expected. This means, that all networks made a stop at a particular destination on the exact same date.

As explained in section 6.2.1, the input of the model are shipments with several characteristics. Most of these characteristics could directly be derived from the PostNL server. However, information about whether or not a shipment needed to be transported under temperature controlled environment or ADR regulations was not directly provided. These characteristics needed to be deducted from the assigned product codes. Moreover, information about pick-up and return tours needed to be obtained from a different data source. Shipments that had an "AD" component are removed from the data set, due to two reasons. First of all, the "AD" component resembles a special service which is not provided by one of the networks incorporated in this research. Secondly, this characteristic means that it might be a pick-up ride, but it can also appear in the data set as a shipment. This way, the shipment can appear multiple times in the data set.

Furthermore, as explained in section 6.2, destination addresses from shipments are checked on a list of wholesalers. This list is also provided by PostNL. Due to the fact that the software used to model this process sometimes has trouble with string variables, an extra column is added to the data set that contains a one if the destination address of the shipment is present on the list. Otherwise, the cell contains a zero.

6.3.3 Discrete event simulation model

This section elaborates on how the conceptual model is built in the Simio software. Each of the decision steps visualised in figure 6.2.1, were implemented in Simio.

A source object is placed in the model environment. This source generates entities (shipments) based on their pre-notification time and date. The amount of pallets, colli, roll containers or other shipments created, is decided based on the shipment size. This shipment size depends on the number of deliveries suppliers have ready for PostNL.

Moreover, the other characteristics defined in the data set are inherited by the entity that is created. Based on the product code shipments are directed to a certain path, as explained in the conceptual model in section 6.2. This is explained in more detail in section 9.1. Each of the parameters set in the model are derived from the PostNL network. The pre-notification data set, as well as the list of wholesalers, is imported from Excel to the Simio model. A simulation run of two months was chosen.

6.4 Summary of the model conceptualisation

This chapter tried to capture the network of the logistics service provider PostNL in a quantitative model to answer the following sub-question:

How can a logistics service provider network be captured in a quantitative model to model the effects of design alternatives?

By creating a conceptual model of the data-processing step, insights in the model components and in- and output variables are created. Based on this, some simplifications and assumptions about the model are made. After that, the conceptual model can be implemented in the discrete event simulation software Simio. Within this software the different sub-processes can be modelled and visualised.

Chapter 7

Design alternatives to improve the current system of PostNL

Based on the current state analysis in chapter 5 and the model conceptualisation in section 6.2, design alternatives are proposed to improve the current system of PostNL. This section elaborates on these design alternatives and addresses the following sub-question:

What alternatives can be used to enhance the efficiency in the distribution of products from suppliers to hospitals?

First an explanation of how and why these alternatives have been created is provided in section 7.1. After that the two design alternatives are explained in sections 7.2 and 7.3. Finally, a short summary of this chapter and an answer to the sub-question is given in section 7.4.

7.1 Creating design alternatives

After analysing the current system of PostNL (chapter 5), it became clear that the main bottlenecks appear in the data-processing phase. Furthermore, it is expected that implementing design alternatives in an early stage will improve the efficiency of the system the most. By talking to PostNL employees more insight in the current bottlenecks has been obtained, as discussed in section 5.3. Based on this, discussions about possible design alternatives were started.

During these discussions, several alternatives were proposed and the expected implementation effort, time, costs and success rate of these alternatives were evaluated. From this, the two design alternatives with the highest rate of success and the biggest expected impact on the efficiency were chosen to elaborate on further. These two design alternatives are discussed in more detail in sections 7.2 and 7.3.

In this research, it has been chosen to implement a rather simple design alternative and a design alternative that is expected to be complicated to implement. A simple design is chosen, because it is expected that this design yields many benefits with limited implementation effort. While a more complicated design is expected to yield the highest results, but is more difficult to implement in the current system.

These benefits will not only apply to the logistics service provider PostNL, but also to the other core stakeholders involved; suppliers of end-products and the hospitals. Since PostNL has to keep those stakeholders in mind when changing their operating system, the effect of the design alternatives for these stakeholders should also be evaluated. It is expected that these design alternatives have a positive impact for hospitals and suppliers.

Furthermore, these design alternatives are focused on improving the efficiency of the network of PostNL with respect to the costs, CO2 emissions, number of vehicle movements and overlap. These KPIs are important to PostNL, but also to the suppliers and hospitals.

7.2 Design alternative 1 - Integrating processes of different networks

This first design alternative is proposed to decrease the overlap between network, reduce operating costs, CO2 emissions and vehicle movements. It is expected that the implementation of this design alternative improves the efficiency of the current system of PostNL.

Within this design alternative, it is proposed that all shipments pre-notified to PostNL are checked on the list of wholesalers. This means that the process in the Pharma&Care network remains the same, but in both the Cargo and Mikropakket network changes are made. This new process is visualised in figure 7.2.1. As can be seen in this figure, a small change is made for the Cargo shipments, because now not only shipments originating from VWR, Eurodis or Pharma&Care Belgium are checked on the list of wholesalers, but every shipment is checked on this list. Furthermore, shipments pre-notified to the Mikropakket network are now also checked on the list of wholesalers. When the destination address is present on the list, the shipments are sent via the Pharma&Care network, otherwise the original data-processing steps are followed. Figure 7.2.1 shows this new process where red arrows present the different flows between the current system and this first design alternative.

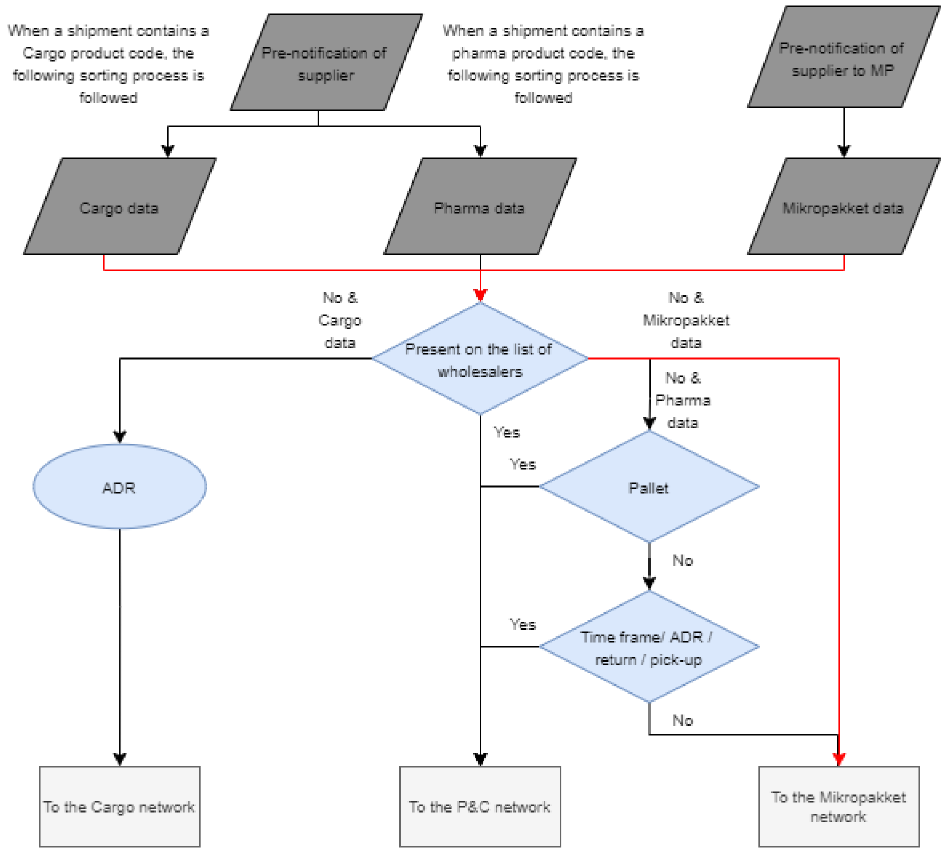


Figure 7.2.1: Schematic overview of design alternative 1

When implementing this design alternative, more shipments are expected to be consolidated in the Pharma&Care network, due to the check on the list of wholesalers. If the destination address of a shipment is present on the list, the shipment is sent via the Pharma&Care network. It is expected that the consolidation of these shipments lead to less overlap between networks, less vehicle movements, and therefore less operating costs and CO2 emissions. These effects are also reflected in the literature review in chapter 2 (Aljohani and Thompson, 2019; Ben-Daya et al., 2008; Conway et al., 2011; Verlinde et al., 2012).

Implementing this design alternative in the PostNL system is relatively simple, because no changes need to be made in the current Pharma&care network. Furthermore, in the current Cargo system some shipments are already checked on the list of wholesalers. Therefore, changing this to a system where all shipments are checked on the list is relatively easy.

However, implementing this system in the Mikropakket network is expected to be more difficult due to the fact that a new process step needs to be added. Currently, the Mikropakket network does not have any steps within the data-processing phase. So, after implementing this design alternative a change in operating systems needs to be done. However, since this data-processing system already exists and no new system needs to be created. However, changing a complete order management system of a network is expensive and rather difficult even though the new system is already in use by a different network.

In order to implement this design alternative multiple PostNL teams have to cooperate. The IT team need to make sure that the different systems can be linked together or that a new system is implemented. Furthermore, the team in operations need to make sure the extra expected volume from different network can be handled according to the correct standards. More shipments are expected to arrive at the last minute and need to be added to the system to be handled that same day.

7.3 Design alternative 2 - Implementing a smart planning process

The second design alternative is a more complicated alternative. As discussed in section 5.3, only a few parcels from the Pharma&Care network are redirected to the Mikropakket network, even though the planning team regularly needs to send chauffeurs to destinations for only single colli. This leads to expensive stops for the Pharma&Care network. Furthermore, multiple deliveries are done to the same locations with multiple networks. This generates more vehicle movements than necessary, which result in higher operational costs and more CO2 emitted. Therefore, the second design alternative that is proposed is focused on the collaboration between the different networks. With this alternative it is expected that the overlap between destination stops, the number of stops, the operational costs and the CO2 emissions drop extremely.

Within this second design alternatives the three networks (Cargo, Pharma&Care and Mikropakket network) collaborate more. A new system is created where shipments, based on their pre-notification data, are consolidated and redirected to a certain network. This new process is visualised in figure 7.3.1. This figure shows the additional process, the original process, as visualised in figure 6.2.1, remains intact. This additional process is added after the original process.

Within this additional process, shipments are checked on multiple characteristics. First, it is checked if the total number of colli destined to an address is less than five and the number of pallets sent to that address is zero. If this is the case, shipments are redirected to the Mikropakket network. If this is not the case, the destination addresses of the shipments are checked on overlap. If there is no overlap between networks, the shipments remain in its original network. However, if there is overlap between networks, multiple characteristics are checked before redirecting the shipments. The shipments are redirected to the Pharma&Care network if the answer to the following questions is yes: (1) GDP regulated, (2) pallet shipment in Pharma&Care network, (3) no Cargo pallets and (4) more than five Pharma colli. If the answer to these questions is "No", the shipments are redirected to the Cargo network. A schematic overview is presented in figure 7.3.1.

