Master's degree in Industrial Engineering & Management

Assessing the integration of same-day delivery option from the sustainable, financial, and service angles: a case study in the e-commerce sector

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UNIVERSITY OF TWENTE.

BEERWULF

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Management Summary

Background and research goal

Last-mile delivery is by far the most critical and expensive segment within the food retail chain. The high standards set by many third-party logistics (3PL) providers have triggered the customers' expectations for delivering online-purchased goods in a faster and more flexible way. As a result, last-mile delivery has become a hot topic in the logistics environment and offering extra delivery services is a key factor to survive and grow as a business. In addition, now that people are resuming their daily routines after the COVID-19 pandemic, attended home delivery will no longer be the most suitable choice. In this competitive environment, determining which combination of delivery options can be offered to the customers becomes a strategic decision for the businesses.

Beerwulf, a leader in the beer e-commerce sector, is interested in exploring alternatives to the current delivery scheme represented by standard home delivery (SHD), a service that delivers to the customers in 1-4 days depending on the customer location. The focus of this research will be on same-day delivery (SDD), an option that allows the customers to purchase and receive the products within the same day. The goal of this thesis, hence, is to develop a model representative of the coexistence of the two delivery modes and assess under three dimensions, service level, sustainability, and costs, the added value to the business for extending its home-delivery scheme.

Modelling approach

The decision on which delivery mode to investigate in this research was preceded by a customer's study on their preferences regarding different delivery options. A survey was designed internally by Beerwulf and submitted to a group of customers identified as representative of the purchasing behaviour for the targeted markets. The results of the survey disclosed interesting insights into customer satisfaction with respect to SHD. First, customers do not appreciate being constrained to a unique delivery service. Second, depending on the market, the delivery date is not always communicated to the customer, rather a time range of 2 up to 4 days is indicated for the delivery. As a consequence, this setup generates frustration in the customers as they feel forced to arrange their daily routines based on the delivery. Out of all the alternatives to SHD mentioned in the survey, a strong preference in all markets towards same-day delivery was registered. Combining the survey results together with experts' opinions at Beerwulf, it was agreed to limit this research to same-day delivery in two markets: the Netherlands and the United Kingdom.

Since the business' request was to investigate a realistic framework to integrate the SDD option in the current network, together with the need of exploring its impact under different circumstances, a discrete-event simulation approach was chosen for the thesis. Discrete event simulation has proved to be a suitable analysis tool when the environment is complex, and solutions cannot be tested in real-life. New performances metrics were designed to assess the quality of the proposed scenarios. The simulation methodology described in Law (2015) was selected to carry out the research.

Results

Eight scenarios were designed for each market, and simulated over two demand periods, namely a high-demand and a low-demand period. In the high-demand period, none of the scenarios suggests the implementation of same-day delivery in both cities. This outcome was mainly driven by the share of customers who select the same-day option, resulting either significantly below or above the truck capacity selected for the same-day vehicle. In the scenarios where the fraction of SDD orders is high, the service level performances are penalized by the little capacity available, generating high costs due to reimbursements paid to the affected customers. On the contrary, when the fraction of SDD is low, the service level is excellent, reaching performance of 95.1%, opposed by the high costs caused mostly by the fixed transportation fee.

In the low-demand period, experiments with a low selection rate for the SDD outperformed only in the service level dimension, scoring values of 99.9%. These great performances were not reflected in the financial dimension, where each same-day order had a negative impact between -22.3€ and -7.8€, mostly driver by reimbursement cost. The same applies for the carbon footprint, with situations where the emissions per order were 3.48 times higher compared to lowest emissions achievable with explored configuration. Conversely, when the selection rate for SDD increased, the simulation provided interesting results. In one scenario designed for the city of London, the SDD integration showed to be even profitable for Beerwulf, with a positive margin of 0.28€ per order shipped. In all the other cases, the costs per SDD order ranged between -5.2€ and -0,7€. In terms of quality of service offered to the customers, values up to 95.2% were found. Also, from a sustainability perspective, the emissions did not differ that much from the optimal ones.

The scenarios considered did not provide the business enough guarantees for a quick implementation. Still, the area of research for further investigation has been delineated, disclosing insightful characteristics of Beerwulf logistics network. Outcomes of this work may help the business to invest its resources in developing its strategy in the last-mile segment and examine either different cities or other logistics conditions.

Acknowledgments

This thesis concludes a path started back in 2015, when I was not even sure if I was pursuing the right academic direction. Countless people supported me in this journey, motivating and steering the wheel when needed. I would like to start thanking Beerwulf for the opportunity given and the knowledge that I absorbed throughout these months. In particular, thanks to my company supervisors Sjoerd de Reus and Gianni Croes who guided me in this project, offering their expert opinions on the topic and also for being my mentors in my first professional experience. I want to thank the University of Twente for consolidating and expanding my academic knowledge, especially my university supervisors Martijn Mes and Eduardo Lalla who patiently provided me with invaluable feedback, often encouraging me to explore other initiatives.

I cannot forget to mention my friend Vusal, person without whom I could have never managed to succeed this Master, co-working in almost all projects and supporting each other during Covid time when our relatives were distant like never before. Same gratitude goes to my best friend Giacomo who from Italy shared with me countless nights of studying, fun and for being the first contact for any sort of life matters.

Lastly, my family deserves a huge thank for all the love and massive efforts they did to make me accomplish such important step in my life. To my parents who stood behind me, and mostly, for believing in me. Eternally grateful, mum and dad.

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List of abbreviations

BW	Beerwulf
LM	Last-Mile
LMP	Last-Mile Provider
3PL	Third-Party Logistics
ETA	Estimated Time of Arrival
NPS	Net Promoter Score
SHD	Standard Home Delivery
SDD	Same-Day Delivery

1. Introduction

Section 1.1 introduces Beerwulf as a business, with a short description on the product-mix they offer and the current framework for home delivery. In Section 1.2, the challenges in the e-commerce sector are outlined, emphasizing the need for this study. Sections 1.3 focuses on the trends in last mile logistics and determines the core problem for this research. In Section 1.4, demographic details of the research scope and the type of analysis that is intended to be performed are presented. The last section illustrates the structure of this thesis, associating research questions and sub-questions to the chapters.

1.1 Background information

Beerwulf, founded in 2017, is a young Dutch retailer company who belong to the Heineken group. The company is specialized in the beer sector, selling its products online across 10 different countries in Europe, including the UK. Beerwulf assortment ranges from beer boxes that contain either bottles or cans (or both) to draught appliances and their complementary refills kegs. The whole distribution network relies on three warehouses operated by two 3PL partners. Products are dispatched via different last mile carriers that differ on the destination country. At the moment, customers receive their orders through standard home delivery. This delivery mode is probably the most popular one in the e-commerce sector as the efforts for meeting service and cost requirements are minimal compared to other premium last-mile delivery solutions. Once the orders are fulfilled at the warehouse level, these are shipped to one or multiple consolidation centres, depending on how far the customer's address from the warehouse is. The information available to the customer for the standard delivery is not the same: for some markets an ETA (Estimated Time of Arrival) is communicated to the customer during the checkout phase, whereas for other markets the customer only receives a day range within the delivery will occur. These circumstances have been proved to lower the customer satisfaction and impact the business in the long run. To contrast this trend, the business must explore alternatives to the standard home delivery and update its delivery proposition.

1.2 Motivation of the research

Thanks to the growth of the internet economy, the e-commerce sector is overtaking traditional *physical* shopping. This revolution in the retail sector is drastically changing the way people perceive the shopping experience. However, this raises new challenges for logistics since the supply chain has to cope with the increased fragmentation to satisfy the needs of customers. As a result, the e-commerce environment is becoming extremely competitive, and many marketing strategies are calling for outstanding delivery performances.

Another trend observed in the e-commerce sector reveals that customers are becoming more "conscientious customers" as their purchasing behaviour is getting influenced by sustainability concerns. As reported by Ignat & Chankov (2020), this is reflected in the checkout phase, since

displaying to the customers the environmental effects of a shipment can drive them towards the greener delivery option.
These challenges are also affecting Beerwulf as a business. In 2020, *standard home delivery* was not problematic since people were confined to their homes to prevent the spread of the COVID-19 virus. This favourable situation has indeed reduced the risk of delivery issues such as failed delivery attempts (either the recipient is not home, or the carrier arrived earlier/later than planned) or lost parcels. However, these circumstances are likely to change soon as people will start again to be away from home for longer periods.

The goal of this research is to investigate other delivery options and assess the impact on both customers and Beerwulf's network. Since the introduction of new delivery modes can be considered a massive intervention for a business, determining in advance the benefits and downsides becomes a fundamental step. Therefore, the best approach to comply with these requirements is to perform a simulation study and determine under which conditions a delivery mode is a valuable alternative for the company. In addition, testing new delivery modes in real-life and assessing their relative advantage is not feasible: 1) business interventions on the strategic level, as these are indeed the subject of this work, usually require significant investments from the company and the payback period can take several years, 2) the contractual terms between the carrier and the business would require the company to commit for a long period and the agreements cannot be withdrawn in a short/medium horizon, and 3) even if it would be possible to integrate temporary delivery options, the organization cannot keep changing the delivery scheme since it would result in a counterproductive action against the customer perception. In other words, if a customer is comfortable with a specific delivery mode, removing it from the delivery scheme has certainly an impact on the customer satisfaction. All these elements strengthen the decision for carrying out this research through a simulation study.

1.3 Problem identification

In the last decade, customer satisfaction has become a key factor to determine the success of a business. Customer satisfaction is often defined as the degree to which a customer is satisfied with buying and benefiting from a purchased product/service. In the retail sector, this is measured by the value perceived during the whole purchasing experience. At Beerwulf, the customer experience is measured through the Net Promoter Score (NPS), a well-known metric in the marketing field which encompasses different stages of the customer journey such as the appreciation with respect to the available products, the economic advantage, the delivery process, the tasting experience, etc.

To have a more accurate map of the customer journey, this score is recorded twice at Beerwulf: the first time when the customer purchases the product (NPS1), the second time when he/she receives it at home (NPS2). The fact that NPS2 is slightly lower compared to the NPS1 it is caused by different reasons: the value-for-money impression, the product not matching expectations, etc. It should not come as a surprise that this discrepancy also arises from the delivery mode available. A study conducted in Taiwan within the e-commerce sector states that quality in the delivery service was the most impacting factor of customer satisfaction, followed by the product quality (Lin et al., 2011). Another study conducted in Sweden in 2019 revealed that the last-mile delivery experience influences both the shopping experience and customer satisfaction (Vakulenko et al., 2019). And finally, the consultancy firm PwC reported in the *Global Consumer Insight Survey* (2018) that e-commerce buyers highly value a differentiated and fast delivery offer. Even if at Beerwulf the delivery process is not the major driver for changes in the NPS, these results prove that last-mile delivery has a considerable impact on customers' online experience and this research aims to close the gap between the NPS1 and NPS2.

The core problem

If it is acknowledged that providing a flexible and differentiated delivery option to the customers dictates the success of a business, still, the alternatives to *standard home delivery* need to be discussed. In late 2020, Beerwulf's customers were asked to express their preferences regarding the following delivery modes: same-day delivery, on-demand delivery, and pick-up points. Same-day delivery (SDD) allows the customer to receive the order by the end of the day if purchased before a fixed time. On-demand delivery is a more advanced delivery mode, where orders are being delivered in a few hours from the purchase moment. Companies that provide this type of service are for instance Gorillas and Getir, who crowdsource their delivery service from individuals who offer it. Contrary to these two last-mile modes that deliver at the door, with pick-up points the order is delivered to a location chosen by the customer from the ones offered by the last mile provider.