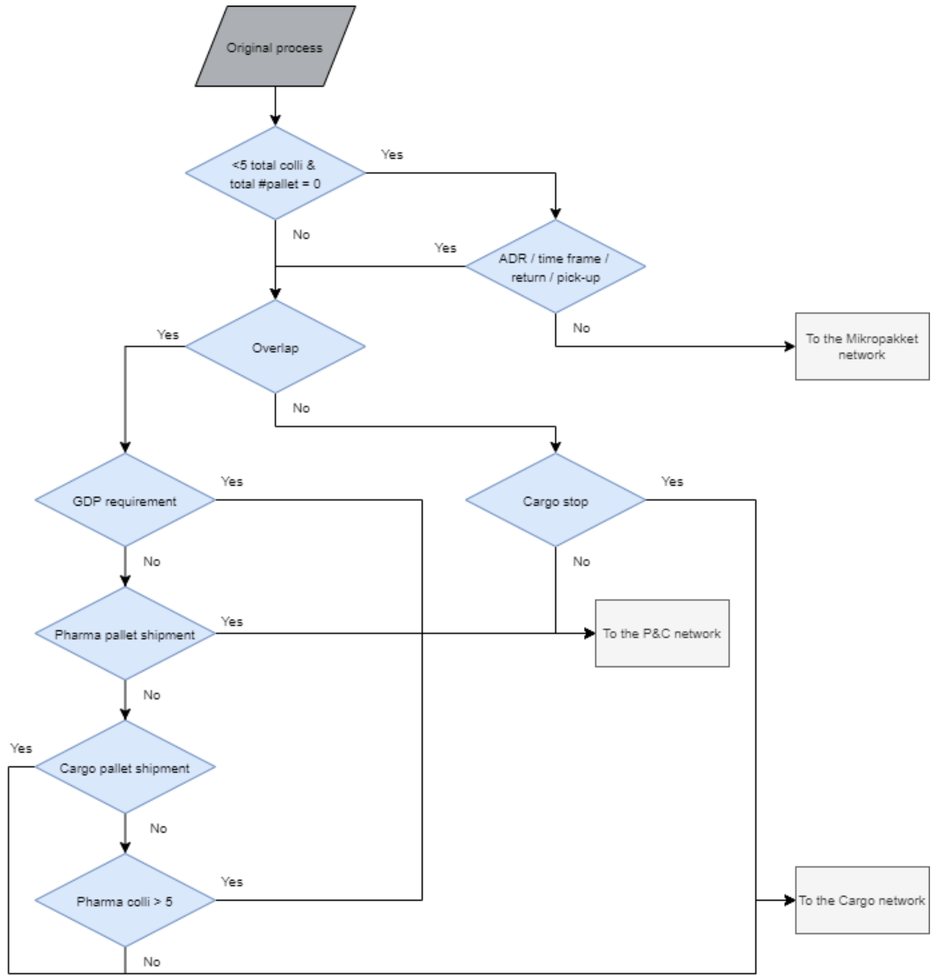


Figure 7.3.1: Schematic overview of design alternative 2

By implementing this design alternative, shipments can be consolidated not only within a network, but also between networks. A case study executed by Erik Eriksson (2010), found that collaboration between partners can reduce the operating costs significantly. Furthermore, the increased information exchange results in less last minute changes which reduces the number of disruptions (Vereecke and Muylle, 2006; Wagner et al., 2010). These effects are favorable for PostNL, but also for the receiver. The stakeholder analysis in section 5.1, has found that reducing the number of deliveries during the day will benefit receivers. It is expected that their productivity increases when the number of deliveries is reduced. Furthermore, research by Wagner et al. (2010), has shown that investing in additional resources results in cost reduction. In addition, implementing partnering resulted in a increase in performance (Wagner et al., 2010).

When considering the stakeholders involved, a positive effect is expected for the receivers and suppliers. It is expected that the number of deliveries are reduced and suppliers do not need to change their operating practices.

Implementing this design alternative is expected to be expensive and difficult. The application that needs to be created in order for networks to collaborate is expensive and time consuming. The IT team of PostNL or an external team has to create an application that is able to verify shipments on overlap. Furthermore, all three networks have to change their operating practices, because more shipments are expected to arrive in the final sorting stage. These shipments need to be handled with the same care as shipments that are not redirected.

Implementing this design alternative will have its difficulties due to the different order management systems between networks and the absence of a link between the Cargo and Mikropakket network. First of all, the three networks involved have their own order management systems. These systems operate in a different way and have difficulties communicating with each other. Therefore, linking the systems together might prove to be more difficult. This could be solved by implementing the same order management systems for each of the three networks. Or creating a new application that is able to link the systems together.

Secondly, it is expected that shipments from the Cargo network are redirected to the Mikropakket network and vice versa. In the current system, no physical link exists between these networks. Adding this link between the networks is expected to be costly. A vehicle has to drive between the two hubs to exchange shipments. It is expected that no extra personnel is needed to load and unload this truck. However, these shipments do need to be sorted in the correct way to make sure no errors occur. By adding an extra step to the process, human errors might occur.

7.4 Summary of the design alternatives

This chapter elaborated on how alternatives have been created, what they mean and the expected results. This helps answer the sub-question:

What alternatives can be used to enhance the efficiency in the distribution of products from suppliers to hospitals?

Design alternatives have been created to improve the data processing phase, because it is expected that the highest results can be achieved when changing a process early in the system. During brainstorm sessions with PostNL employees two design alternatives have been created that focus on reducing the number of stops and operating costs, increase the revenues, and reduce the overlap between networks.

To answer this sub-question the following two design alternatives have been proposed. In the first design alternative a rather small change to the current system is proposed. It is recommended that all shipments pre-notified to PostNL are checked on the list of wholesalers. The second design alternative consolidates shipments in all networks. It is expected that this design alternative is more difficult to implement since a new application needs to be built. By implementing these design alternatives, the collaboration between networks can be improved.

Chapter 8

Model verification & validation

In this research, a simulation model has been created. In order to find how accurate this model represent the real world, the model is verified and validated. Sections 8.1 and 8.2 elaborate on the verification and validation of the simulation model, respectively.

8.1 Model verification

In order to ensure that the model is designed according to the requirements, the simulation model is verified (Sharma, 2015). In this verification step, the model is inspected whether the conceptual model is translated correctly (Robinson, 2012; Sargent et al., 2016). Moreover, model verification is needed to ensure that the model is implemented correctly (Arifin and Madey, 2015). Furthermore, run errors are solved before running the model (Robinson, 2012).

The simulation model created in this research is verified by using the "watch" function in the Simio software. This way shipments (model entities) can be followed throughout the entire simulation run. This way shipments can be easily checked if they follow the correct path. Based on the observations done while using the "watch" function, it can be concluded that the model behaves in the expected way.

Furthermore, a small dummy data set that contains shipments with specific characteristics is implemented in the simulation model. This way, the researcher could calculate in advance how many shipments should follow a certain path and end up in a specific network. By using status labels in the simulation software the shipments traveling a certain path and can be tracked. After running the dummy data set, it can be concluded that the model operates in the expected way.

Finally, a simulation model is verified when no simulation run errors occur. After carefully solving every run error that occurred, the simulation model is now free of run errors. From this can be concluded that the model is designed according to the requirements and the simulation model is verified.

8.2 Model validation

The model validation step is carried out to make sure the assumptions made during the modeling phase are correct. Any discrepancies that occur in this stage might be caused by earlier steps, e.g. in developing the simulation model or acquiring data. A model is valid when the model outcomes are within the acceptable range of accuracy (Ling and Mahadevan, 2013; Sharma, 2015).

The model validity can be determined based on a subjective or objective method. An objective validation test applies a mathematical procedure. While a subjective validation method is based on a statement or other piece of information that is considered to be correct by a person. Most often, a combination of the two techniques is used (Liu et al., 2011; Sargent et al., 2016).

To validate the model used in this research two objective methods and one subjective validation method is used (Sargent et al., 2016). The techniques used are cross-validation, sensitivity analysis and face validation. These validation techniques are discussed next.

8.2.1 Cross-validation

This section elaborates on the objective validation technique: cross-validation. Within this method, the results of the simulation run are compared to results of an already validated model (Sargent, 2010). In this case, the output of the real system of PostNL is compared to the output of the simulation model. Table 8.2.1 shows the number of shipments that end-up in a specific network after the data-processing step in the real system, in the simulation model and the difference in outcomes between the real system and simulation model.

Table 8.2.1: Outcomes of the cross-validation method

Network	**Output real system**	**Output simulation model**	**Δ Output**
Pharma&Care	23,894	23,894	0
Cargo	1,901	1,901	0
Mikropakket	14,085	14,085	0

As can be seen in this table, the outcomes of the simulation model are exactly the same as the outcomes in the real world system. This means that the assumptions made during the modeling phase are correct. There are no discrepancies visible in this stage. Therefore, it can be concluded that the simulation model is valid.

8.2.2 Sensitivity analysis

This section elaborates on the objective validation technique: sensitivity analysis. A sensitivity analysis is performed to assess the robustness of the input variables. By doing such analysis it can be measured how much the output variables can be changed by changing the input variables (VanderWeele and Ding, 2017). This way, the most important parameter can be identified and the relation between the variables can be determined (Kim et al., 2011).

By varying the input volume in the simulation model, the sensitivity can be measured on the results of the output. After conducting a sensitivity analysis and analysing the output, it can be concluded that varying the input volume does not have a big impact on the output. Non of the output measures are extremely sensitive to changes in the input variable.

8.2.3 Face validation

This section elaborates on the subjective validation technique: face validity. Face validity let individuals with knowledge about the system evaluate the behaviour of the simulation model. These individuals are asked to check whether the behaviour of the model is reasonable (Sargent, 2010). With the help of graphical displays the behavior of the model is animated.

The face validation step is executed twice, once during the modeling phase and once the model was completed. Two PostNL employees have looked at the graphical animations in order to check if the simulation model behaved according to the real world system. During the modeling phase there were some discrepancies signaled. It appeared that the number of shipments distributed with the Pharma&Care network was lower than expected, while the number of shipments sent via the Mikropakket network were higher than expected. It appeared that one of the decision steps in the simulation model did not behave as expected. It is believed that this happened due to the fact that the simulation software Simio is not able to handle string variables. Therefore, these string variables are transformed into integer variables. After this, the number of shipments ending up in the Mikropakket and Pharma&Care network were as expected.

Once the model was completed, no difference between the behavior of the real world system and the simulation model is found. Based on the validity check by two PostNL employees in the simulation phase and once the model was completed, it can be concluded that the simulation model created in this research is valid.

Chapter 9

Results of the simulation runs

This chapter elaborates on the data obtained from running the simulation model. For every design alternative the output data has been analysed. First, the experimentation set-up is discussed in section 9.1. After that, the results of the design alternatives on the KPIs are visualised and explained in section 9.2. Finally, the output of the design alternatives is evaluated in section 9.3.

9.1 Experimentation set-up

This section elaborates on the experimentation set-up in the simulation model. The Simio model starts empty. Products (entities) are created in the simulation model based on their pre-notification time and date. In this model, the data of the first two months of the year 2020 is used. This represents the run time of the model. This data is prepared, as explained in section 6.3.2, and loaded in the Simio simulation model as a data table. Each row contains a shipment with a certain shipment size, destination address and other characteristics (ADR, temperature controlled or time-frame deliveries). The data contains shipments from all three networks (Cargo, Mikropakket and Pharma&Care). Furthermore, the list of wholesalers is imported in the Simio model. This table presents the addresses where pallets are often delivered by the Pharma&Care network.

In addition, as shown in table 6.2.1, the processing time of in this model is kept constant, because this research focuses on improving the logistics network by implementing a consolidation policy and not a process optimization policy. Furthermore, there is no warm-up period needed in the model, because the processes of PostNL are a daily routine. Each day start with new shipments. No shipments are expected to stay behind in the system, because sorting errors are excluded from the model. With this model and this model run-length, the effects of the design alternatives on the overlap between networks, the costs and the CO2 emissions can be calculated.