Without going into details, all the targeted countries reacted with a strong preference towards same-day delivery, followed by pick-up points. After discussing the survey results with several people in the organization, the decision on which delivery mode to focus on resulted in the following:

1) *Standard home delivery*
2) *Same-day delivery*

The reason why the pick-up points have been excluded from this study was driven by the fact that most of Beerwulf's assortment exceeds 15 kg and customers are not likely to collect heavy orders themselves if they can receive them directly at home. Next, pick-up points - including parcel lockers - are raising issues in the alcohol sector as the age of the person who collects the parcel cannot always be checked. These two reasons explain why pick-up points, and in general, any form of parcel collection have been discarded from this research.

The On-Demand delivery is more advanced in terms of logistics network and IT integrations. For launching this type of service, the business must develop relationships to support local inventories at the LSP site, with frequent replenishments. Such complexity cannot be handled at the moment, also because of restrictions in the dimension/weight of the products. These reasons lead to exclude this interesting last-mile mode from this project.

As the goal of this research is to investigate the impact of different last-mile alternatives, it is worth mentioning that distribution channels (e.g., Amazon, Bol, Tesco, etc.) could represent appealing solutions in this study. However, the pool of accountable parties would expand, influencing the already outsourced logistics activities. Moreover, it will by nature reduce the control on the operational level from Beerwulf side. Given these aspects, exploring other channels besides the ones mentioned above are out of the scope of this research.

1.4 Research scope

Geographical

An aspect that has not been mentioned yet is the geographical focus of the study and the characteristics of the population that are investigated. As already explained at the beginning of this chapter, Beerwulf is currently selling its products in 10 countries. Performing such a study on the whole network is not realistic due to its vastness and heterogeneity. Next to it, the new delivery option investigated in the thesis is not available for all the markets and over the whole territory (e.g., it is not possible to delivery in one day to Austria from BW warehouses). Therefore, it is straightforward that the focus area must be narrowed down.

The first decision is to target two different markets who do not share the same warehouse. This allows to establish independent logistics relationships among the two markets. The second decision taken together with the company is to focus on a city level and exclude the extra-urban or rural areas, as most Beerwulf customers live in highly populated cities. Both customers' demographic density and sales volumes realized in 2020 led to the selection of the two capitals for the Netherlands and the United Kingdom, namely Amsterdam and London. Focusing on a single city is not ideal for the following reasons: 1) when it comes to determine if a solution is promising or not, the results cannot be benchmarked with other performances, 2) the interest expressed toward the same-day delivery observed in the survey did not show evidence for restricting the study to a single market.

Type of analysis

In the literature, most of the research exploring the impact of delivery modes focusses on the time dimension, followed by the carbon footprint. This thesis aims to evaluate the integration of the delivery options from three perspectives:

1. Costs: what is the economic impact on Beerwulf business, and what are the implications for the customers during the check-out phase.
2. Carbon footprint: how the potential implementation of a new option would affect the environment.

3. Time: what are the direct implications for customers and the degree to which the service level provided to other customers is affected by the premium delivery modes.

It is worth mentioning that none of these facets prevail over the others, rather it will be relevant to trade-off the respective value propositions (VP). The literature will be reviewed to see if prior works have already addressed this problem.

1.5 Research Design

The previous section has pointed out the urgency for examining other delivery options to be added next to the *standard home delivery*. At this stage, the main research problem can be formulated with the following question:

"*How can the current logistics processes be redesigned to support the integration of the same-day delivery option next to the standard home delivery, and what would be the impact for the business in terms of service level, sustainability, and financial dimensions?"*

To ease the approach to the core problem, this work will address the following sub questions:

RQ1: What is the situation regarding the current and prospective delivery offers within Beerwulf's distribution network?

- What are the elements of Beerwulf's distribution network?
- What are the characteristics of standard home delivery regarding routing, timing, and volumes at each stage of the process?
- What would be the characteristics of the order flows for same-day delivery and on-demand delivery?
- What metrics are currently in use to assess the performance of the standard delivery?

RQ2: What approaches does the literature recommend for developing a simulation study and which approaches are suitable for evaluating the effects of the last-mile delivery?

- What is known by literature regarding frameworks for modelling and simulate supply chain networks? Which solutions are proposed in the literature to evaluate the last mile segment on the three levels, service, sustainability and costs?
- Which solutions does the literature provide in replicating the demand behaviour profile?

RQ3: How to design a simulation model representative of Beerwulf's distribution network for both cities ?

- How can the delivery modes be modelled and how do they interact with each other?
- What information is necessary as input for the simulation model?
- Which facets will be considered in the model design and what metrics are used?

- How can the outcomes of the model be compared to the real performances of the current set up and to what extent are these acceptable for the research?

RQ4: What experiments should be performed in the simulation that are representative of real situations and how can the results be analysed?

- What are the experimental factors and how are the scenarios designed?
- What are the performances of the delivery modes and what insights can be drawn from the results?

RQ5: How can the results be interpreted to communicate the research findings to the company management? Which limitations were encountered during this research?

The first research question is covered in Chapter 2. First, the structure of Beerwulf's supply network is outlined, focusing on the processes that occur between the warehouses and the end customers. This also includes the description of both information and physical order flows for the current delivery offer. As the other two delivery options are not yet implemented, information must be gathered to shape the potential changes in the way orders are processed. The chapter ends with an overview of the metrics that are currently in use to assess the performances of the deliveries.

Throughout the third chapter, simulation methodologies and modelling techniques are researched in the literature. One of the goals is to develop a structured framework where a model representative of Beerwulf's distribution network can be built. Studies like this thesis will be explored for two reasons: 1) check if the available approaches can be applied according to the purpose of this work, and 2) find other metrics that can be added to the current ones to assess the performances of LM delivery modes.

The third research question is answered in Chapter 4, explaining how the model is built, together with the variables that describe its status. As the time dimension plays a primary role in the whole distribution process, a significant part is dedicated to this topic, for instance how orders come in during the day, how these are processed/prioritized at the warehouses, when they are dispatched, etc. Finally, the performances of the model are compared to the real ones and considerations about that will be given.

Chapter 5 is dedicated to the Design Of Experiments (DOE). The information given in the second chapter regarding the two cities are used for building the scenarios that will be analysed with the simulation model. Also, considerations from the management and data from the past are collected to perform more realistic experiments. Next, indications on the length of the time horizon to assess the performances and effects are given. The final part of the chapter reports the results obtained from the different scenarios.

The last research question aims to reflect on the results and extrapolate insights from them. The implications of having multiple delivery options are presented in Chapter 6, attempting also to determine the mutual relationships among the delivery modes. As already mentioned, the goal of this research is not just to assess the results only from the economic perspective but also examining the impacts on customers and the environment. In essence, the review of the results must trade-off the different facets demanded by Beerwulf management.

Chapter 7 concludes the thesis, illustrating the achievement and a recommendations plan to support future logistics decisions at Beerwulf. Moreover, limitations encountered during this project are discussed and areas for future research are identified.

2. Context analysis

This chapter answers the following question "*What is the situation regarding the current and prospective delivery offers within Beerwulf's distribution network*?". In Section 2.1 and 2.2, a brief introduction on the company history and the structure of Beerwulf's distribution network is outlined. The two new delivery options are discussed in the perspective of including them in the current logistics setup. Lastly, the KPIs currently adopted by Beerwulf are presented.

2.1 Company introduction

The adventure of Beerwulf started in 2017, as part of the Heineken group. The recent growth and the acquired knowledge in the beer market have granted Beerwulf partnerships with many suppliers and mergers with other beer retailers. Whereas Heineken is more focused on the large-scale retail trade (e.g., supermarkets, restaurants, stores, etc.), Beerwulf's business model is built around the end-consumers. According to the 2021 market structure, the company sells its products across 10 markets: Austria, Belgium, France, Germany, Italy, Luxemburg, Portugal, Spain, The Netherlands, and The United Kingdom.

2.2 Network structure

Beerwulf's assortment can be divided into two categories: the *open-category* and the *closed-category*. The former consists of all the beer boxes that contain either bottles or cans. The latter includes the draught appliances and their respective refills. In this category, there are three different classes based on the litre capacity: 2 litres, 5 litres, and 8 litres. The term *closed-category* refers to the fact that if the customer wants to buy a refill keg, it must own a specific appliance to use it. Similarly, if the customer wants to have purchase a draught machine, this can only be used with its kegs. The term *open-category*, on the contrary, does not bind the customer to any extra device/tools, with the exception of a bottle opener.

Figure 1. Open category

Figure 2. Closed category

As the products of the two categories are not available in all the ten markets, the various stages of the supply chain need to be treated separately and are described as follows:

1. *Inbound logistics,* the logistics process for the transportation of goods purchased from the suppliers (raw materials) to the 3PLs who provide warehousing services.
2. *Fulfilment,* the activities related to storing the product fulfilling the orders, labelling the parcels, consolidating, and loading the goods into the carriers' vehicles. All these processes take place in the warehouses.
3. *Outbound logistics,* the shipments that occur between the warehouses and the sorting centres of the carriers. Usually, these are managed by the last-mile logistics providers who ship themselves directly to the end customer or by freight brokers.
4. *Last-mile delivery,* the final stage where the orders are sent from the sorting centres to the end customers.

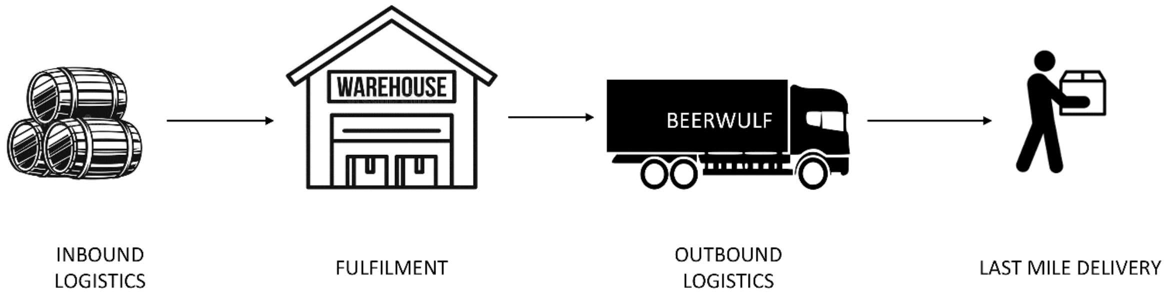


Figure 3. Logistics processes of Beerwulf's supply chain

These four segments, also showed in Figure 3, provide an overview of the logistics activities that occur between the beer suppliers and the end customers. Another fundamental phase frequently considered when shaping the supply chain is reverse logistics. However, it has been agreed that reverse logistics now does not interfere with the last-mile performances, thus it has been excluded from this research.

2.2.1 Inbound Logistics

This part of the logistics process entails all the transfers from the suppliers' production facilities to the warehouses where Beerwulf holds its operations. For the open category, most of the beer suppliers are located in Austria, France, Belgium, Germany, The Netherlands, Italy, United Kingdom, and Spain. Since all beer boxes are prepacked in the Netherlands, all bottles and cans are received in the Dutch warehouse. For the closed category, the countries are only three: Italy, The Netherlands, and the UK. Contrary to the open-category, the closed-category products are shipped to all three warehouses, which are located in these countries.

2.2.2 Fulfilment

The concept of fulfilment varies depending on the logistics environment. All logistics activities at Beerwulf are outsourced, therefore in this case it is appropriate to refer to outsourced fulfilment. As already mentioned in the previous paragraph, all the products for the open category are prepacked in the Netherlands. The beer assortment in the boxes cannot be picked by the customer, meaning that the composition of the box is fixed. Therefore, these boxes are copacked upfront and put back on the shelf, awaiting to be picked by a warehouse worker when a customer request that product. The beer boxes are also sent to the other two warehouses. For this category, the number of available products ranges from 10 up to 30, depending on the market. For the closed category, the process is slightly different. All the draught appliances are stocked in the warehouse, and these are picked only after a customer purchase. Regarding the refills, the customers are allowed to create an order with their favourite kegs mix. This flexible option in selecting the kegs demands for a Make-To-Order (MTO) strategy in the fulfilment activities. After the orders are fulfilled, these are taped, palletized, and moved to the outbound area. If for some reason an order cannot be fulfilled (shortage of manpower in the warehouse, higher volumes than forecasted, etc.), this is either cancelled or backlogged and fulfilled the day after. The fulfilment process is the same for all the warehouses.

2.2.3 Outbound Logistics

Once the products reach the dispatch area, the pallets are loaded onto vehicles and shipped either to the other warehouses or to the sorting centres of last-mile providers. Most of these transfers are handled by the last-mile providers themselves, but on some occasions other parties participate (freight brokers).

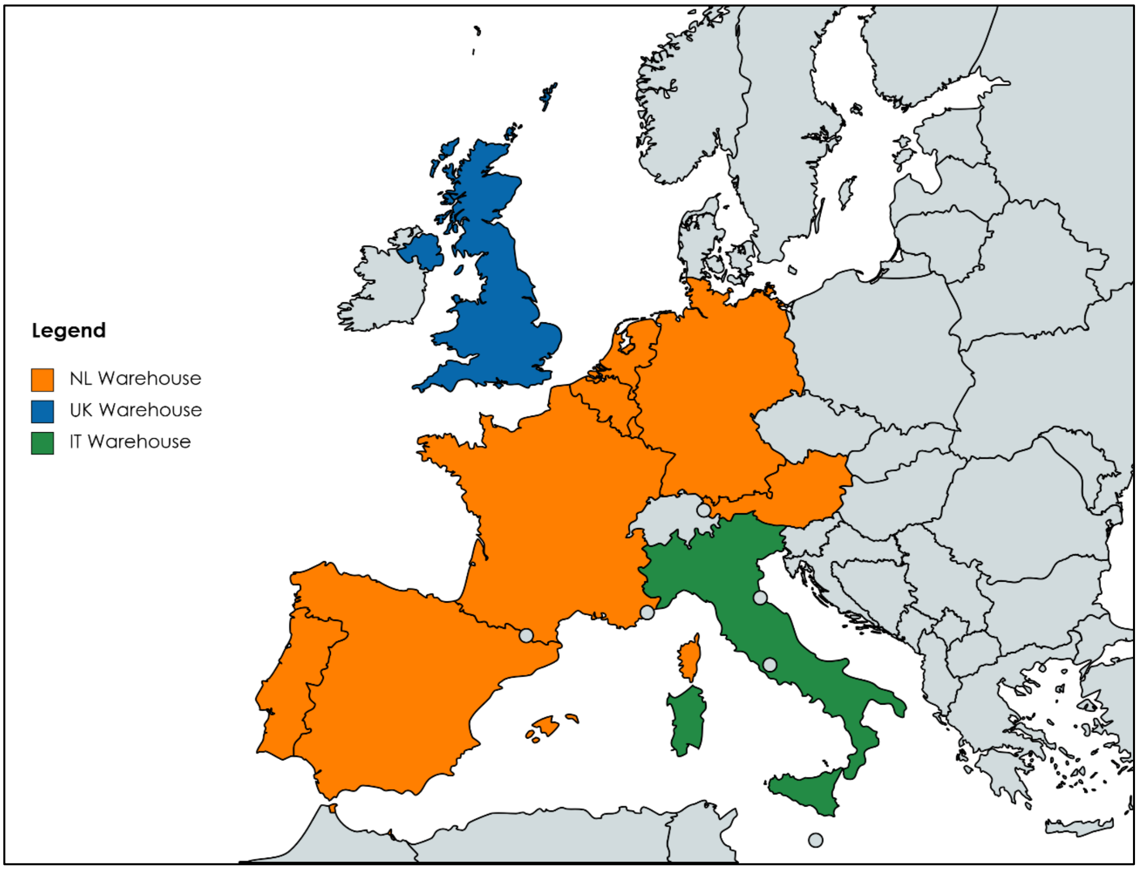


Figure 4. Beerwulf markets coloured based on the warehouse supplier.

Figure 4 shows for each country the supply relationship with the three warehouse. Two of the warehouses, namely the ones in Italy and the UK serve their internal markets. The Dutch warehouse supplies multiple countries: Austria, Belgium, France, Germany, Luxemburg, Portugal, Spain and the Netherlands itself. Since for the open category almost all the fulfilment activities take place in the Dutch warehouse, the transfers to the other warehouses are part of outbound logistics.

2.2.4 Last-mile delivery

In the last-mile delivery phase, the orders are sorted in the LMPs' distribution centres and shipped to the customers. From a carrier's perspective, the open and closed categories share the same delivery requirements, therefore the products are not treated in different ways. More details on the last mile stage are provided later in the chapter.

This first part of chapter 2 has been dedicated to answering the first sub-question of RQ1: describe and familiarize with the different tiers of Beerwulf logistics processes. To summarize what has been discussed so far, the supply chain consists of four stages: inbound logistics, fulfilment, outbound logistics, and last-mile delivery. Even though inbound logistics has a strategic role in the success of the company, it will not be included in the analysis of how the orders are being processed and delivered, nor in the simulation study. This decision was driven by the following considerations: 1) any disruptions that may occur in the inbound processes will affect all the downstream processes, regardless of the delivery modes, 2) all products received by Beerwulf from the suppliers must be first stored in the warehouse before being shipped to the customers. Activities such as *cross-docking* cannot be attained in the current setup, excluding any pre-fulfilment at the supplier location.

2.3 The physical flow of standard home delivery

Now that all the elements of the distribution network have been presented, the focus can be shifted towards the currently available last mile offer, *the standard home delivery*. As the fulfilment activities in the warehouses share the same characteristics, no matter the destination country, the description of standard home delivery will start from the moment when the products are dispatched at the warehouses. Since the portfolio of supplied countries is quite large, the different flows are grouped based on the last-mile carrier assigned to the country. In other words, the countries that share the same carrier are examined jointly. To better picture the supply chain at Beerwulf, figures regarding volumes and delivery performances are provided per segment. To avoid the effect of seasonal variations, these numbers are representative of non-peak periods.

Austria-France-Germany (AT-FR-DE)

These three countries share the same logistics provider, which is DPD. After the orders have been dispatched from the Dutch warehouse, the goods travel to a consolidation hub located in Oirschot, a place in the centre of The Netherlands. Here, the orders are sorted and shipped to the three countries in different trucks. Once the orders reach the destination country, they are again sorted in the regional depots and again sent to the local depots where they are finally consolidated and delivered to the end customer. Some of these depots are in Hamburg (DE), Duisburg (DE), Chilly Mazarin (FR), and Jonage (FR). In Figure 5, a visual representation of the AT-FR-DE is provided where the black depot corresponds to the sorting centre in Oirschot. The average delivery time for customers belonging to this segment ranges between 3 to 6 days, and the number of orders that are coming in on a daily basis averages between 400 and 700.

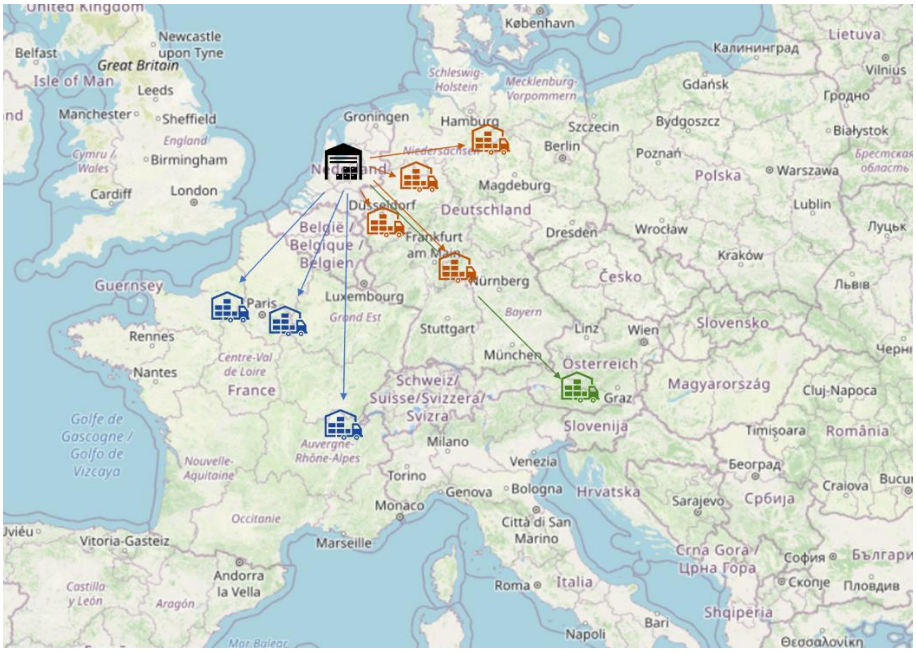


Figure 5. Outbound network for Austria, France, and Germany.

The Netherlands

The orders of Dutch customers are handled by DHL and are delivered first to a consolidation centre in Utrecht, a city located in the middle of the country (in Figure 6, Beerwulf's warehouse is identified with the black icon and the consolidation centre is showed in orange). At this stage, the orders are aggregated and sent to the city hubs (orange vans), where they are loaded on vans and eventually shipped to the final customers. Thanks to its modest size and the fact that the distribution network is fed from an internal warehouse, the deliveries in this country can be completed within 1 or 2 days. The number of orders received in a single day range between 300 and 1000 orders. This wide interval is explained by the effect of weekday dependency; for instance, customers are buying more towards the end of the week since in the weekend there are events, parties, BBQ, etc. The topic of the order distribution will be explained in more detail in Chapter 4.

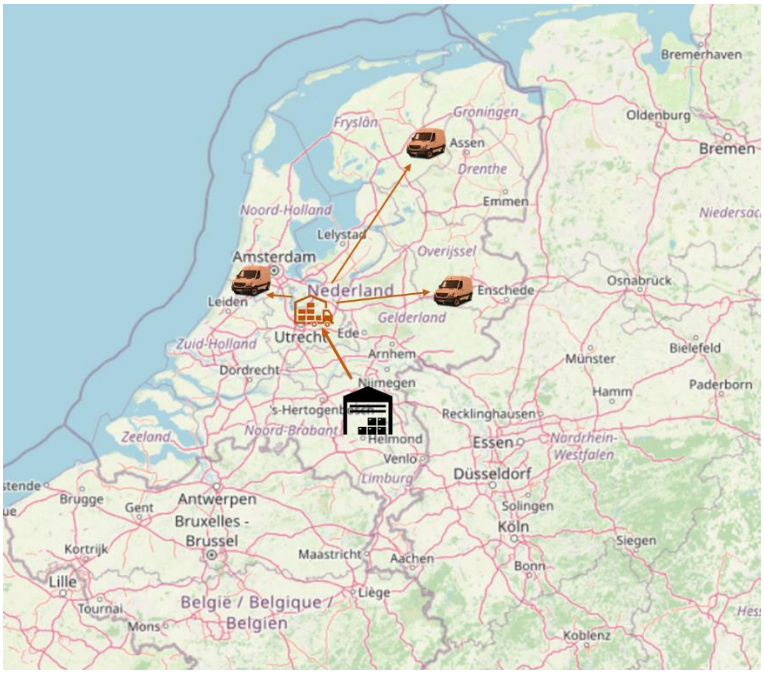


Figure 6. Outbound network for The Netherlands market.