9.2 Results of the simulation runs

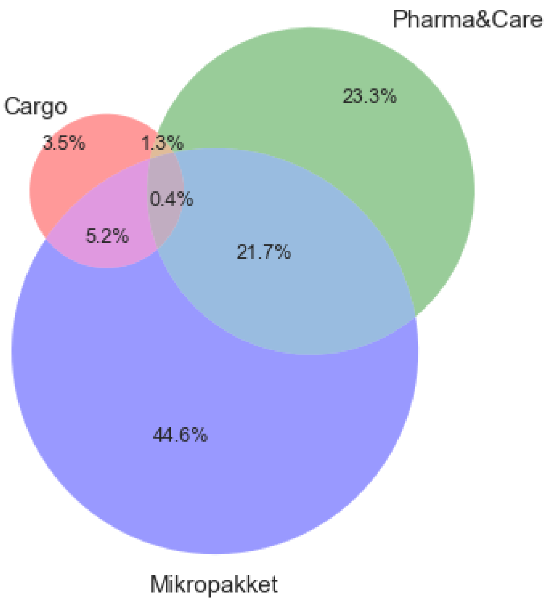
The data obtained from the simulation model can be used to analyse the performance of each of the design alternatives. First, the overlap between destinations is analysed and how this changes after implementing the design alternatives. This is explained in section 9.2.1. After that, the redirecting of shipments between networks is discussed in section 9.2.2. Furthermore, the number of stops over the three networks and the transfer of shipments to other networks is analysed in section 9.2.3. After that, it is evaluated how the number of stops per network translates to costs and CO2 emission in sections 9.2.4 and 9.2.5, respectively. Finally, a summary of the results is provided in section 9.2.6.

9.2.1 Results overlap

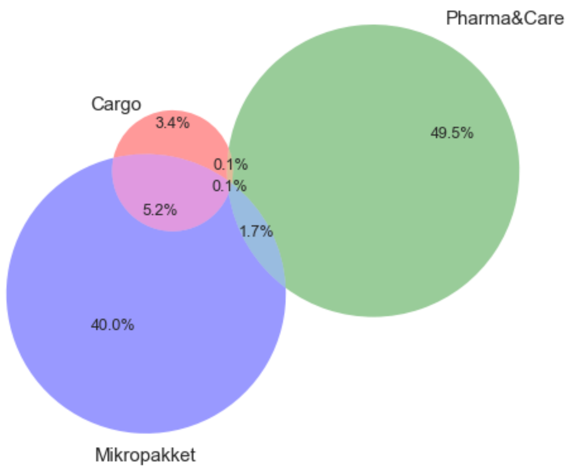
One of the ways to calculate the efficiency of the PostNL network is to establish how much overlap there is between networks on destination addresses and dates. Therefore, this section elaborates on the overlap.

The data obtained from the simulation runs have been sorted by date, postal code and network. Based on this, calculations can be done to find the relative overlap between the networks. As can be seen in figure 9.2.1a, the three networks have a lot of overlap in the current system. There is especially a lot of overlap between the Mikropakket and Pharma&Care network. 21.7 percent of the deliveries done by the Mikropakket and Pharma&Care network are done on the same date to the same destination. There is 1.3 percent overlap between the Cargo and Pharma&Care network, 5.2 percent overlap between the Cargo and Mikropakket network and 0.4 percent overlap between all three networks. As described before, this results in higher costs, higher amount of CO2 emitted and a less efficient system.

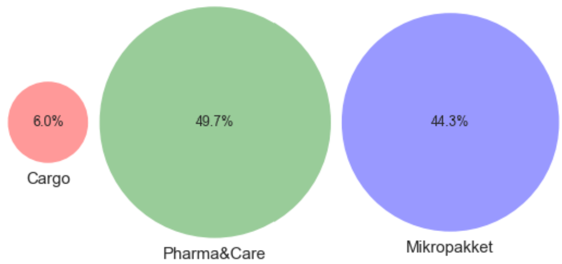
When looking at figures 9.2.1b and 9.2.1c, it can be seen that the design alternatives have a great impact on the overlap between the networks. This is the result of a more consolidated network. The overlap in the first design alternative is still 5.2 percent between the Mikropakket network and Cargo network. However, there is only 1.7 percent of overlap between the Pharma&Care and Mikropakket network, 0.1 percent overlap between the Pharma&Care and Cargo network and 0.1 percent overlap between all three networks. When considering the second design alternative, there is no overlap between the networks. This is due to the fact that shipments in all three networks are being consolidated based on their destination address. The overlap in the first design alternative can be explained by the fact that not all destination addresses are present on the list of wholesaler and are therefore not redirected to the Pharma&Care network.



(a) Overlap between the networks based on postal code and date in alternative 0



(b) Overlap between the networks based on postal code and date in alternative 1



(c) Overlap between the networks based on postal code and date in alternative 2

Figure 9.2.1: Overlap between the networks based on postal code and date

9.2.2 Shift in shipments between networks

As mentioned in chapter 5, PostNL already transfers parcel to other networks based on certain criteria. Table 9.2.1 presents the difference in number of shipments sent via a network per product type for each of the design alternatives compared to the current state. Between the brackets the relative difference between the current and new state is presented. When the current state did not have any shipments in s category, no relative difference is presented in the table.

Table 9.2.1: Number of shipments per network

Product type	Initial network	Final network	#Shipments alt. 0	Δ Shipments alt. 1	Δ Shipments alt. 2
Colli	Cargo	Cargo	1,686	-32 (-1.9%)	-530 (-31.4%)
Colli	Mikropakket	Mikropakket	12,966	-5,920 (-45.7%)	-7,760 (-59.8%)
Colli	Pharma&Care	Pharma&Care	23,139	0 (0%)	115 (0.5%)
Pallet	Cargo	Cargo	215	-71 (-33.0%)	-52 (-24.2%)
Pallet	Pharma&Care	Pharma&Care	582	0 (0%)	0 (0%)
Colli	Pharma&Care	Mikropakket	1119	0 (0%)	-215 (-19.2%)
Colli	Cargo	Pharma&Care	149	32 (21.5%)	497 (333.6%)
Colli	Mikropakket	Pharma&Care	0	5,920	7,298
Colli	Mikropakket	Cargo	0	0	462
Colli	Cargo	Mikropakket	0	0	33
Colli	Pharma&Care	Cargo	0	0	100
Pallet	Cargo	Pharma&Care	24	71 (295.8%)	52 (216.7%)

As can be seen in table 9.2.1, most shipments remain in their original network, only some shipments have been transferred to other networks due to the design alternatives. When looking at the Cargo network, it can be seen that the total number of colli in the Cargo network has stayed roughly the same throughout the different design alternatives. This is especially true in the current state and the first design alternative. This is also true for the second alternative. However, when looking at table 9.2.1 it can be seen that the number of colli pre-notified in the Cargo network and send via the Cargo network has been reduced. These colli have been redirected to the Phamra&Care network. The colli sent via the Cargo network is being complemented in the second alternative with colli from the Mikropakket network. From this can be concluded, that most of the colli sent via the Cargo network do not have a destination address which are similar to the addresses on the list of wholesalers. Then the shipments should have been transferred to the Pharma&Care network, according to the first design alternative. Furthermore, since there is a shift in volume in the second alternative, it can be concluded that there is overlap between destination addresses of all networks, because shipments are consolidated and possibly redirected based on multiple criteria.

Furthermore, when looking at the number of pallets sent via the Cargo network, it can be seen that this number has been reduced in both design alternatives compared to the current state. These pallets have been redirected to the Pharma&Care network, due to the fact that the destination address is on the list of wholesalers (design alternative 1) or there is overlap between the destination addresses of the pallets in both networks and are therefore consolidated in the Pharma&Care network (design alternative 2).

When looking at the Mikropakket network, table 9.2.1 shows that the number of colli in the Mikropakket network has been reduced enormously in both design alternatives. Most colli have been redirected to the Pharma&Care network. The changes in the first design alternative can be explained by the fact that the destination addresses of the shipments are present on the list of wholesalers. The shift in the second design alternative is due to the overlap between destination addresses in the Mikropakket network and mostly Pharma&Care network.

Finally, as mentioned before a lot of volume, both colli and pallets, have been redirected to the Pharma&Care network in both design alternatives. Only some colli is still being transferred to the Mikropakket network. This is probably due to the characteristics of the shipments. As can be seen in table 9.2.1, the amount of colli transferred from the

Pharma&Care network to a different network has been reduced when the second design alternative is implemented. This shift can be explained by the fact that these shipments have no characteristics nor similar destinations as the shipments sent in the Pharma&Care network.

9.2.3 Results number of stops

By implementing the design alternatives as explained in chapter 7, it is expected that the total number of stops made by PostNL are reduced. Therefore, this section elaborates on the number of stops made with each network after running the discrete event simulation model, how they have changed due to the decision-making model and how these relate to each other.

Figure 9.2.2, shows the total number of stops per network in each of the design alternatives over de complete simulation run. This bar plot shows that the total number of stops in the complete PostNL network have been reduced by implementing the design alternatives. Furthermore, the implementation of the design alternatives have a positive impact on the number of stops in the Cargo and Mikropakket network. In both alternatives the number of stops have been reduced.

However, when considering the total number of stops in the Pharma&Care network, the number of stops have increased slightly. The increase in the first design alternative can be explained by the fact that the destination addresses of shipments from Cargo or Mikropakket are present on the list of wholesalers and therefore redirected to the Pharma&Care network, while this network originally did not need to made a stop there on that date.

The increase in the number of stops in the Pharma&Care network in the second design alternative can be explained by the fact that shipments from all networks are being consolidated. This means that when shipments from the Mikropakket network need to be consolidated with shipments from the Cargo network, it might be better to redirect all to the Pharma&Care network due to the characteristics of the shipments. Even though the Pharma&Care network does not need to made a stop at that particular address on that day.

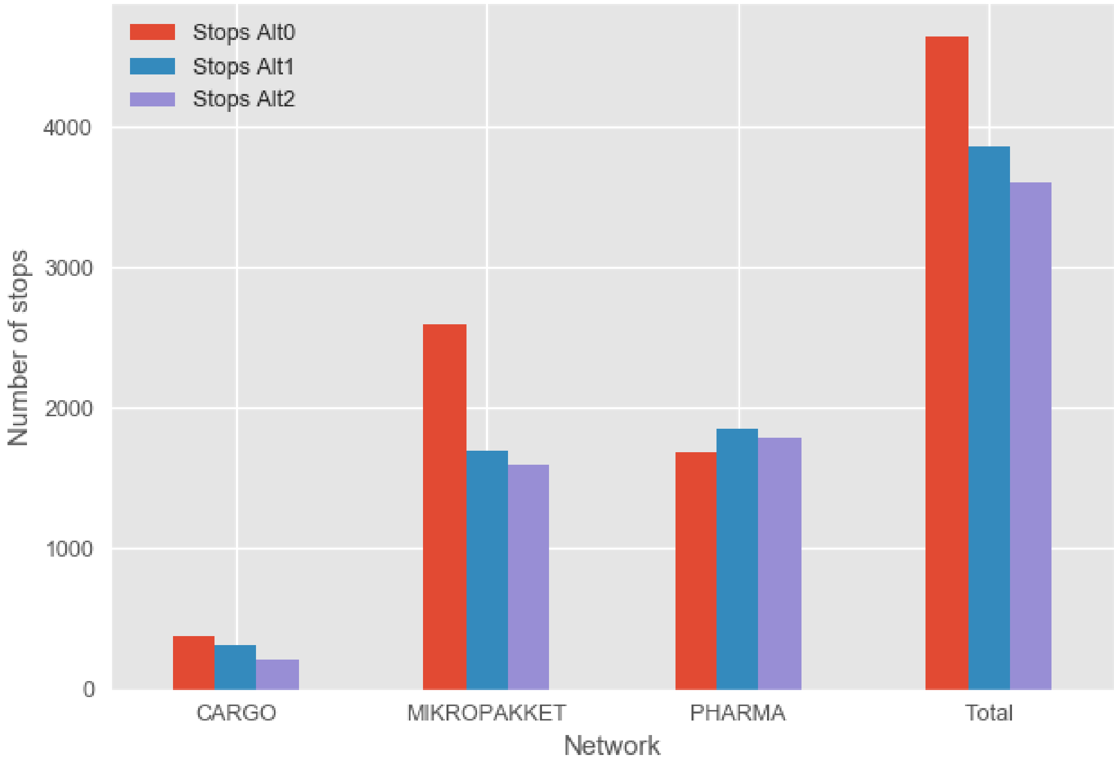
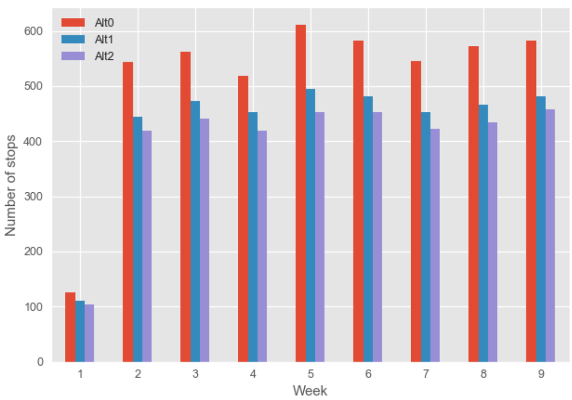
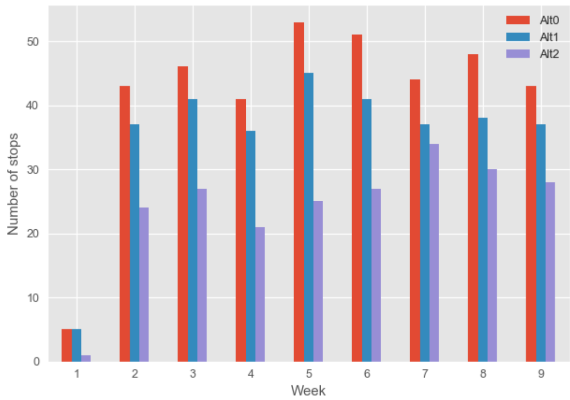