The United Kingdom

In the UK, the goods are picked up at the UK's warehouse in Birmingham by two different 3PLs: Yodel and Hub-Europe. The former is responsible for both collecting the parcels at Beerwulf's warehouse and delivering them to the end-customers; the latter functions as an intermediary between the warehouse and Yodel's sorting centre. The two players arrange themselves the schedule for who is in charge of collecting the orders at the warehouse. The orders are processed in the central depot in Wednesbury and further dispatched to other regional depots, where they are finally consolidated in small vans and delivered to the final customer (Figure 7). Some of these local hubs are in Glasgow, Southampton, Truro, Reading. Since most of the UK population is condensed around major cities, together with the fact that the warehouse is located in the country, the customers can be reached in a shorter time, with an average delivery time of 1-2 days. The UK represents the biggest market for Beerwulf, recording every day a number of orders between 1500 and 3000. Due to its high volumes, a single dispatch slot is not sufficient to cope with the demand; therefore, the warehouse arranges with the carrier four collections per day in order to be able to spread evenly the volumes throughout the day.

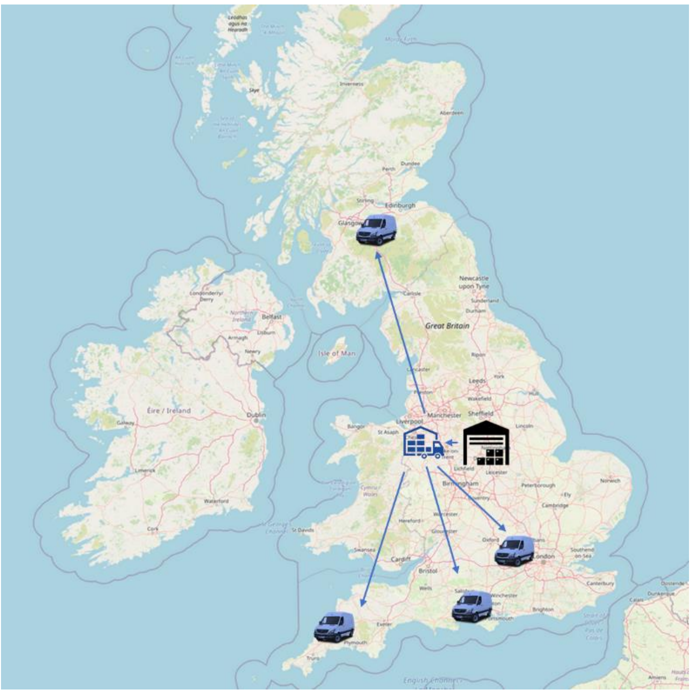


Figure 7. Outbound network for the UK market.

Other countries

As the volumes associated with the remaining countries only form a moderate share of the total volumes flowing in Beerwulf's distribution network, the relative last-mile paths will not be discussed in detail. Also note that the focus of our study does not include any of these countries.

Even though the AT-FR-DE market is not part of the research scope, still the impact on the logistics processes in the Dutch warehouse is significant. The relationship between this set of countries and the NL market will be explained later in the research. In addition, some of the carriers are not dedicated to a single country, meaning that outlining clear boundaries within the same carrier's delivery processes is not feasible. All these elements again prove that a simulation study is required to analyse how the performance of one process affects the others.

It is important to highlight that the description of the physical flows does not provide a complete picture of how orders are processed and shipped to the final customer. In this regard, the time dimension plays a major role in the logistics processes and still needs to be attached to the product flows. Therefore, the following sections aim to assign a time component to the Beerwulf customer journey, and all the events will be presented in chronological order. First, the order acceptance phase is outlined and the sequence of events that occur in the warehouse is described. Second, a quantitative description completes the standard home delivery framework.

2.4 Order acceptance

The process starts when the customer purchases the product on the Beerwulf website. Before the checkout, a request is sent to the warehouse to verify the immediate availability of the product. If the order can be fulfilled, the customer receives an acknowledgment of the order with a *Purchase Order* (PO) code attached to it. The orders are temporarily queued into a virtual buffer according to a FIFO logic and waved to the warehouses every 15 minutes. The time when the customer purchases the products is subject to the concept of *cut-off time,* a threshold that discriminates when an order is fulfilled and dispatched, but more importantly, when the order is likely to be received by the customer. Indeed, when the customer purchases products on the Beerwulf website, an estimate on the ETA (Expected Time of Arrival) is communicated to the customer, considering the current time and the cut-off time assigned to that country.

The *cut-off time* encompasses both the capacity of the warehouse and the dispatch time agreed with the carriers. If the order is placed after the cut-off time, the decisions associated with fulfilment and dispatching are the same for all the orders until the next cut-off time. In other words, the delivery date highly depends on these *cut-off times.*

The warehouse capacity is arranged by the warehouse itself, based on Beerwulf forecast of volumes that are expected to be handled that day. As the customer purchase behaviour cannot be explained through a deterministic variable, it is inevitable to run into over/underestimations. To prevent delays associated with underestimating the daily volumes, Beerwulf can anticipate the *cut-off time* in such a way that customers do not receive a biased indication of the ETA. It goes without saying that anticipating the *cut-off* time determines additional volumes for the day after. Therefore, this action can generate a bullwhip phenomenon downstream the distribution chain. Nevertheless, these types of actions are only taken when the gap between the real orders and the forecasted ones is very broad. Both the warehouses and Beerwulf aim to maximize the outbound volumes to meet customer expectations.

The preparation activities in the warehouses are driven by the dispatch times, meaning that the products must be palletized and stored in the loading area before being loaded on the carrier vehicles. Even though the orders are sent to the warehouse in a FIFO logic, all the orders sharing the same characteristics are divided into batches to increase efficiency. A good example is represented by refill orders: all the kegs of the same type are collected from the shelf on an aggregated level, since going back and forth in the picking area for each order is not efficient. This way of working also improves the placement of the boxes on the pallet since they are all of the same size. During the fulfilment phase, the labels are printed and stickered to the boxes, and ready for getting dispatched. From this point, the products are handled by the last-mile providers.

To clarify on the relationship between the cut-off time and the dispatch time, it is worth discussing how these time thresholds are determined. In the last mile environment, the carrier is usually the one establishing the time by which the products must be received in the first distribution centre after they leave the warehouse. This is needed as in the logistics environment, the parcels are usually sorted and shipped at the end of the day. The travel time between the BW warehouse and the carrier sorting centre is determined and subtracted from the latest arrival time at the distribution centre. This time constitutes the *dispatch time* in the warehouse. The last step to determine the cut-off time involves the freight capacity, more specifically, the number of parcels that are expected to fit in a truck. The working time needed to fulfil these orders is deducted from the dispatch time, generating the cut-off time. If these parameters are not tuned correctly, the truck will leave only partially loaded, or worse, some orders might be delayed. Furthermore, the *cut-off times* are fixed throughout the weekdays unless unexpected events arise, and changes are required. Below, Figure 8 shows the sequence of events to determine the cut-off time.

Figure 8. Sequence of events that link the cut-off time and the carrier latest arrival time.

2.6 Volumes & Times

In the framework for standard home delivery, the infrastructure of the distribution network, as well as the physical flows of Beerwulf products, have been identified. The final step to conclude this picture requires a quantitative characterization, for example, the exact time for the cut-off, when the fulfilment activities take place, etc. In the following paragraphs, the description will be given from the warehouses' perspective as the complexity of the operations can be better explained from this point of view.

2.6.1 NL Warehouse

As it has been outlined in the previous sections, the Dutch warehouse supplies multiple countries. In this regard, a successful coordination between the warehouse activities and the LMPs is crucial. For AT-FR-DE, the cut-off time is set at 17.00. All the orders from these countries that have arrived before this time are fulfilled in the morning shift of the day after (8.00-12.00). The dispatch time agreed with the carrier is at 14.00, therefore all the orders for DPD countries must be ready before this time. The volume of these orders usually accounts for 60% of the whole Beerwulf pool of orders handled in this warehouse. Orders going to Portugal, Belgium and Luxemburg are fulfilled between 14.00 and 16.00, and the cut-off time is at 15.00. The reason for a time threshold in the middle of the fulfilment shift is motivated by the low the number of orders that can always be fulfilled in these two hours. Finally, the cut-off time for the NL orders is set at 17.00, but the fulfilment activities for these orders occur in the evening shift since the carrier takes over the orders at 22.00. The volume of Dutch orders handled in the warehouse accounts for 34% of the whole volume.

2.6.2 UK Warehouse

The UK warehouse serves solely the internal market. Contrary to the NL warehouse where the carrier collects the parcels once a day and only after the cut-off time, in the UK warehouse there are multiple collections occurring even before the cut-off time. The reason for such a configuration is two-fold: first, the higher number of orders compared to volumes handles in the NL warehouse grants the UK warehouse to have a continuous stream in the fulfilment activities without compromising its efficiency, second, arranging multiple collections at the end of the day is not feasible for the warehouse, also bearing in mind that the fulfilled orders would stand and occupy the floor space for whole day. In light of these considerations, the cut-off time for UK customers is set at 17.00, and the carrier collections are scheduled at the following times: 7.30-11.00-15.00-19.30.

The cut-off time is checked many times during the day and eventually adjusted for the following reasons:

- The UK is quite a volatile market, therefore estimating the volume of orders that will be handled during a specific day is a challenging task. To prevent incurring extra costs due to an underestimation of the forecast, the cut-off time can be anticipated before 17.00. To better understand this scenario, if the forecasted volume in a day is 2000 orders and before 17.00h this amount is already reached, all new incoming orders will be waved to the next day.
- The fleet capacity of the carriers is limited and requesting an extra slot for dispatching more orders is not feasible. Therefore, if the volume of incoming orders reaches this threshold, the cut-off is moved earlier.

To conclude, the UK market accounts for the 58% of the total volume that is expected to be handled throughout all the warehouses during a single day, which explains the four dispatching slots. In Table 1, a summary of the cut-off times and dispatch times scheduled for each country.

Table 1. Cut-off times and dispatch times scheduled for the different markets.

Countries	Cut-off times	Dispatch times
United Kingdom	17.00	7.30-11.00-15.00-19.30
France-Germany-Austria	17.00 (previous day)	14:00
Netherlands	17.00	22.00

Because of the differences (e.g., in terms of dispatch times, frequency of collections, the capacity of the warehouse), aggregating the logistics paths under a unique flow would have yielded a poor description of the standard home delivery. Mapping in distinct sections this delivery mode allows for a thorough characterization of the logistics activities, covering the operations from the warehouses to the end customers.

2.7 Same day delivery

This premium delivery mode allows the customer to receive the purchased products within the end of the day if the order is placed before a certain cut-off. It goes with saying that in this case the cut-off time should be set earlier than the one for the standard home delivery, as they must be processed and sorted with priority in the carrier's distribution centre. Since this delivery option is not yet available for the customers, providing information on how the processes are structured is not possible. However, it can be assumed that similar relationships will be instantiated between the warehouses and the LM providers. The structure provided is the outcome of many consultations within Beerwulf and with the partners that will be eventually involved if the business will decide to implement the same-day delivery. Similar to the standard home delivery, the details about this premium delivery mode will be organized by segment. First, the framework for the same-day delivery in Amsterdam is described, followed by the one designed for London customers.