Figure 9.2.2: Number of stops per network

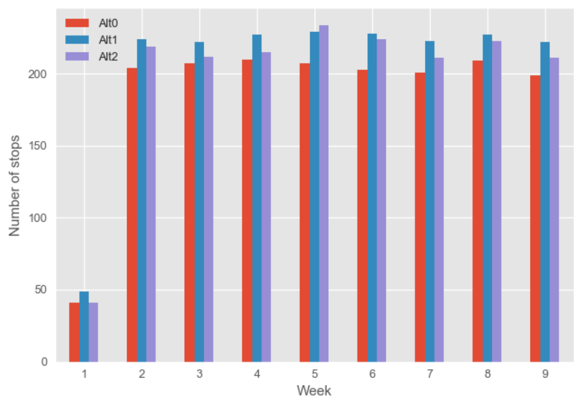
In order to find the robustness of these design alternatives, the number of stops over a period of time is analysed. By doing this, it can be checked if the number of stops are reduced every week due to the implementation of the design alternatives. Figure 9.2.3a, shows that both design alternatives have reduced the total number of stops for PostNL during the complete simulation run. Figures 9.2.3b and 9.2.3d show that in both the Cargo and the Mikropakket network the number of stops have been reduced over the complete simulation run, while the number of stops have increased in the Pharma&Care network (figure 9.2.3c). From this can be concluded that the design alternative are robust and by implementing these design alternatives the overall number of stops are reduced for PostNL.



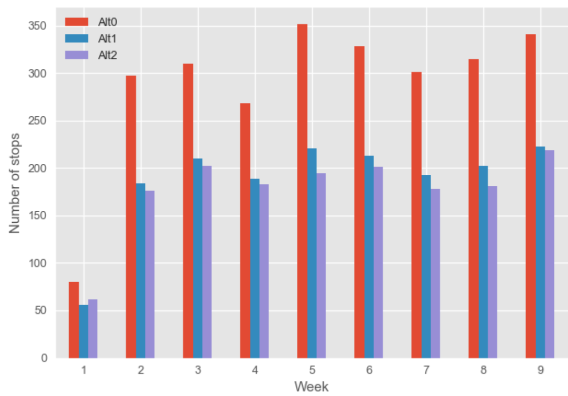
(a) Stops in the PostNL network



(b) Stops in the Cargo network



(c) Stops in the Pharma&Care network



(d) Stops in the Mikropakket network

Figure 9.2.3: The number of stops during the simulation run

9.2.4 Results costs and revenues

This section elaborates on the changes in costs and revenues when implementing the design alternatives. The costs and revenues are calculated based on the average costs and revenues related to the number of stops for each network. The costs and revenues of the current state and the design alternatives are examined per network as well as for the complete PostNL network.

Figure 9.2.4 shows that the revenues remain the same after implementing the design alternatives. This is due to the fact that redirecting shipments is the choice of PostNL. PostNL beliefs that consolidating and redirecting the shipments result in a more efficient network. The customers should not have to pay for the change in the operating practices of PostNL. Therefore, the revenues obtained remain the same.

When looking at the costs that are made, it can be seen that the total costs are reduced after implementing the design alternatives. The costs made in the Cargo and Mikropakket network are reduced due to the reduction in the number of stops after implementing the design alternatives. The costs for the Pharma&Care network have increased slightly due to the redirecting of shipments to this network. Overall the total costs have been reduced.

However, it should be kept in mind that the costs and revenues are calculated solely based on the number of stops made whereas more aspects influence the costs and revenues. For example, the number of vehicle movements and average truck load can influence this. This is not taken into account in these calculations.

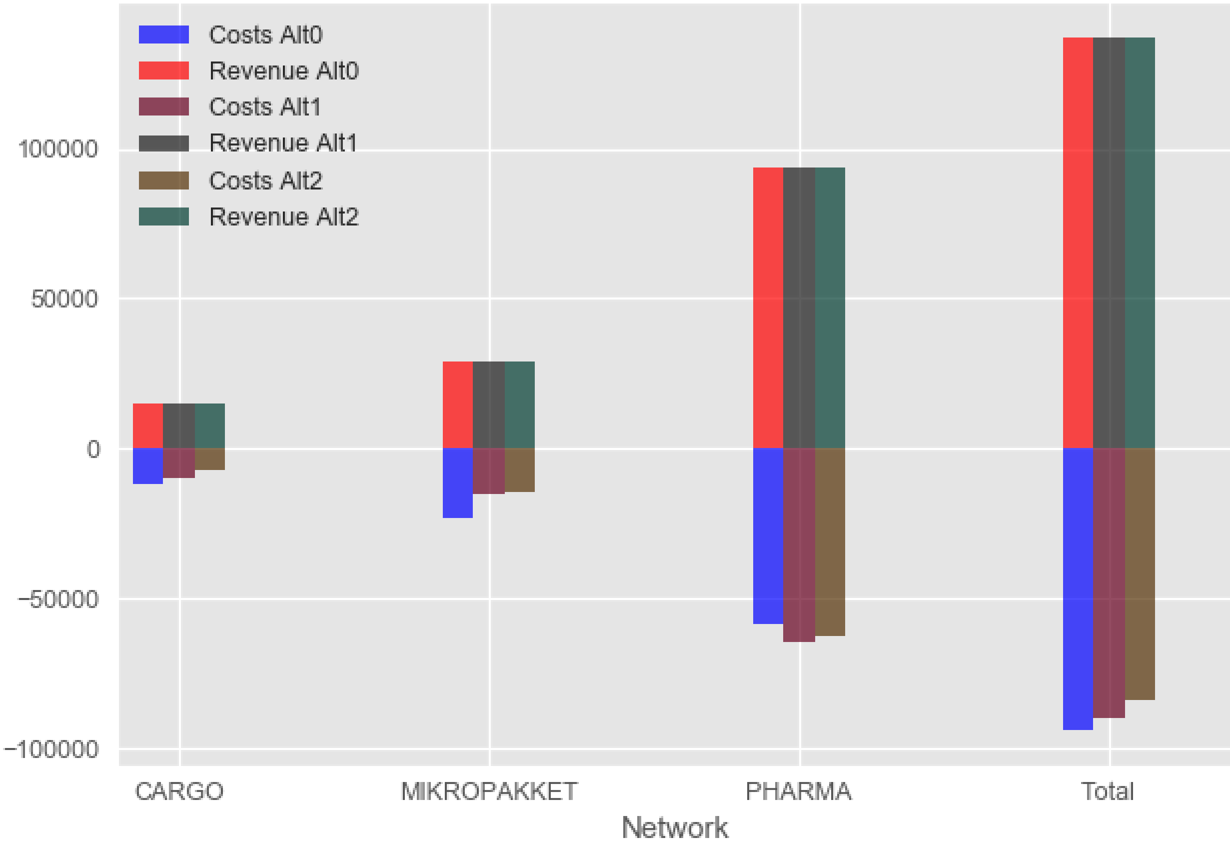


Figure 9.2.4: Costs and revenues of the networks

9.2.5 Results CO2 emission

As explained before in section 2.2.3, the amount of CO2 emitted by PostNL changes when the number of stops changes. This section elaborates on the effect of the design alternatives on the CO2 emissions.

Usually, the total emissions are calculated by the amount of fuel used (in liter, kg or kWh) of the transportation modes multiplied with the key factor. These calculations are the most exact, because it is based on the actual fuel consumption. However, if this data is not available, the emission can be estimated with the help of key figures.

The emissions of the greenhouse gasses for freight transport can be calculated by multiplying the tonne-kilometer with the emission factors of the respective means of transportation. A tonne-kilometer can be explained as one tonne goods that is transported one kilometer in a certain means of transportation.

The key factors (emissions per tonne-kilometer) are calculated by estimating the average load of the type of freight transport mode, an average (road) situation and the average percentage of productive kilometers (empty rides).

This research makes use of key figures, because the actual fuel consumption is unknown. Based on the number of stops, the average length of the drive between two stops and the average truck load, the CO2 emissions for the complete PostNL network per alternative has been calculated and visualised in figure 9.2.5. As can be seen in this figure, the total amount of CO2 emitted is reduced when the design alternatives are implemented. The amount of CO2 emissions are lowest when the second design alternative is implemented due to the fact that shipments to the same destination are being consolidated and therefore the number of stops is lowest.

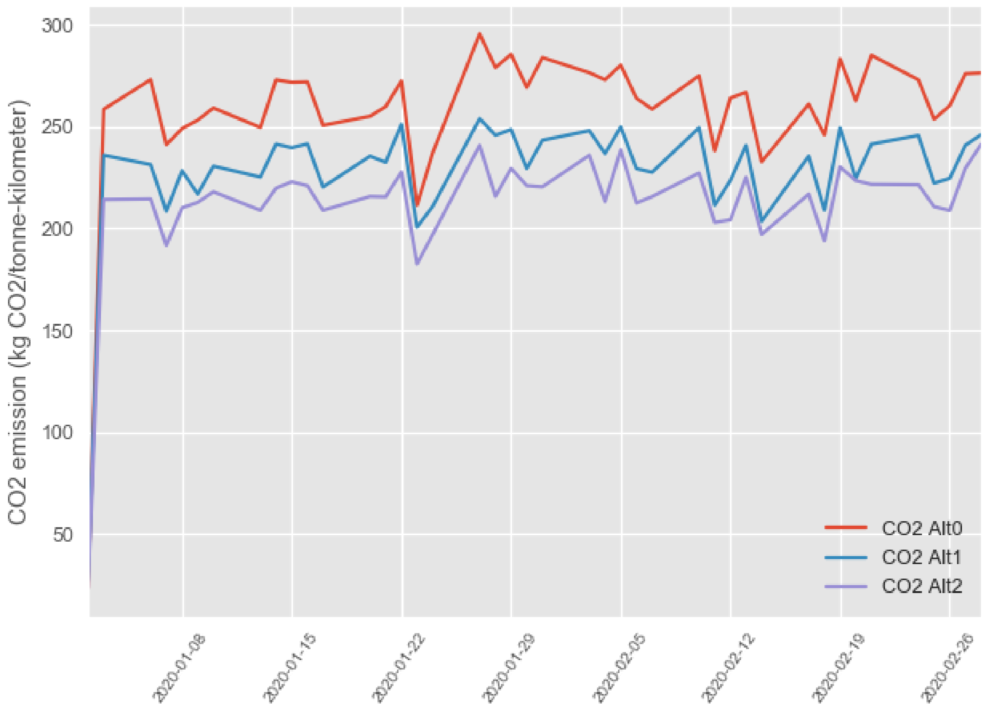


Figure 9.2.5: CO2 emissions for PostNL per alternative

9.2.6 Summary of the data-analysis

In this section, a few analysis have been done in order to calculate the efficiency of the design alternatives. The efficiency of the design alternatives is translated into the overlap between networks, the number of stops, the total costs, the total revenue and the amount of CO2 emitted. Table 9.2.2 shows the results of these analysis.