Amsterdam same-day framework

The first difference compared to the standard home delivery can be found in the physical flow. All the same-day delivery orders will be processed in a different distribution centre than the one used for the standard home delivery, which is located in Zaltbommel (30 minutes drive from Beerwulf warehouse). From this location, the parcels are loaded onto a city van and delivered in the evening to the customers in Amsterdam (Figure 9). One requirement from the carrier is that the orders must be inbound in the DC latest at 15.00. The cut-off is a parameter that still need to be agreed within the company for the following reasons: 1) as the expected volumes for same-day delivery are hard to estimate prior to the implementation, the fulfilment time cannot be deducted from the transit time, and 2) regarding the dispatch time, the warehouse needs to determine when it is possible to schedule a collection for same-day orders. The last issue to be discussed links to the freight capacity. This is a fundamental parameter to be agreed with the carriers since if the volumes are higher than the truck capacity,, the backlogged customers will be disappointed, even more than the regular ones because they paid an extra fee for a premium service. On the contrary, if the requested capacity is considerably higher than the real volumes, the company will incur extra costs and higher emissions per parcel. To conclude, it is important to mention that the same-day delivery option cannot be restricted solely to the customers living in Amsterdam. This means that all the customers living in the Netherland will be able to select this delivery mode.

London same-day framework

The situation for London is similar to one designed for Amsterdam, meaning that same-day orders will follow a different physical flow than the standard home delivery ones. The same-day orders would be shipped from the BW warehouse in Birmingham to a city hub in the North part of London. In this case, the distance between the two depots is considerably higher: 171.5 kilometres with an estimated transit time of 2 hours and 5 minutes according to Google Maps. This long distance also impacts the calculation of the cut-off for the same-day delivery. From the city hub, the orders are consolidated in city vans and delivered to customers (Figure 10).

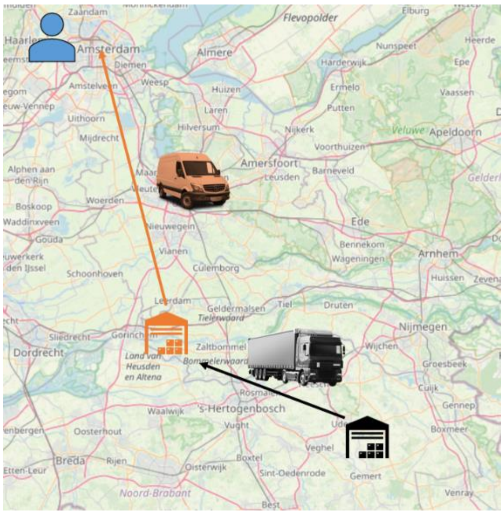


Figure 9. Amsterdam same-day delivery chart.

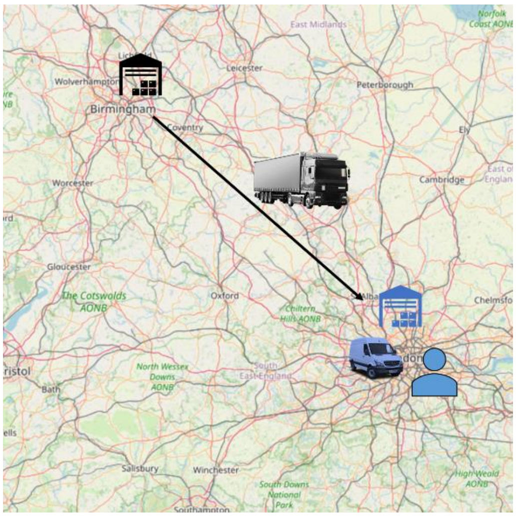


Figure 10. London same-day delivery chart.

One aspect that applies for both cities relate to the carbon footprint. Both carriers have communicated that the city deliveries will occur mostly with zero-emission vehicles or at least, all these emissions will be compensated. Therefore, the emissions for this premium delivery will be calculated only for the journey between the BW warehouses and the city hubs. All these elements have undoubtedly depicted a scenario rich of uncertainties, with many parameters that still need to be defined. However, this situation comes along with an advantage as it leaves freedom for testing different settings in the experimental phase. More details will be provided in Chapter 4.

2.8 Last mile delivery KPIs

Organizations use KPIs to assess their success in achieving targets. Some of these metrics are also used to benchmark their logistics performances with competitors, especially in the e-commerce sector where customer choices are very much driven by last-mile options. At Beerwulf, last-mile performances are measured on two dimensions, cost, and service level. First, the two types of indicators are discussed, then considerations on the available metrics are provided.

2.8.1 On-Time In Full (OTIF)

This KPI belongs to the service level dimensions and it is defined as the percentage of orders that are correctly fulfilled and shipped on time (Gjerdrum et al., 2001), which means that it is also representative of warehouse performances. At the warehouse level, this is measured monthly by the Dispatch Ratio ($DR_{i,w}$):

$$DR_{i,w} = \frac{\#\ of\ orders\ dispatched\ correctly\ and\ as\ planned}{O_{i,w}}$$

where *i* and *w* refer respectively to the month and the warehouse where these are recorded. $O_{i,w}$ represents the number of orders that should have been fulfilled and dispatched at the warehouse in a given month. At the end of the month, each warehouse communicates the dispatch ratio to Beerwulf, considering customer complaints received throughout the month that were attributable to errors occurred at the warehouse level. Most customers' complaints at this level can be linked to mistakes with the fulfilment process, for instance if the wrong item is picked or some SKUs are missing from the original order.

The other contribution to the OTIF is given by LM carriers performances, namely the First Attempt successful ratio ($FA_{i,w}$). This indicator shows the percentage of orders that have been delivered to the customers according to the communicated delivery date, or the agreements in the contract (i.e., for AT-FR-DE there is no planned date, but the delivery must occur within 2-6 days).

$$FA_{i,c} = \frac{\#\ orders\ delivered\ on\ time}{O_{i,c}}$$

Here, the warehouse index is replaced by a country index, as the performances of a single carrier can differ per country. LMPs communicate the performed service level at the end of the month here too.

At this point, the OTIF per country can be computed and it is calculated as follow:

$$OTIF_{i,c} = DR_{i,w} * FA_{i,c}$$

The last step to determine an overall indicator entailing the service level provided to Beerwulf customers consists of a weighted average with the number of orders purchased per country.

$$OTIF_i = \frac{\sum_c OTIF_{i,c} * O_{i,c}}{\sum_c O_{i,c}} \quad where\ c\ in\ countries, i\ in\ months$$

2.8.2 Cost per Parcel

In the last-mile segment, LMPs usually charge their customers based on the number of parcels that have been shipped during a period. These rates are agreed upon in a contract and the structure of these costs can be fixed, dependent on the parcel weight, locations, etc. In addition, there might be some delivery issues generating extra costs such as wrong addresses, returns from the customers, etc. All these factors show why tracking last-mile costs is a necessary task. At Beerwulf, the metric used to monitor the economic dimensions is Cost per Parcel ($CP_{i,c}$):

$$CP_{i,c} = \frac{Total\ last\ mile\ costs_{i,c}}{Total\ parcel\ shipped_{i,c}}$$

As well as the OTIF, the indices *i,c* represent the month and the country.

The two KPIs used at Beerwulf to monitor the fulfilment and delivery performances have been presented. Even though they embody all countries and the activities occurring downstream the warehouses, there are some drawbacks in their structures. First, the OTIF is a lagging indicator which means that by the time that the performances are poor, the situation is already jeopardized. Second, the frequency of when the OTIF is measured is relatively low, meaning that logistics performances are determined only 12 times a year, reducing the power of Beerwulf to challenge logistics providers to achieve a higher service level. Third, the OTIF is highly dependent on the dispatch rate at the warehouses since all downstream performances will be affected if this ratio is low. Also, countries with a higher market split have a major impact on the overall OTIF. The CP indicator includes all sources of costs meaning that if customers' returns start to ramp up, these can generate a biased estimate of the cost per parcel.

In Chapter 2, the current layout of the logistic network for both Amsterdam and London have been presented. Goal of this project consists also in redesigning the current way of measuring the performances and provide Beerwulf a solid structure that will allow the operational department to be more agile in the LSP management.

3 Literature review

In this chapter, the state of the art of modelling distribution networks in the retail environment and simulation techniques to evaluate those models are investigated. The first part is dedicated to the exploration of different methodologies regarding supply chain network modelling in the literature to evaluate which better suits the thesis goal.

3.1 Supply chain modelling methodologies

After almost 40 years from its first introduction (Oliver & Webber, 1982), the research area around the concept of Supply Chain Management (SCM) is still expanding. Riddalls et al., (2000) identify four categories of methodology into which most of the SC modelling approaches fall:

1) Continuous-time differential equations models. This theory expresses, where SC dynamics are expressed through mathematical equations. It can be beneficial provided that the level of aggregation is high. Also, some have attempted to describe stochastic demand through mathematical models, but the complexity present within the solving phase is considerable.
2) Discrete-time differential equation models. Like the continuous-time models, the dynamics are still modelled through mathematical equations. The main benefit is that in this case the time horizon is discretized, an approach that resembles a real-world situation since the status of a system cannot always be determined at any point in time. Some of the inventory problems have been solved using this method, but large problem instances have shown their limitations.
3) Discrete event dynamic systems (DEDS). Probably it is the most applied method to model SC dynamics. This approach allows for modelling discrete processes in a continuous-time horizon. Many mathematical theories have been modelled with DEDS: Markov chain models, queuing models, semi-Markov process models, etc.
4) Operational Research Techniques. This methodology is widely used to formalize SC dynamics into a mathematical model. Within this group, famous techniques have been applied to the SC environment: linear/dynamic programming, queuing theory, Markovian theory, etc. One drawback is the computational effort: large instances result in a long computational time. It is a common practice to complement this method with the DEDS to validate the conceptual framework of the analysed model.

The conclusion of the paper suggests that none of the methods shows an absolute advantage compared to the others, rather their applicability depends on the problem structure and its requirements. However, the authors recommend simulations when the degree of complexity of the system cannot be explained through mathematical formulations. This proposition is also supported by the work of Terzi & Cavalieri, (2004), where the authors encourage the use of simulations instead of analytical approaches particularly in the logistics environment, whenever new solutions are designed and a *what-if* analysis can play a decisive role. In addition, analytical models often do not suit the stochastic dynamics of SC networks

(Long et al., 2011). Another classification divides simulation modelling approaches into DES and system dynamics (SD). Tako & Robinson (2012) reports that the general belief about these two techniques leaves the DES for solving problems on the operational/tactic level whereas SD is mainly employed for strategic decisions. Even though the paper concludes by stating that no evidence was found supporting the idea that a marked line dictates whether SD or DES should be used for specific organization levels, there are substantial differences between the two models. First, as already mentioned, variables in DES change at discrete points of time while for SD these changes occur continuously. Second, DES models can represent the processes on a unit level, whereas in SD these appear on an aggregated level. Third, DES is recommended for modelling stochastic processes and SD usually represents behaviours through deterministic and expected values. Law's book (Law, 2013) divides the simulation approaches into two categories: the discrete and continuous systems. For Discrete Event Simulation (DES), the variables change of status only in defined points of time, whereas for Continuous Simulation this variation can occur at any time.

Other studies support DES for supply chain modelling since it can better explain the dynamics of realistic supply chain networks (Disney & Lambrecht, 2008). Moreover, DES allows for evaluating new configurations without interrupting processes on the operational scale (Chang & Makatsoris, 2001).