Table 9.2.2: Summary of the data-analysis

Objective	Alternative 0	Alternative 1	Alternative 2
Overlap (%)	28.6	7.1	0
Number of stops (#)	4647	3859	3603
Total costs (€)	94,131	90,148	83,958
Total revenue (€)	137,307	137,307	137,307
CO2 emissions (kg/tkm)	10835.5	9563.4	8907.9

9.3 Evaluation

In this section the outcomes of the design alternatives are evaluated. Based on the description of the design alternatives given in section 7 and the stakeholder analysis in section 5.1, the design alternatives are evaluated. The evaluation is based on 6 criteria: (1) amount of overlap, (2) number of stops, (3) the total costs, (4) the total revenues, (5) the CO2 emissions, (6) the implementation time and effort. The different outcomes can be compared by performing a Multi-Criteria Analysis (MCA) (Velasquez and Hester, 2013). A MCA can be used to systematic review the outcomes to identify the costs and benefits of a certain alternative and to be able to rank these alternatives. Furthermore, the alternatives can be quantified which can ease the decision-making process (Huang et al., 2011).

Table 9.3.1, presents the outcome of the MCA for the carrier PostNL, the suppliers and the hospitals. Each of the six criteria have been scored against the outcomes of the alternatives. A high score means that the alternative is doing well, whereas a low score resembles a lower performance on that criteria. The attributes are scored on a scale from 0 to 100. The scores on each criteria are presented in columns Alternative 0, Alternative 1 and Alternative 2. In addition, a column that contains the weight of the attributes is added to the table. These weights represent how important a certain criteria is for the stakeholder. These weights have been established based on the stakeholder analysis in appendix B.1 and section 5.1.

As can be seen in table 9.3.1, both design alternatives score higher than the current state for all stakeholders involved. When comparing the first and second design alternative, it can be seen that the second design alternative scores the highest when adding all scores together. This can be explained by the fact that the second design alternatives score higher on almost all criteria. The design alternatives score the same with respect to the revenue and the second design alternative scores lower with respect to the implementation time and effort. Overall, the score of the second design alternative is highest for all stakeholders involved.

Table 9.3.1: Multi-Criteria Analysis

Objective	**Stakeholder**	**Weight**	**Alternative 0**	**Alternative 1**	**Alternative 2**
Overlap	PostNL	80	10	70	100
	Supplier	0			
	Hospital	90			
Stops	PostNL	60	30	70	80
	Supplier	5			
	Hospital	80			
Costs	PostNL	80	30	60	80
	Supplier	30			
	Hospital	10			
Revenue	PostNL	80	50	50	50
	Supplier	20			
	Hospital	10			
CO2 emissions	PostNL	60	40	60	85
	Supplier	40			
	Hospital	50			
Implementation time & effort	PostNL	90	100	40	10
	Supplier	0			
	Hospital	0			
Total	PostNL		20.400	25.800	29.200
	Supplier		3.650	5.550	7.200
	Hospital		6.100	16.000	20.950

Chapter 10

Discussion

This chapter elaborates on the limitations of this research. Several elements are discussed. First, the interdepence between the KPIs is explained in 10.1. Thereafter, the shortcomings of the design alternatives are discussed in section 10.2. Section 10.3, elaborates on the limitations of the simulation model. Furthermore, the limitations of the analysis of the simulation output data is discussed in section 10.4. Finally, section 10.5 elaborates on the limitations related to the case study method.

10.1 Interdependence of Key Performance Indicators

The Key Performance Indicators (KPIs) chosen in this research to represent the supply chain efficiency do not cover all aspects. For example, the performance of PostNL employees, inventory levels, product demand variance and system capacity have not been incorporated in this study. While these factors can be used to describe the efficiency of the network (Liang et al., 2006). The KPIs used to describe the efficiency in this research are thus not complete. Resulting in a less clear picture of how the design alternatives influence the current system. This might influence the conclusions made in this research about the performance of the design alternatives. Therefore, more in-depth research should be done to gain insight in the most important factors that represent a network's efficiency.

Furthermore, the interdependence of the KPIs should be taken into account. The amount of CO2 emitted by PostNL relates to the number of vehicle movements and the number of stops. While the number of stops also relates to the operational costs. The operational costs are also influenced by other factors, for example the truck load and the empty kilometers. However, these aspects are not incorporated in this research. When incorporating these attributes more in-depth knowledge about the effects of consolidation can be measured, because it is expected that the consolidation of shipments increases the truck load. Furthermore, the costs related to the distribution of shipments is related to the number of shipments delivered by PostNL. While employee costs and equipment costs are not included. When considering these aspects as well, a different conclusion about the preference of design alternatives can be expected.

10.2 Discussion of the design alternatives

The objective of this research is to improve the efficiency of the current system of PostNL. This is done by introducing two design alternatives. In the first alternative shipments from all networks are checked on the so called list of wholesalers and then resume to their original process. In the second alternative an extra application is added which checks for overlap on destination addresses between networks. This way, all shipments destined to a certain address are consolidated and not just within a network.

When considering the implementation effort of both design alternatives, it can be concluded that especially the second design alternative is complicated to implement due to the fact that a new tool has to be created for PostNL. Whereas, with the first design alternative no new applications need to be made. However, implementing the first design alternative might still prove to be difficult, because the operating practices of the Mikropakket network needs to change. This requires a complete new system and a team specialised in these kind of applications. By not incorporating the implementation time, effort and costs in more detail, the recommendations to PostNL might change.

Finally, both design alternatives can be implemented in two ways. First of all, the order management system can be changed. By implementing a new system, communication between the networks is expected to be more easy. Secondly, a new hub can be built where the three networks are located together. Currently, the three networks have their own hub in different cities. However, when implementing one of the design alternatives, more vehicle movements are expected between the networks which can lead to more CO2 emission and more costs. In order to solve this, a new hub can be built from where the networks operate. This way, shipments can be redirected to a different network up to the last moment. By building an extra hub, the outcomes of the design alternatives with respect to the implementation costs and effort are expected to change. It is expected that the first design alternative might be more beneficial for PostNL when considering these aspects.

10.3 Limitations of the simulation model

In this research a discrete event simulation model has been created. However, there are a few limitations with respect to the input data and the model. First of all, the quality of the input data is not consistent. Data obtained from the Pharma&Care and Cargo network is complete, but the data acquired from the Mikropakket network is not complete. A few destination addresses and house numbers where missing from the data set. Due to this it was decided to estimate the simulation model based on the postal codes.

This might result in a less accurate estimation of the model. It might be the case that some shipments are handled differently than from when the postal code was combined with the house number. It is expected that the effect of this discrepancy is largest in the first and second design alternative, because here shipments are handled based on several characteristics. Within the second design alternative shipments are redirected based on their postal code. So, it might be the case that more shipments are redirected than necessary. However, it is expected that this discrepancy does not have any influence on the output of the simulation model, because only hospital data is included in the model. More than one hospital is not expected in the same postal code. Furthermore, this can be seen in the model validation section (8.2).

Finally, this research only focuses on deliveries towards hospitals, even though PostNL deliveries many products to other organizations. For example, only 25 percent of the Mikropakket network data set has been used in this research. Therefore, the overlap presented in section 9.2.1, seems larger than it would be in reality. This is also the case for the Cargo network. The Cargo network is mostly focused on non-healthcare customers. Therefore, results shown in chapter 9 could give a different view on the situation. When considering all the deliveries made by PostNL within these networks, the percentage of overlap is expected to be lower. This means, that the benefits related to the implementation of the design alternatives might be reduced.

10.4 Limitations of data-analysis

This section elaborates on the limitations with regard to the data-analyses of the output data of the simulation model. First of all, the costs and revenues are calculated based on the average costs and revenues per stop while the costs and revenues differ per shipment. This is due to the different contracts between PostNL and the suppliers. Due to the fact that there was no clear picture about the average costs and revenues made per shipment, the average costs and revenues per stop is included. However, when incorporating more detail, a clearer picture of the effects of the design alternatives on costs and revenues can be given.

Furthermore, the costs for the transfer of shipments between networks has not been incorporated in the analysis. While it is expected that several trips between networks have to be made. However, in the current system the Pharma&Care network already makes a trip to the Mikropakket network. Therefore, it is expected that leaving out this extra trip does not affect the costs much.

Furthermore, these extra trips also result in more handling costs. These costs have not been included in the data-analysis, because it is expected that no extra personnel is needed to handle these processes. However, due to the extra processes that are done manually, human errors might occur.

Finally, the CO2 emissions are calculated based on key figures. This means, that the calculated CO2 emissions in this research are an estimation. In reality the savings could be more or less. When using the real fuel consumption, a more accurate estimation can be made to calculate the actual CO2 emissions. The real CO2 emissions could not be calculated in this research due to the fact that the fuel consumption is not known to PostNL.

10.5 Limitations with respect to the method

In this research a case study has been conducted for the logistics service provider PostNL. The data that is collected can be tailored to different cases, which is one of the strengths of this method. However, there is no strict design of a case study. This leads to different design choices which could lead to poor results (Johansson, 2007; Meyer, 2001). However, when applying a framework and keeping in mind the quality criteria, i.e. transferability, truth-value, and tractability, the case study method is of value (da Mota Pedrosa et al., 2012). Furthermore, only one case has been examined which makes it difficult to generalize the outcomes of this research for other logistic service providers. Only an estimation on the effects for other logistics service providers can be made. Due to this, no real conclusions can be made about the effects of implementing a receiver-led consolidation technique in a logistics service provider network.

Chapter 11

Conclusions & Recommendations

This chapter presents the conclusions of this study. First, the sub-questions are answered in section 11.1. Secondly, the scientific and societal contribution is discussed in section 11.2. Finally, recommendations for both PostNL and further research are given in section 11.3.

11.1 Answer to the research questions

This research has been conducted to find an answer to the main research question:

What is the impact of receiver-led consolidation alternatives in the PostNL supply chain with respect to trade-offs between costs, CO2 emissions and vehicle movements between PostNL and other stakeholders?

In order to find an answer to this question, three sub-questions have been established. Each of these sub-questions are discussed and answered.

Sub-question 1: What is the structure of the current logistics network of PostNL that transports the products from suppliers to hospitals and what are the bottlenecks?
With the help of the actor identification in section 5.1, all actors involved in the supply chain of shipments towards hospitals are mapped. The three core stakeholders in this research are: (1) suppliers of end-products, (2) hospitals, and (3) the carrier.

By decomposing the processes of the logistic service provider PostNL, a schematic model is made in section 5.2. This model consists of seven parts: (1) data-processing, (2) planning, (3) loading, (4) dispatch, (5) distribution, (6) pick-up, and (7) unloading. This schematic model is an answer to the first part of this sub-question.

The second part of the sub-question relates to the bottlenecks. The bottlenecks identified relate to the efficiency of the current system of PostNL. There seem to be multiple bottlenecks. First of all, overlap between destination addresses appear between the three networks (Pharma&Care, Cargo and Mikropakket). Secondly, the Pharma&Care network sometimes needs to make a stop for less than five colli which is fairly expensive for this network. These inefficiencies can be explained by the fact that networks barely cooperate with each other and the Pharma&Care network makes use of a list of wholesalers which is not updated frequently.

Sub-question 2: How can a logistics service provider network be captured in a quantitative model to model the effects of design alternatives?
Most bottlenecks are found in the data-processing phase, therefore this research focuses on this process. This process is captured in a conceptual model. This model incorporates all the different components of the process which can be used to build a quantitative model.

This quantitative model is captured in a discrete event simulation model. This simulation model is based on the conceptual model, but requires simplifications and assumptions of the system. These are based on the literature review and presented in section 6.2.2. This quantitative model of the data-processing phase is an answer to the second sub-question.

Sub-question 3: What alternatives can be used to enhance the efficiency in the distribution of products from suppliers to hospitals?
In order to enhance the efficiency of the current system of PostNL two design alternatives have been created. In the first design alternative a rather small change is made to the current system. All shipments pre-notified to the three networks are checked on the list of wholesalers. When their destination address is present on the list, the shipments are redirected to the Pharma&Care network. Otherwise, the shipments remain in their original process. This process is visualised in figure 7.2.1. The second design alternative consolidates shipments over all networks. Based on the characteristics of the shipments, the shipments are redirected to a certain network. This process is visualised in figure 7.3.1.

These design alternatives have been built in the simulation software. The effects of the design alternatives can be calculated based on the output of the simulation model. The effects on the efficiency of the system have been calculated based on four KPIs: (1) overlap between network, (2) the number of stops, (3) costs and revenues, and (4) CO2 emissions. Based on the data-analysis and the Multi-Criteria Analysis in section 9.3, it can be concluded that the second alternatives yields the highest results on all KPIs.

However, implementing these design alternatives might prove to be difficult. When implementing the first design alternative no changes need to be made for the Pharma&Care network. Only a small adaptation needs to be made in the Cargo network, but a complete system change is needed for the Mikropakket network. Furthermore, when implementing the second design alternative a completely new application needs to be built that can communicate with the three different operating management systems. For this application a specialised team is needed.

Main research question: What is the impact of receiver-led consolidation alternatives in the PostNL supply chain with respect to trade-offs between costs, CO2 emissions and vehicle movements between PostNL and other stakeholders?
The effects of implementing one of the design alternatives on the costs, CO2 emissions and vehicle movements is rather big. This means that implementing a receiver-led consolidation technique is beneficial for the efficiency of a logistics service provider's network. Moreover, implementing such technique is valuable for suppliers and hospitals.

Based on the evaluation of the design alternatives, it would be most beneficial to implement the second design alternative. Within this design alternative all shipments are consolidated over the different networks which leads to the highest benefits. This design alternative is also most valuable for the other core stakeholders (suppliers of end-products and hospitals) involved. However, implementing this design alternative is highly costly and time consuming.

11.2 Scientific and societal contribution

In chapter 2, two knowledge gaps have been identified: (1) the lack of academic research on the effects of implementing a receiver-led consolidation technique in a logistics service provider's system and (2) the lack of academic research on the trade-offs stakeholders need to make regarding the receiver-led consolidation design alternatives. This study makes two scientific contributions. Furthermore, two societal contributions are done in this study: (1) create insight in the perspectives of stakeholders involved, and (2) create insight in the effect of receiver-led policies on the environment.

Insight in the effect of a receiver-led consolidation policy in a logistics service provider network
The effects of consolidation is a well discussed concept in scientific studies. These effects are measured in different studies in different ways. However, a receiver-led consolidation policy is rather new to the academic world. Therefore, only estimations about the effects on the efficiency in a logistics service provider's network can be given. With the help of this study, the effects on KPIs were measured and insight in the effects of a receiver-led consolidation policy is created which can be seen as a scientific contribution.

Insight in the trade-offs between KPIs and stakeholders when implementing a receiver-led consolidation policy
Academic studies on KPIs for several actors is well covered which is shown in the actor analysis in section 5.1. However, how these KPIs are intertwined with the effects of a receiver-led consolidation policy in unknown. This study has created insight in the trade-offs a carrier need to make when implementing this policy. Furthermore, insight in the KPIs of other actors, that need to be kept in mind by the carrier, is created. This insight is a scientific and societal contribution.

Insight in the environmental effects of a receiver-led consolidation policy
The distribution of shipments have an effect on the air and noise pollution in urban areas. By improving the current operating practices, less air and noise pollution is expected. This study has shown that implementing a receiver-led consolidation policy can reduce the number of vehicle movements towards receivers and therefore less noise and CO_2 will be emitted which can be seen as a societal contribution of this study.

11.3 Recommendations

This section elaborates on the recommendations for both PostNL and further research in sections 11.3.1 and 11.3.2, respectively.

11.3.1 Recommendations for PostNL

This research carried out a case study for PostNL. This has created insight in the effects of a receiver-led consolidation policy in a logistics service provider's network. Based on the outcomes of the simulation runs, it is recommended that the second design alternative, as proposed in section 7.3, is implemented in the current system of PostNL. This design alternative yields the highest results with respect to the reduction in overlap, costs and CO2 emissions, as discussed in section 9. In this design alternatives shipments from the Cargo, Pharma&Care and Mikropakket network are consolidated.

However, when implementing this design alternative PostNL should keep a few aspects in mind: (1) the current order management system, (2) the incomplete pre-notification data, (3) incomplete data set, (4) the competencies of the Cargo network and (5) error sensitivity.

First of all, a new order management system is needed to make sure the three networks can communicate with each other. Currently, the three networks use different systems that cannot communicate with each other. Implementing and acquiring such system is time consuming and costly.

Secondly, this research assumed that the pre-notification data is complete and can be used immediately. While in reality, the pre-notification data is often not complete, arrives too early or too late, or only comes through the system when the shipment is already inside the hub and scanned.

Thirdly, in this research only shipments towards hospitals are taken into account. While PostNL delivers many shipments to other destination addresses as well. Therefore, the results presented in chapter 9 might differ when data from all shipments is used. It is expected that the relative overlap between networks is reduced.

Fourthly, the volume handled in the Cargo network is much higher than indicated in this research due to the fact that the Cargo network is not focused on delivering to hospitals. Furthermore, based on the results of the simulation run, it seems that not much volume is redirected from the Cargo network to the Mikropakket network. However, many shipments are redirected from the Cargo network towards the Pharma&Care network.

Fifthly, due to the additional link between networks, more shipments are redirected. This creates more complexity within the sorting process of each of the networks which can cause more errors. Especially, because the exchange of shipments and handling these exchanged shipments is expected to be done manually. Therefore, more human errors can be made.

To conclude, based on the results from the simulation run in chapter 9, it can be concluded that the second design alternative performs better. However, the different aspects discussed above should be kept in mind when implementing this design alternative. It is recommended that the collaboration between the networks is extended. It is expected that this yields the highest benefits for PostNL, hospitals and suppliers of end-products.

11.3.2 Recommendations for further research

As described in chapter 10, there are several limitations to this research: interdependence of KPIs, design alternatives, and the method.

First of all, it is proposed that additional research is carried out to gain knowledge about the criteria that measure the network's efficiency. When more in-depth knowledge on these KPIs is gained, more concise experiments can be done and more specific design alternatives can be proposed. These design alternatives can then be used by multiple logistics service providers and not just PostNL.

Secondly, as described before, the implementation time and effort of the design alternatives should be researched in more detail. For each logistics service provider's network, this implementation time and effort can differ. Therefore, more in-depth research on how to implement the design alternatives should be done. This way, the implementation time and effort can be calculated.

Thirdly, since only one case study has been carried out on the effects of a receiver-led consolidation policy on the supply chain's efficiency, no real conclusions can be drawn. Therefore, it is recommended that more case studies are carried out before generalizing the outcomes. This way, more knowledge can be gained from introducing a receiver-led consolidation policy in a logistics service provider's network.

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Appendix

Appendix A

Methods used

A.1 BPMN method

The different logistic networks can be analysed by business process flow diagrams. The different products flowing from suppliers towards the hospitals, have their own characteristics and it might be better to use different networks of PostNL. Therefore, several networks of PostNL would need to be analyzed to understand the specifications of the networks.

The different processes of a logistics service provider can be analyzed using a Business Process Modeling and Notation (BPMN). This is a standard for business process modeling and helps visualize the processes (White, 2007). The BPMN is based on a traditional flow charting technique. Its goal is to be understandable for all business users, process implementer, customers and suppliers. Moreover, it ensure that the models are executable (von Rosing et al., 2015).

A.1.1 The building blocks of BPMN

There are several basic elements of which a model created with the BPMN method consists off, as is shown in figure A.1.1. An object can be an event, activity or gateway. These objects are linked by either a sequence flow or message flow. A sequence flow is used to show the order in which the activities are performed, while a message flow indicates the flow of messages between processes (Dijkman et al., 2008).

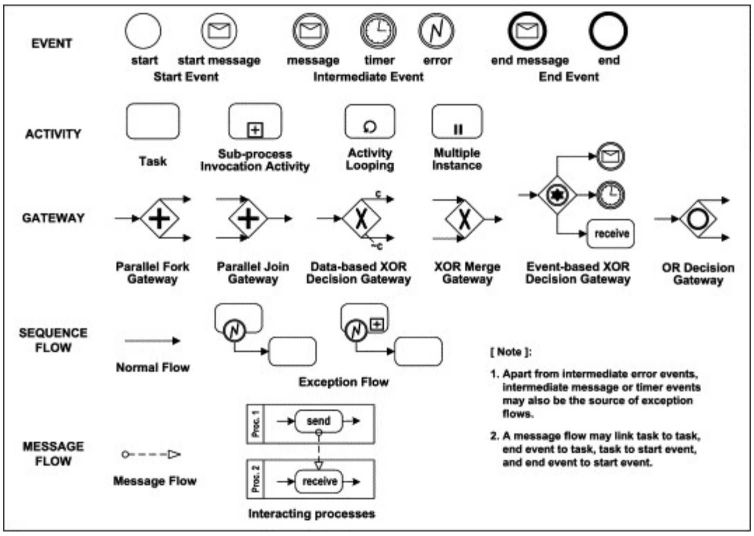

Figure A.1.1: BPMN elements (Dijkman et al., 2008)

Furthermore, a BPMN consists of swimlanes. These swinlanes can be used to organize activities in different categories. This way, the various capabilities or responsibilities of a stakeholder in a particular activity can be visualized. In BPMN there are two types of swimlane objects, i.e. pool and lane. A pool represents a participant in the process and is visualized in figure A.1.2. This is used when there are separate entities involved. A lane is a part of a pool and is used to organize and categorize activities (White, 2007).

Figure A.1.2: Representation of a pool (left) and lane (right) (White, 2007)

A.1.2 Advantages and disadvantages of BPMN

There are several advantages and disadvantages identified. According to Kocbek et al. (2015), the main advantage of the BPMN is the simplicity of the model. This makes that BPMN is easy to understand. Furthermore, capturing the control flow as well as handling the data in a process is done well in the BPMN method. This makes that the BPMN method is often combined with other technologies (Cruz et al., 2012). However, this method does have its disadvantages. First of all, the concept of costs is not easily implemented in the model (Kocbek et al., 2015). Still, BPMN is considered a powerfull tool to represent the activities in a coorporation (Curtis et al., 1992).