Simulation Frameworks

The next step is to determine a framework for conducting a simulation study. As SC problems are not likely to share homogeneous characteristics, a unique framework applicable for all simulation studies cannot be found in the literature. Therefore, two studies are presented and compared, aiming to find one that is suitable for this research.

Robinson, (2004) proposes a reviewed framework based on the work of Landry et al., (1983), and preserves the cyclical shape , as can be seen in Appendix A. From the real-world problem, a conceptual model is developed, and is later translated into a computer model. Solutions and understanding of the model behaviour are revealed through the experimental phase and if improvements are obtained, these are implemented in the real world. Within this cycle, the authors included other actions, such as validation and verification, meant to guarantee the quality of the model. According to (Law, 2013), *validation* is "the process of determining whether a simulation model is an accurate representation of the system, for the particular objectives of the study"; and *verification* assesses if "the assumptions document has been correctly translated into a computer program".

Law (2007) also offers a framework for a simulation study. One difference from Robinson (2004) can be recognized in the explicit phase of data collection prior to the model definition. A recursive procedure checks that the conceptual model is translated into a true representation of the real-world system. In addition, particular attention is given to the verification and validation processes.

The framework proposed Law is more elaborate than the one presented by Robinson (check literature sources). Hence, Law's framework is used to conduct this research.

3.2 Literature sources to assess the impact of last-mile delivery

At this point of the thesis, it should be evident that a simulation study is a powerful tool when it is necessary to understand how the system behaves under different conditions. The goal of this study is to determine the feasibility and assess the impact of new last-mile solutions from three different angles: service, sustainability, and costs. This approach falls under the name of "Triple E approach", Simao et. Al (2016). Originally, the three dimensions of the Triple E approach were: 1) efficiency, 2) efficacy and 3) environmental impact.

Following this categorization, several papers regarding both logistics networks and same-day delivery have been collected in order to support shaping the path for the following chapters.

In the context of supply chain analysis, simulation is recommended to evaluate how costs and profitability are affected under different conditions. The last-mile segment in particular has received a lot of attention in the last decade, as its impact accounts for 13% up to 75% of the total supply chain costs (Gevaers et al., 2009). The great variety of factors impacting this expensive stage also results in a wide spectrum of last-mile problems. The approaches designed to solve these problems cover long-term plans, such as locations and facility capacity planning (Che et al., 2022), as well as short-horizon decisions, including routing and scheduling problems (Azi et al., (2012),Klapp et al., (2020)). The last ones, given the hard challenges arising in city-logistics, are recently embedding more customers' needs, since customer satisfaction has been proved to have a positive economic impact for the last-mile logistics (van Duin et al., 2016).

Same day delivery is a recent trend for online purchases. One of the core aspects for same-day problems relates to the time dimension, when decisions must be taken. In (Voccia et al., 2015), the authors present a formulation for same-day delivery problem (SDDP), where scheduling and routing decisions are subjected to time constraints. The results in the paper show that predicting customers' locations in combination with a high arrival rate for the orders, it can positive affect the service level delivered to the customers. Moreover, scenarios when delivery time windows are close to the purchase time outperform situations where most of the orders must be delivered towards the end of day. This paper assumes that the goods are already available at the dispatch centre which in the Ecommerce sector is not always the case, which significantly limits the decision space.

Another aspect widely discussed in the literature for the same-day delivery is its environmental impact. In a study conducted by McKinsey & Company, 25% of the people interviewed expressed their willingness to pay an extra fee for same-day delivery, especially in the young age range (Joerss et al., 2016). As a consequence, more vehicles are expected to travel in the cities, contributing to traffic and air pollution (Berlin et al., 2016). The majority of the literature focuses on the impact of the same-day delivery in the last leg of the last-mile segment, from the distribution centres to the final customer. These problems are often approached with VRP formulations, (Zhang et al., 2020), and discrete event simulations (Guo et al., 2019)(Klapp et al., 2020). The literature has recently focused on methods to trade-off the inefficiencies of same-day delivery, and how to reduce its negative economic impact. In the work of (Prokhorchuk et al., 2019), the authors design a Markov decision process to compute dynamic pricing for same-day delivery routing. Every time a customer requests the same-day delivery, a route is generated for each delivery deadline, followed by an estimate on the opportunity costs if the customer is added to that route. Based on these opportunity costs, prices are generated for each time slots and the model is updated after the customer makes a decision. The interesting part of this study is that the pricing differentiation can influence the customer behaviour, leading to more profitable scenarios. However, this sophisticated model requires an end-to-end integration with the seller (e.g., thorough a delivery management system (DMS)), to ensure that the customer decisions are shared in time with the last-mile carrier. Also, this study proves that a fixed price for the delivery is not ideal since 1) customers have a preference for a restricted set of delivery slots, meaning that some of these are busier that others 2) customers' locations impact the routing decisions, therefore the costs for a delivery slot must take into account this component.

Ultimately, to ensure that the customer perspective in this research is in line with the current trends, the consumer behaviour in in the online retailing was researched. In (Nguyen et al., 2019), the authors analyse the most important attributes for the customer when it comes to select the delivery mode. The investigated attributes are delivery speed, time slot, daytime/evening delivery, delivery date and delivery fee. Based on the data collected through a survey, two models for predicting a consumer's choice where designed and simulated over different scenarios. The findings revealed that customers are highly sensitive to the shipping fee, followed by delivery speed and time slot. However, they authors point out that these results are much dependent on the income of the customer, and the product purchased. For example, the shipping fee paid for an urgent and expensive product is almost not perceived by the customer. More importantly, this study was conducted on a single country which means that some assumptions and outcomes may not be applicable across different countries.

The reviewed literature has shed light on the major challenges around the last-mile segment, and more specifically, the same-day delivery. Inbound logistics for the same-day delivery demonstrated to have a key role on all the three dimensions investigated in the thesis, costs, service level, and sustainability. Vehicles' capacity and dispatch times are two elements that can be modelled in accordance with the strategy of the business. Still, studies similar to the scope of this research could not be found in the literature, as the majority focus only on a short window of the outbound logistics. Finally, the consumer behaviour in the commerce sector was researched to guarantee that realistic scenarios are designed later on in the thesis.

3.3.1 Service

In the context of urban logistics, the service, together with costs, are probably the dimensions studied the most. The service level perceived by the customer derives from the performances of multiple actors in the supply chain: suppliers, warehouses, last-mile carriers, etc. One of the most common measures to determine the service level provided to the customers is the *Order Fulfillment Cycle Time* (OFCT), which refers to the time it takes from when the customer places the order and when it is received. Communicating to the customer an accurate OFCT can positively influence customer satisfaction, as it represents a promise made with the customer (Zhu et al., 2020).

Another traditional metric used to measure the service level is the *on-time delivery* (OTD). This KPI reflects the percentage of orders that have been delivered to the customers according to the planned date (Chan, 2003). Similarly, *on-time shipping* measures the percentage of orders that have been dispatched at the warehouse level.

3.3.2 Sustainability

Starting off with the concept of sustainable SC, many studies have addressed the problem of sustainability not only from the environmental perspective but also embracing societal and economic factors (Chaabane et al., 2012). Considering the thesis scope, this section will only present results from the environmental point of view.

Air pollution is becoming a critical factor for human health and reducing the environmental impact of last-mile delivery is an urgent action (Schnieder et al., 2021). Most of the approaches to reduce the emission start with an existing supply chain where the goal is to optimize the process to lower the environmental impact. Some of these consist of transportation problems, such as VRP optimization problems where the emissions are in the objective function (Liao, 2017; MirHassani & Mohammadyari, 2014); rearranging the operations inside the warehouse and the transhipments to the distribution centres (Rüdiger et al., 2016); and outsourcing the logistics activities to 3PL providers to reduce the empty volumes in the trucks (Tang et al., 2014)..

One of the pollutants that have been studied the most in the logistic sector is CO2. The CO2 emissions are usually expressed in relation to the unit/parcel level. In Giuffrida et al., (2016), the authors showed that collection delivery point (CDP) delivery is less pollutant compared to home delivery, supported by a simulation analysis where the CO2/parcel rate is almost three times higher than home-delivery since a failed delivery generates extra emissions..

3.3.3 Costs

In the context of supply chain analysis, simulation is recommended to evaluate how costs and profitability are affected under different conditions. Similar to the sustainability aspect, the literature provides countless approaches to estimate or minimize the costs at different levels of the supply chain. Bottani & Montanari, (2010) developed a simulation framework to evaluate supply chains costs up to 5 tiers. Some of the economic metrics that are used in the article to assess the supply chain structures are unitary transport costs, total holding costs, fixed location costs, total costs of orders, etc.

Last-mile delivery has received a lot of attention in last decades since 40% of the logistics costs of a B2C business are attributable to the last-mile segment (*Challenges Opportunities Last-Mile Delivery*, 2018). A literature study conducted by Mangiaracina et al., (2019) shows that the factors impacting the last-mile costs can be divided into three classes: 1) transport means cost, which in the case of traditional delivery is the cost associated with the use of vehicles, 2) driver cost, namely the cost to pay the worker to drive the vehicle for the delivery, and 3) opportunity cost. The last component is more abstract than the others and it estimates the costs associated with the customer level of satisfaction, like costs of a failed delivery.

In Chapter 3, the goal was to lay the foundation for structuring this research. The first part was dedicated to the research of supply chain modelling techniques available in the literature, identifying which one best suit the purpose of the study. After having established that discrete event simulation fits the requirements of this research, some simulation frameworks were discussed. One of the research sub-questions was to investigate literature sources with a similar setup, where the three dimensions are investigated jointly. However, the number of similar works was very limited as most of the research are addressing one dimension only. Hence, two main sources were discussed followed by a categorization of KPIs that were found interesting for this work. To conclude, the scarce availability of studies where the three dimensions are tackled at the same time demonstrates the innovative setup of this thesis.

4 Model definition

In the second chapter, the structure of the current distribution network has been outlined, and a realistic framework for the new delivery option has been identified. The role of Chapter 4 is to translate these schemes into simulation models that will be used to assess the feasibility of same-day delivery. The first task is to elaborate a theoretical model that will be representative for a scenario where the two delivery mode coexist. This means also reworking the current dispatch policies, which will need prioritization rules for the different order types. The next step consists in identifying the inputs necessary for the simulation models and determine how these will be integrated into the models. Lastly, the metrics for assessing the simulation performances will be introduced.

4.1 Model description

In this subsection, the theoretical framework for the two cities will be presented, along with a detailed description of the logistics activities included in the model. Since the two models do not share the same characteristics, a general overview on how the orders are received, processed, and dispatched is presented. This will help the reader to understand the basics of the logistics context, but more importantly, assign a temporal component to the major activities.

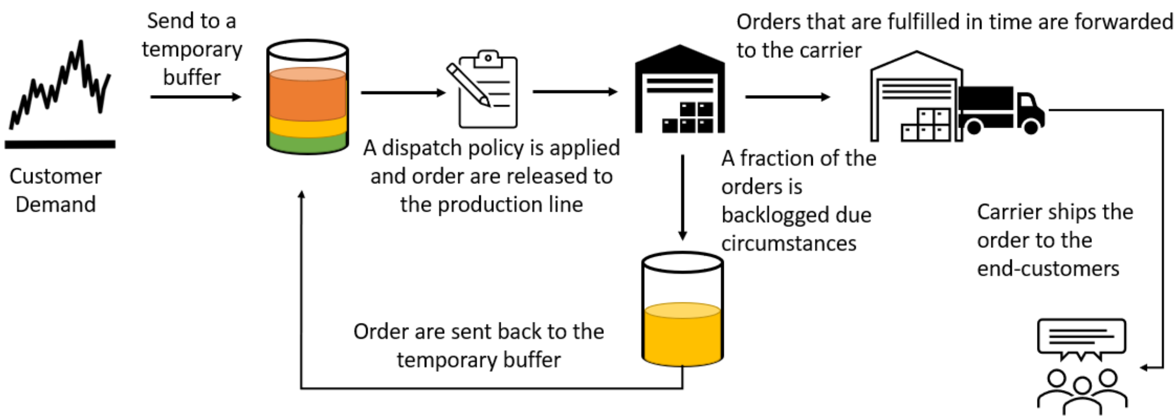


Figure 11. Diagram of the order flow, from the purchase moment to the customer delivery.

Customer demand is generated on a daily basis and split according to the cut-off time. The reader may picture the orders coming along with a timeline, in such a way that each order can be identified through an *order-time*. In Figure 12, the orders in orange are the ones before the cut-off time and are sent to the same working shift, also called dispatch slot.

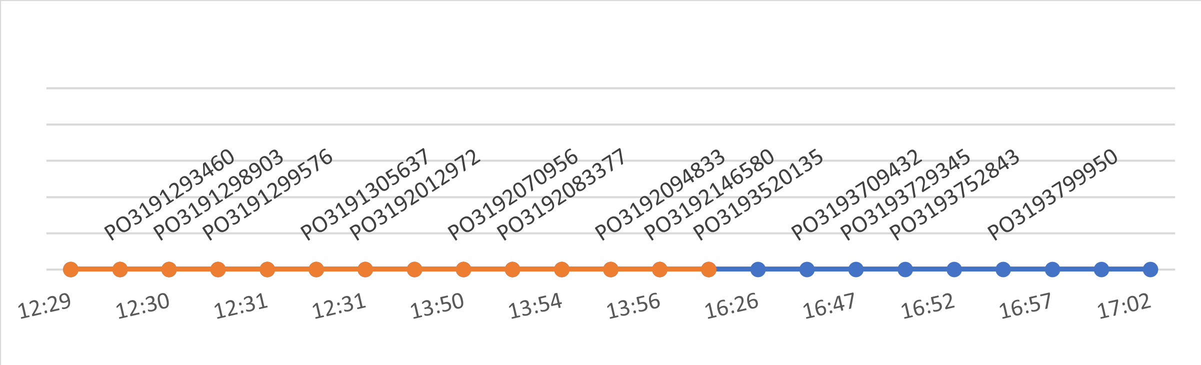


Figure 12. Visual on the timeline of orders in relation with the cut-off time.

After the orders are received, these are assigned to a specific shift based on the allocation policy established in the warehouse. The logic of the allocation policies will be presented in detail later where the warehouses are discussed separately. All the orders belonging to the same shift are sorted following a dispatch rule, and based on the output list, the whole set, or a fraction of them, is fulfilled and loaded on the truck. If some orders were not dispatched, these are backlogged and forwarded to the next dispatch slot. The orders shipped from the warehouse are received by different distribution centres, according to the delivery mode selected, where they are sorted and loaded onto last-mile vehicles used for delivering to the end-customer. All these steps are displayed in Figure 11. Before approaching with the characterization of the two models, it is important to share the decisions taken on which extent the delivery modes must have been represented. Being the standard home delivery not the focus of this research, its contribution in the model is limited to the warehouse activities, meaning that the shipments from the warehouse to the distribution centres is not examined. Although this aspect was extensively debated with the organization and the last mile partners, the lack of information on the outbound flow and its fragmentated nature hampered a full implementation of this delivery mode. Still, its impact in the fulfilment activities will be included, guaranteeing the integrity of the research scope. With respect to the same-day delivery, the model will cover the activities from the purchase moment until the products are being delivered to the carrier sorting centre. Extending the model to the last mile leg where the products are delivered at the customer door is not feasible since Beerwulf does not have control on that part. At the same time, knowing that city vans are green, and that the products received in the city hub are guaranteed to be delivered within the same day, adding to the models this section will not bring extra value to the research, and not adding them will not undermine the quality of this work. After this introduction, the two frameworks can be explained in more details.

4.1.1 NL case

The current scenario in the warehouse works with two shifts, a morning and an evening shift. The morning one is responsible for fulfilling orders of the AT-DE-FR segment, whereas the evening one is dedicated to NL orders. The same shifts have been integrated in the model as well, which means that the incoming orders can only be processed in one these two time-windows. To refer to these shifts, the acronyms '*mor-*' and '*eve-*' followed by a weekday number are adopted. Since the warehouse works only from Monday to Friday, the combinations of numbers will range between 1 (Monday) and 5 (Friday). In the table below, all combinations are listed.

Table 2. Shifts' names adopted for the NL warehouse.

Monday	Tuesday	Wednesday	Thursday	Friday
mor-1	mor-2	mor-3	mor-4	mor-5
eve-1	eve-2	eve-3	eve-4	eve-5

At this point, all the relationships between the demand and the allocated shifts for the dispatch can be made. The first segment to be analysed is the AT-FR-DE. In Figure 13, the top table represents the weekly demand, where each day is divided in two by a red bar which symbolizes the cut-off time. The bottom table shows the working shifts for this segment, which are only morning shifts. The reader may notice that the pool of orders fulfilled in a single shift comes usually from two different days. More importantly, Monday and Tuesday shifts cover a wider range of time, usually resulting in higher volumes to be handled those days. There is indeed a negative trend throughout the week in the number of orders dispatched in a shift (high on Monday and low on Friday).

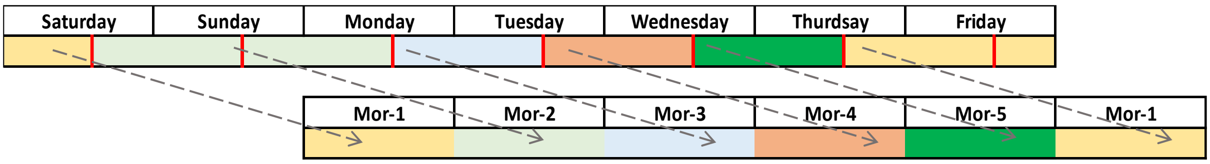


Figure 13. Order allocation policy for the segment AT-FR-DE.

The allocation policy for the NL segment assigns the orders in the evening shift as reported below. It can be noticed that the Monday shift covers a wide interval of customer demand, determining high pressure on the operational level for that day (Figure 14).

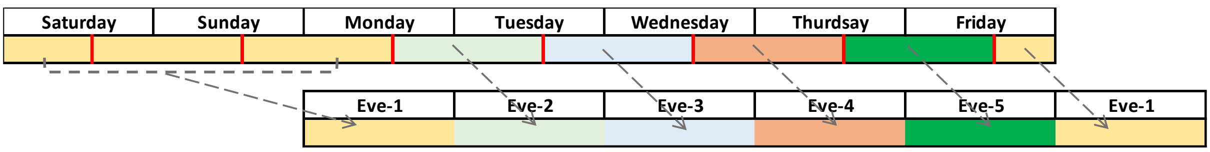


Figure 14. Order allocation policy for the NL segment.

Before discussing the design of the dispatch policies, it is important to envision the different decisions affecting the order management. The process of allocating an incoming order to a working shift is detached from a dispatch policy. The explanation lies in the fact that in an optimal situation where the warehouse is always capable of fulfilling the orders and backlogs are never occurring, a dispatch policy would never be necessary as no prioritization is required. Also, since in the current configuration the carriers are visiting the warehouse only once per day, the orders that are backlogged will be necessarily transferred to the next dispatch slot for that segment. To summarize, dispatch policies determine the sequence in which orders must be dispatched whereas allocation policies consist in distributing the orders to specific shifts.

Dispatch policy

The current dispatch policy in use for both segments consist of a FIFO policy (First-In-First-Out), which means that the orders are being prioritized based on their purchase time. This also implies that backlogged orders are prioritized first since their lifetime in the system is longer. Since each order can eventually translate into multiple parcels, it is important to check that the number of parcels to be handled will not exceed the max capacity that can fit in a truck. Before outlining the scheme to determine the set of orders that will be dispatched in a shift, some constraints and assumptions are defined :

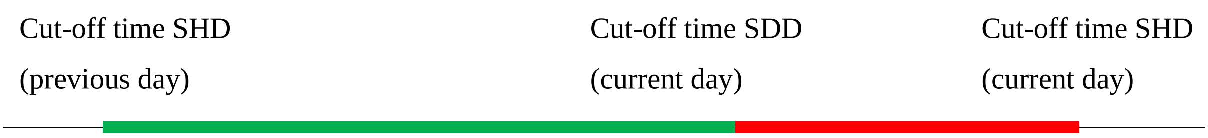
1) Orders that are backlogged cannot be delayed any further. This consideration also reflects the operational decisions occurring in the warehouse. Also, this quantity is never that high that only backlogged orders are fulfilled in a single shift.
2) In case the number of parcels in a dispatch slot exceeds the max capacity, no extra backlogs can occur due to other circumstances (information received is incomplete, mismatch between the forecasted demand and actuals, etc.). Again, this assumption is in line with the operational level as well.
3) Since the parcels boxes differ in sizes and weights, the number of products that fits on a pallet is not fixed, as well as the number of pallets in a truck, which means that a fixed capacity threshold cannot be set. Therefore, the capacity will be a random variable uniformly distributed with 1000 as lower bound and 1200 as the upper bound.

With these constraints in mind, the basic dispatch policy can now be explained. The orders assigned to a shift are retrieved and the max capacity for the shift is determined. First, a check on the backlogged orders is made and if there are any, these orders are given the highest priority. This means that all backlogged orders are correctly fulfilled and dispatched. Then orders are sorted on purchase time and until the remaining capacity is not zero, orders are accepted for dispatch. To cope with the possibility of running into backlogs due to logistics disruptions, if the truck is not fully loaded, some orders are taken out from the dispatch list and moved to next shift. The topic on the backlog probability will be reinforced in Chapter 5. In Appendix B, a detailed version of the flowchart for the basic dispatch police is provided.

It can be observed that there is no interaction between the two segments. Some episodes from the past showed indeed that when problems occurred in one shift, the other was never affected. However, with the introduction of same day delivery, this relationship is likely to change. To conclude the picture on standard home delivery, being the NL orders dispatched in the evening shift, the delivery will undoubtedly occur the day after, or even further if the order is placed during the weekend (see the allocation policy above).

4.1.2 NL case with same-day delivery

The integration of same-day delivery into the current delivery scheme requires a closer examination. The NL carrier will set a time by which the same day orders must be received in the sorting centre in Zaltbommel. However, the dispatch time still need to be determined. Since the dispatch of same-day order is likely to occur early in the afternoon, the most logical decision on the fulfilment shift falls in the morning shift. Before moving forward with this hypothesis, the warehouse management was consulted, and they confirmed that there are no barriers to process simultaneously same-day orders and the ones from the AT-FR-DE segment. In order to get a full picture for this delivery mode, different situations that may occur throughout the day will be explored, with the realization of two time-windows:



The first time-window is represented by the green line, and it is delimited by the cut-off time of standard home delivery of the previous day, and the cut-off time for the same-day delivery in the current day. If the customer purchases the order within this time frame, the product will be delivered the same day. The area in red is bounded by the cut-off times of the two delivery modes occurring in the same day. For example, when the cut-off time for SDD is set at 2 PM, and the customer orders either on Wednesday at 7PM or on Thursday at 11AM, the products will be delivered in both cases on Thursday.