A.2 Case study method

In this research, the case study method is used. The case study method entails collecting, analyzing, presenting and reporting data (Tellis, 1997). The data that is collected can be tailored to different cases, which is one of the strengths of this method. However, there is no strict design of a case study. This leads to different design choices which could lead to poor results (Johansson, 2007; Meyer, 2001). However, when applying a framework and keeping in mind the quality criteria, i.e. transferability, truth-value, and tractability, the case study method is of value (da Mota Pedrosa et al., 2012). Furthermore, it is possible to generalize the outcomes of one particular case study, because the case study method examines a particular case in its real-world context which provides in-depth understanding of the situation (da Mota Pedrosa et al., 2012).

In this research, a case study is conducted for the logistics service provider PostNL. This way, an answer to the how and why questions can be found (Tellis, 1997). In this research, the question of how to improve the current system of PostNL is asked. Using the case study method can give inside in how PostNL can improve their processes as well as providing inside in how other logistics service provider can improve their practices. Moreover, this method makes it possible to study several aspects, like costs and number of deliveries, and the relation between them (Meyer, 2001). These aspects are important to the various stakeholders involved, i.e. hospitals and suppliers. When using the data provided by PostNL, a detailed description of the various perspectives of stakeholders can be given (Tellis, 1997).

Appendix B

Actor analysis

This appendix elaborates more on the actor analysis. In order to get the most favorable results for every actor, PostNL has to incorporate the other actors in their analysis (Enserink et al., 2010). This actor analysis is performed in four steps: (1) indication of actors involved and their relationships, (2) problem statement of the actors involved, (3) interdependence between actors and (4) conclusion.

B.1 Step 1: Actor identification and their relationships

In the pharmaceutical supply chain, PostNL has to cooperate with several stakeholders. The pharmaceutical supply chain involves several players, i.e. primary manufacturers, secondary manufacturers, distribution centers/wholesalers, carriers and retailers (i.e., pharmacies) and hospitals (Singh et al., 2016). The actors involved all have a certain perspective on the case which are shown in table B.1.1.

Table B.1.1: Identified actors and their perspectives

Actor	**Perspective**
Primary manufacturer	Reduce operating costs
Supplier of end-products	• Reduce operating costs • Increase service performance
Logistics service provider	• Reduce operating costs • Attract more customers • Reduce CO2 emission
Pharmacy	• Attract more customers • Reduce the number of deliveries • Service level
Hospital	• Reduce the number of deliveries • Increase service level
Household	Receive medication

The relations between the stakeholders are visualized in figure B.1.1. In terms of economic importance, three stakeholders are most important, i.e. the supplier of the wholesale product, the hospital and the carrier (Holguín-Veras et al., 2016).

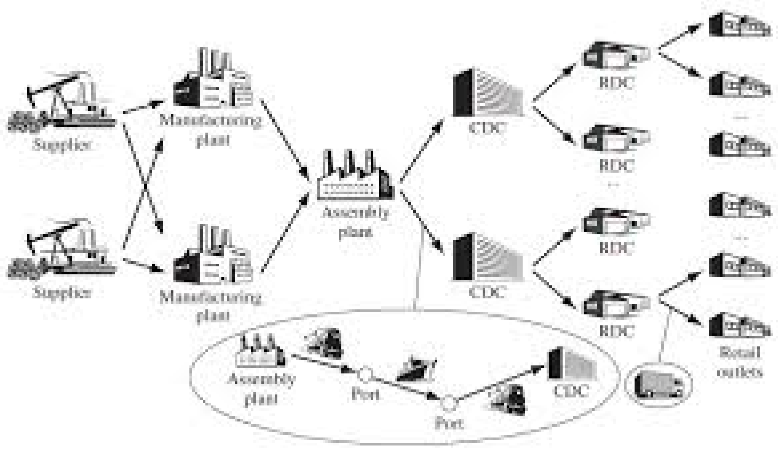

Figure B.1.1: Physical representation of the supply chain (Ghiani et al., 2004)

B.2 Step 2: Problem statements of the actors

This section elaborates on the problem statements of each of the actors displayed in table B.1.1. This steps gives insight in the differences and similarities between the goals, perspectives and objectives of each of the actors. By doing this, a clear overview of potential conflicts can be determined. Furthermore, this creates insight in how to communicate with different stakeholders (Enserink et al., 2010). For every actor the general interest, the perspective on the research problem and the preferred situation are discussed.

Primary manufacturers
The general interest of primary manufacturers is the potential of reducing transportation costs. If this can be achieved by consolidating shipments, they would not oppose unless this reduces their service level (Holguín-Veras et al., 2016). Their preferred situation would be a situation where they do not need to change their operating practices, but still save money with respect to the transportation costs.

Suppliers of end-products
The general interest of wholesalers is largely similar to the interest of the primary and secondary manufacturers. Also the wholesalers would like to reduce the transportation costs (El Mokrini et al., 2016). They would like to achieve this through no changes to their current operating practices. Furthermore, they would like to increase the reliability, responsiveness, flexibility and quality of the service and the products (Mokrini et al., 2015). Regarding the consolidation of shipments, no problems are expected unless changes need to be made to their operating practices.

According to El Mokrini et al. (2016), suppliers mainly want to focus on their core competences. In order to do this, the logistic processes are outsourced. However, they only would like to outsource these processes if they can save costs and improve their service performance. The service performance is related to the reliability, responsiveness, flexibility and quality of the service and the products (Mokrini et al., 2015).

Furthermore, capabilities that suppliers ask from PostNl are several items. First and foremost, costs are important. Suppliers would like to reduce the operating costs and this can only be achieved if PostNL offers prices for the distribution of the goods that are lower than the operating costs of the suppliers. Furthermore, suppliers would like to have electronic data exchange to achieve major benefits such as reduced cost, increased processing speed, reduced errors and improved relationships with business partners. Another wish is often related to Good Distribution Practices (GDP) and Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). However, an ADR requirement is less often asked for by the suppliers.

Furthermore, suppliers could request for the transportation of pallets, break bulk cargo or roll containers. Especially, pallets and break bulk cargo are often requested. Roll containers are not that often requested. However, when the shipments are presorted there might be potential to use roll containers more often. These can be seen as a key demand. Furthermore, the performance of PostNL is important. PostNL is expected to do better than other logistics service providers, otherwise suppliers would not choose to work together with PostNL. Finally, there are some capabilities that are not specifically asked for, but are important to the suppliers.

Logistics service provider (PostNL)
The logistics service provider would foremost like to reduce operating costs (Holguín-Veras and Sánchez-Díaz, 2016). Secondly, their is an increasing interest in sustainability which can be translated in fuel efficient vehicles or reducing the number of vehicles needed (Bhatnagar et al., 2017). A logistic service provider is eager to implement consolidation techniques as a way to reduce costs and CO2 emission (PostNL, 2020).

When looking at the logistic service provider in this case, PostNL, more concrete goals can be formulated. The case is carried out for the PostNL Health team. This team serves several suppliers with different characteristics. Due to this diversity in characteristics multiple networks of PostNL are used to aid the suppliers. Therefore, this team focuses on the collaboration between the different networks. With insight in the bottlenecks, improvements in collaboration between networks can be found and tested in a simulation model. In 2018, PostNL has created long term goals to reduce the CO2 emissions. The goal is to deliver the last mile of all parcels emission free. This means that as soon as a parcel leaves the distribution center and until it reaches the customer, no emissions are expected to be produced by PostNL. In order to reach this goal, a sub goal has been set up. In 2025, PostNL would like to deliver the last mile free of emissions in 25 city centers and in 2050 the deliveries in all cities must be emission free. Finally, PostNL would like to reduce their operating costs. They believe that by collaborating more with the networks, operating costs can be reduced. By reducing the operating costs, more profit can be made and lower prices can be asked to customers.

Pharmacies and hospitals
According to Aljohani and Thompson (2019), hospitals and pharmacies would like to reduce the number of deliveries during the day in order to improve the productivity and reduce operating costs. Furthermore, service level and product quality are also two aspects with are really important to these actors (Jola, 2018). Furthermore, when

considering collaborating with a logistic service provider transportation according to ADR and GDP regulations preferred (Jola, 2018). Furthermore, hospitals would prefer set time frames in which PostNL is allowed to deliver the goods. This way, large shipments can be divided over the day to reduce the pressure during rush hour.

Households
The general interest of households is mainly regarding accessible healthcare and medication that is in stock (De Vries and Huijsman, 2011). Furthermore, reducing the amount of CO2 emitted due to a logistics service providers' operating practices are seen as one of the major problems that need to be addressed according to citizens (PostNL, 2020).

B.3 Step 3: Interdependence between actors

By looking at the different perspectives of the actors and their relations between each other, a power-interest grid can be created (Enserink et al., 2010). This grid shows how much influence an actor has and how big the interest is and is presented in table B.3.1.

Table B.3.1: Power-interest grid

		Level of interest	
		Low	High
Power	Low	• Primary manufacturers • Households	• Pharmacies
	High		• Logistic service provider • Supplier of end-products • Hospitals

As becomes apparent from table B.3.1, three actors (logistic service provider, supplier of end-products and hospitals) have both a high level of interest and a high level of power within this research problem. This is mainly due to the economic importance (Holguín-Veras and Sánchez-Díaz, 2016).

B.4 Conclusion actor analysis

Within the three steps explained above, the actors related to the case are identified, their perspectives with regard to the research problems has been described and how these relate to each other.

From this can be concluded that the logistic service provider, the supplier of end-products and the receiver (hospitals) are the core actors with respect to their level of interest and power, but also with respect to their economic importance. On most parts, these stakeholders agree with each other. However, the main focus differs per stakeholder. Hospitals mainly want to reduce the number of incoming shipments, the supplier of end-product wants to reduce the transportation costs without having to change their operating practices, and the logistic service providers would like to reduce the transportation costs and amount of CO_2 emitted.

When a logistic service provider would like to implement a receiver-led consolidation technique, no resistance is expected from the hospitals and no resistance is expected from the suppliers unless they need to make changes as well.

Appendix C

The internal processes of PostNL

In order to get a good understanding of the internal processes of PostNL and its components, PostNL has created BPMN models. This method is explained further in section A.1. This section elaborates on the unloading, planning, loading and distributing processes.

C.1 BPMN of the planning process

In the planning process, pre-notifications from suppliers are being handled and routes for the drivers are created. As can be seen in figure C.1.1, the IT department receives a pre-notification from the supplier about a certain delivery that needs to be picked up and delivered to a certain locations. When the parcels are sorted to the specific network, the data is released to a planning program called Tracc.

In the morning the planning team starts with processing the orders, after that the planning begins. The planning department determines the routes that need to be driven by the chauffeurs. The planning team prints the shipping list, loads it in the scanner and hands it over to the driver or warehouse personnel. After this, the loading list is processed in Tracc. The destination list for the chauffeurs and the product labels for the parcels are being printed from Tracc, and when needed shipping documents are provided to the driver. Then the drivers may be released and everything is handed over to the driver.

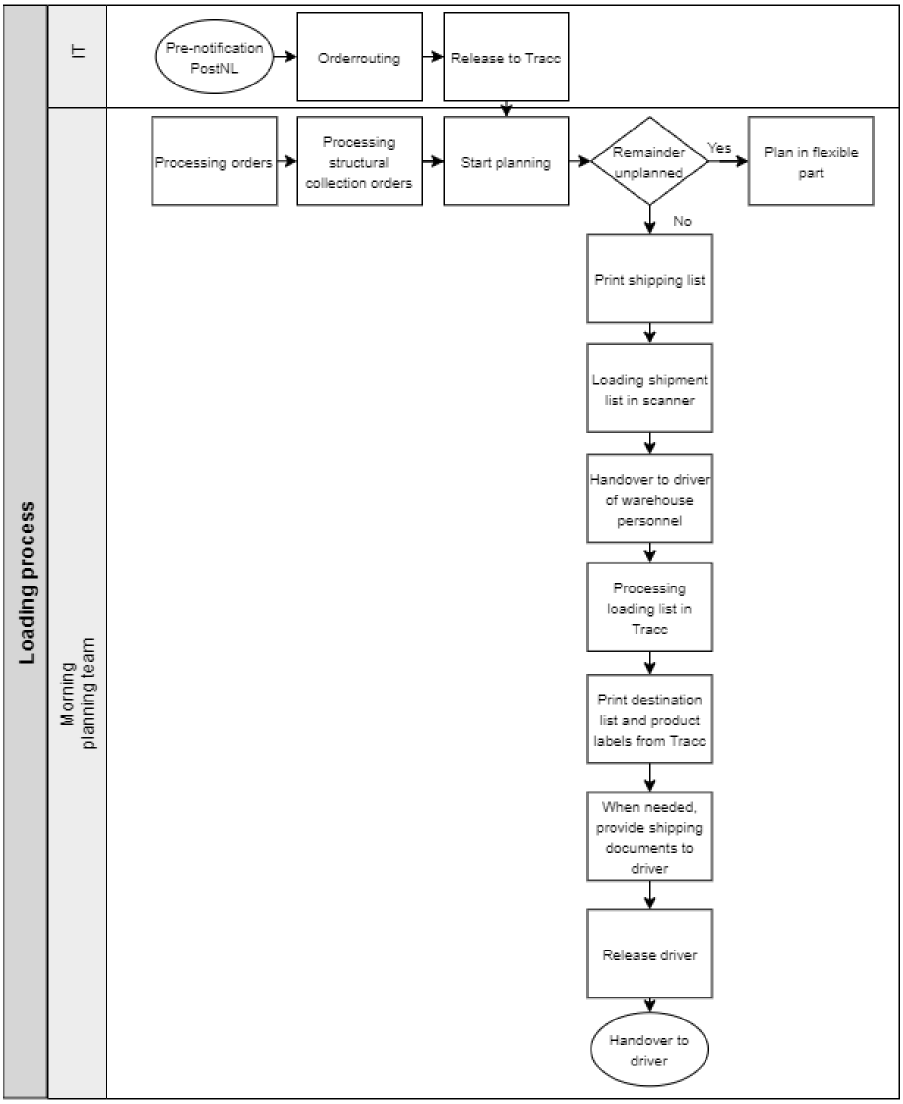

Figure C.1.1: BPMN of the planning process

C.2 BPMN of the loading process

The loading process consists of many components linked together and is visualised in figure C.2.1. First, the planning hands over the information of the shipment to the warehouse personnel. This information contains the specifics of each shipment. This is information about the truck in which the shipment needs to be loaded and the destination of the shipment. The warehouse personnel receives this information from the planning department and starts collecting the shipments. The shipment is scanned before it is loaded in the truck. Scanning the cargo is necessary to keep track of the products that are sent. After scanning of the shipment, it is loaded in the truck. When this step is finished, it is communicated to the team leader. The team leader receives the loading list and checks if the complete shipping list is loaded in the truck. The driver follows exactly the same steps as the warehouse personnel.

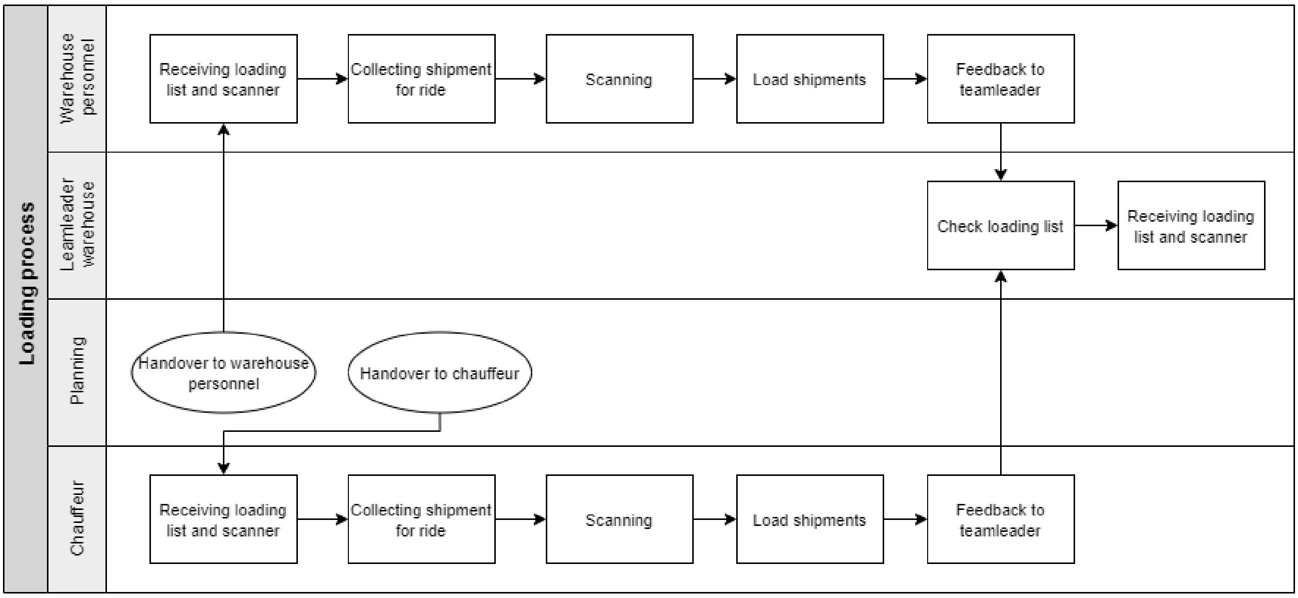

Figure C.2.1: BPMN model of the loading process

C.3 BPMN of the distribution process

As can be seen in figure C.3.1, the distribution process consists of many steps, especially for the chauffeur. This process starts when the chauffeur receives the information package. This package contains information about the destinations and the parcels that are inside the truck. After this, the driver starts this particular ride in the scanner and starts driving. During this ride, it is possible that the planning department adds another destination to the ride when a supplier makes a request. The driver then accepts this extra delivery in the scanner to make sure this destination is added to the ride. When the chauffeur reaches a destination the parcels are being unloaded or loaded when it is a collection ride. When the goods are loaded in the truck, the quantity of the goods needs to be registered in the scanner and on the loading list. When finished, the driver removes this stop from the scanner and continues with his/her route. If the chauffeur needs to unload goods at the destination, it is first checked if the goods are available. If not, the driver shares this information with the planning department that might reach out to the customer. If the goods are available, a signature is needed from the receiver. The goods are scanned and the payment of the bill might need to be handled manually. After that, the trip can be continued until the chauffeur passed all the destination. Finally, the driver returns to the depot.

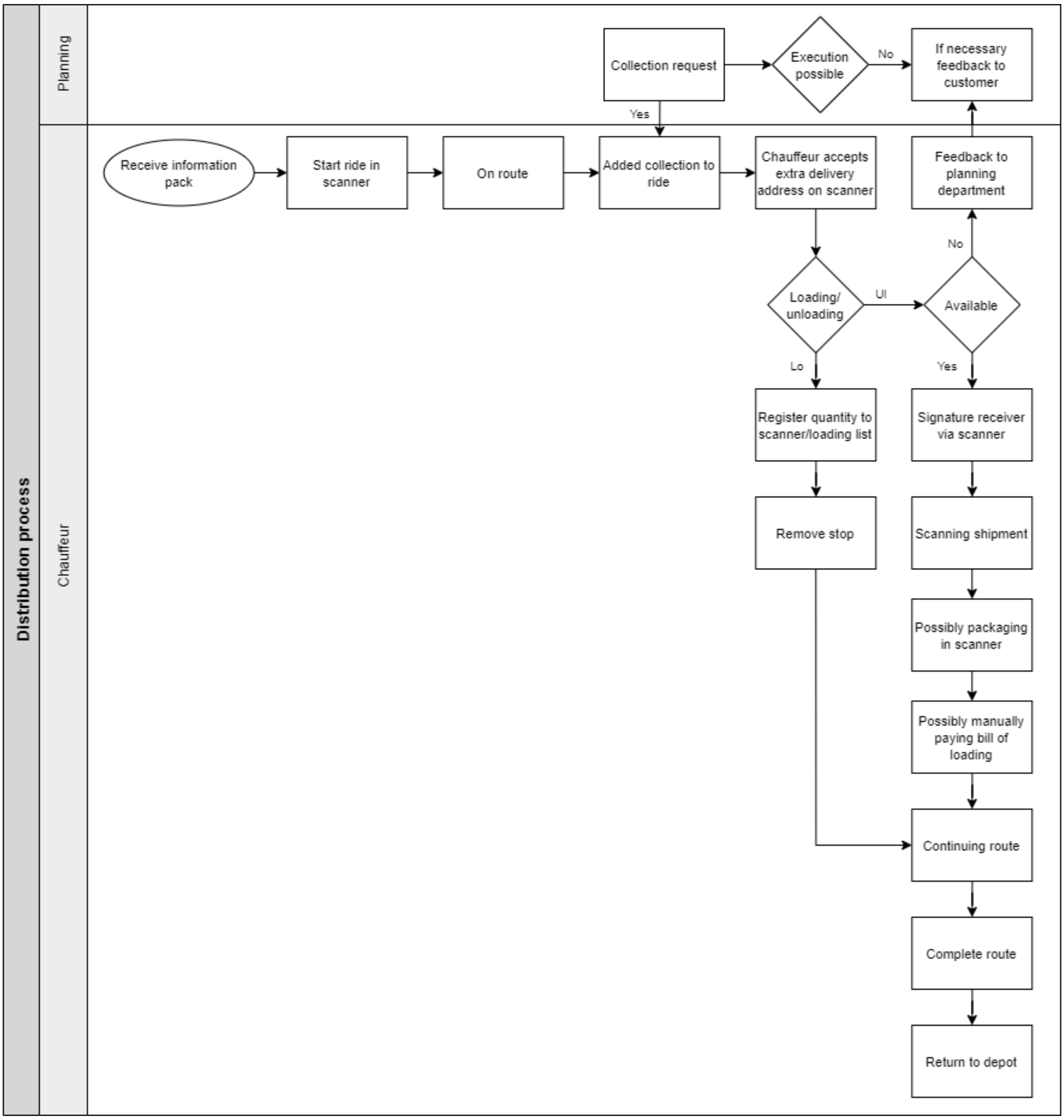

Figure C.3.1: BPMN model of the distribution process

C.4 BPMN of the unloading process

The unloading process of PostNL is visualized in figure C.4.1. As can be seen in this figure, the process starts when a truck arrives at the warehouse. The warehouse personnel scans the pallets that are inside the truck. If the shipment is a pallet, it goes directly in the presorting process. If the shipment is not a pallet, it is collected for carré sorting. Carré sorting means that pallets or roll containers are put next to each other with a specific postal code. The parcels and pallets that are brought in are manually sorted by postal code. The parcels are put on the designated roll container or pallet.

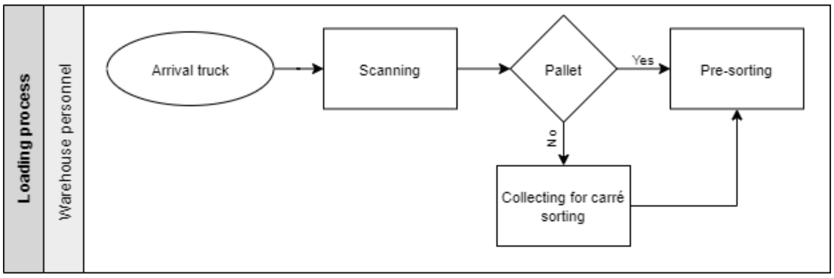

Figure C.4.1: BPMN model of the unloading process