If the customer purchases in the red zone, the delivery date will not change as the dispatch will occur the day after anyway. Therefore, it is not fair to charge the customer with an extra fee if the expectations are the same as with the standard home delivery. Since the warehouse is only working from Monday to Friday, the last day in a week that a same day delivery can occur is indeed Friday. In the weekend, more precisely after the cut-off on Friday for standard home delivery, customers will be offered the same-day delivery option, which means that the orders are delivered on Monday, opposed to the standard home delivery that will be delivered on Tuesday.

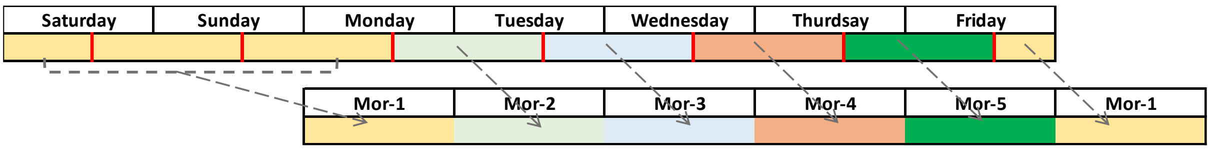


Figure 15. NL same-day delivery allocation policy.

The allocating policy for same-day delivery is very similar to the one developed for standard home delivery. However, there are two main differences. First, the orders are allocated to the morning shift, which indeed will be queued with orders from AT-DE-FR. Second, the dispatch date coincides with the delivery date (Figure 15).

In the case with solely the standard home delivery, the capacity in a shift was mainly determined by the number of parcels that can fit in a truck for the AT-DE-FR segment. With the introduction of same-day delivery, the capacity of a morning shift has two components: 1) the capacity of a standard home delivery truck, and 2) the capacity of a same-day delivery *vehicle* of NL customers. The word *vehicle* is used to highlight the fact that specifications about the vehicle for dispatch are yet to be defined, becoming a design factor in the experimental phase.

Dispatch policy

With the inclusion of same-day delivery in the morning shift, the FIFO dispatch policy does not hold anymore. According to Beerwulf and LSP partners, it seems reasonable to assume that priority will be given to same-day delivery orders, followed by orders from the AT-DE-FR segment. The backlog risk for same-day orders is only attributable to the capacity of the vehicle, which means that the warehouse cannot face situations where these orders are backlogged due to operational issues. In this regard, same-day orders that have been backlogged the previous day are processed first. These are followed by regular same-day purchases. Both categories are subjected to the capacity of the same-day vehicle. The next category to be fulfilled are backlogs from the AT-DE-FR segment, and ultimately the regular purchases.

4.1.3 UK case

Contrary to the NL case, there is a unique working shift in the UK warehouse since the number of orders flowing in throughout the day is considerably higher, improving the operational efficiency. Due to the high volumes, orders are currently dispatched four times per day with trucks all sharing the same size (roughly 1200 parcels fit in one truck). For the sake of consistency, the shift in the UK will be named *mor,* even though there is only one shift.

Monday	Tuesday	Wednesday	Thursday	Friday
mor-1	mor-2	mor-3	mor-4	mor-5

The allocation policy for the UK segment is represented in Figure 16, and it is the same as the one used for the NL segment. Here, the effect of pushing the weekend demand on Monday's shift generates even higher fluctuations in the warehouse compared to the NL one.

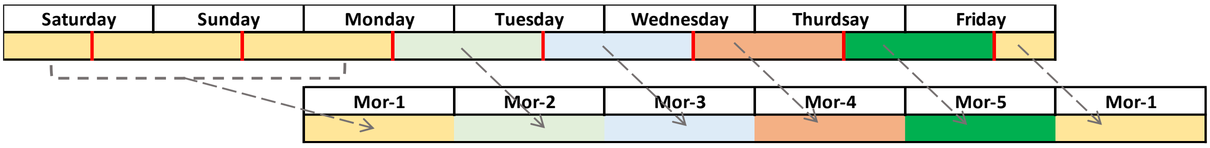


Figure 16. Allocation policy for standard home delivery in the UK.

Dispatch policy

Similar to NL, the UK warehouse follows a FIFO policy, still prioritizing orders that eventually have been backlogged the day before. On the other hand, as the orders are getting dispatched at different moments during the day, the split cannot be based solely on the cut-off time as it happens for the NL segment: an order can be dispatched if it was waved to the warehouse at least one hour before to the arrival of the truck at the warehouse. In terms of delivery time, there are no differences between orders that are dispatched in the morning or in the evening as they are all being sorted simultaneously at the carrier distribution centre. The fact that there are four dispatches throughout the day is only attributable to capacity issues and to ease the outbound schedule for the warehouse. The flowchart available in Appendix B applies to the UK as well.

4.1.4 UK case with same-day delivery

Again, the introduction of the same-day delivery in the UK can be treated similarly to the NL case. Orders subjected to same-day delivery will be prioritized first to make sure that the risk of backlogging these orders is minimized. To make sure that the resources in the warehouse are used efficiently, the orders for the same day will be fulfilled at the same time, just before the corresponding dispatch. These activities are likely to overlap with the standard orders that are being dispatched with the second truck arriving during the day. Some standard orders indeed might be moved to the third truck in case the volumes for same-day delivery are significant. Therefore, the capacity in the warehouse will be shared among the two types of orders, and it will be restricted to 1300 parcels. This assumption is based on the current configuration that allows for loading a full truck. In Figure 17, an example of the volumes distributed across the four dispatches is shown. The blue bars represent how the volumes are distributed with the current configuration. The oranges and green bars denote the standard and the same-day orders in the scenario where the two options are available. In the second dispatch, it can be noticed that the same-day orders push to the next slot a fraction of standard orders, as the first one must be shipped on time.

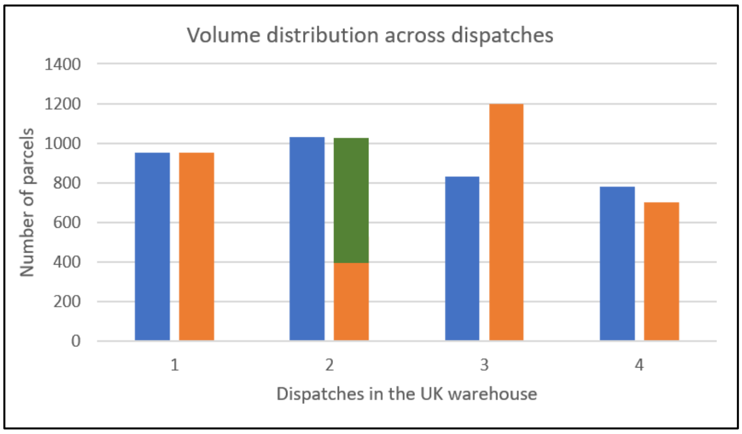


Figure 17. Comparison of volumes distribution with and without the same-day delivery.

4.2 Model inputs

In section 4.1, the theoretical models for the two case-study have been depicted. Being this simulation a time-series analysis, determining the time component of some variable is a crucial step. More specifically, two inputs are analysed: customer demand and backlog probability.

4.2.1 Customer demand

Customer demand can be considered the most relevant input for this study, meaning that if a wrong representation of customer demand is modelled, the outcomes of the simulation model cannot be used by the company, or even worse, they will result in misleading conclusions.

From a preliminary analysis conducted on customer orders, and further validated by other company colleagues through interviews, purchasing behaviour differs per weekdays and per hour. It should not come as a surprise that customers are not likely to place orders during the night, whereas marketing tools such as newsletters and promotion codes, which are sent out during the day, can boost the sales in a short time frame. As it happens for many stochastic arrival processes, the hypothesis that customer orders follow a Poisson process was formulated. However, there are some criteria that must be met:

- Events are independent of each other, which means that the occurrence of one event does not alter the probability that another event will occur.
- The average rate is constant
- Two events cannot occur at the same moment

The first two points can be considered applicable for Beerwulf customers, but the third point deserves a deeper consideration. As the order time is recorded in a timestamp format, the *arrival* of an order can be expressed in day, minutes, and seconds. Therefore, selecting the right format to express the order time, can prevent to have multiple orders flowing in at the same moment. For this reason, the time unit used to validate this hypothesis was the *second*. Here the steps that have been followed to model customer demand.

Step 1 – Data collection

To proof that the orders follow a Poisson process, i.e., that the interarrival time between two orders is exponential distributed, a large data set is required. The country and period selected for retrieving the order times are the UK, the biggest Beerwulf market, and June. The decision related to the month was that sales across weeks were quite even, and more importantly, the data set was considerably large. After a data-cleaning phase, the size of the data set resulted in 56,748 records.

Step 2 – Data processing

The second phase consists in allocating the arrival times in the right hour of the right weekday. Splitting 56,748 records into 7 (days) x 24 (hours) = 168 slots is not an activity that can be carried out manually, therefore a script was developed in Python to ease this process. After order times were filled into the right slot, interarrival times were calculated as the difference between two subsequent orders. This process has been repeated for each of the 168 hours. The final step was to fit the interarrival times into histograms and verify if they were exponentially distributed.

Step 3 – Data Analysis

One of the 168 hours was selected for the analysis. The decision on which set of interarrival time had to be analysed fell on a Monday, 10 – 11 AM. The number of bins to use was determined using the Sturges's rule, where k, the number of bins, is:

$$k = 1 + log_2(n)$$

where *n* is the sample size, resulting in k = 11. The mean μ of the interarrival times was computed and used to determine the arrival rate λ for an exponential distribution.

$$\lambda = 1/\mu$$

Using this arrival rate, the probabilities of the exponential distribution using the same intervals were retrieved and plotted against the histogram of actual records. The similarity of the two distributions is evident, showing almost a perfect match.

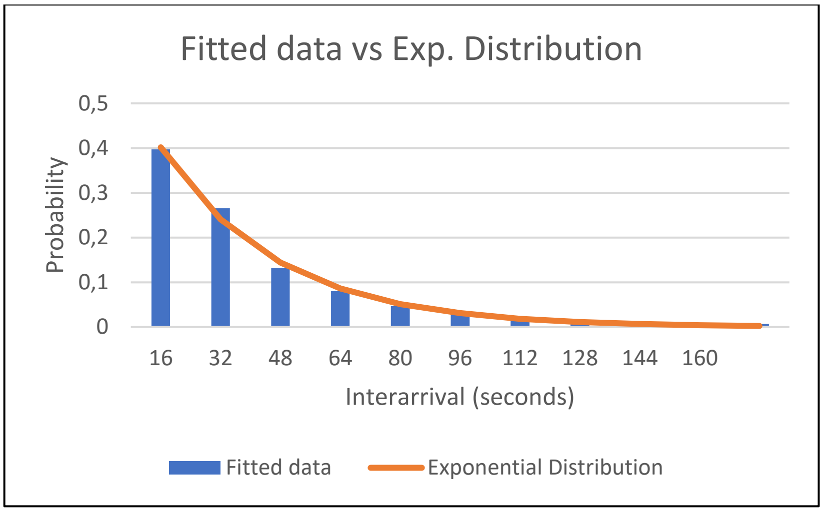


Figure 18. Fitted data plotted against a derived exponential distribution.

The hypothesis regarding the order arrival that follows a Poisson process has been proved to be valid also through a Q-Q plot. Instead of developing an order generator tool that yield interarrival times based on an hourly arrival rate, the literature has demonstrated that there are other valid procedures that provides results of the same quality. The so-called Thinning Procedure takes the number of arrivals in a fixed time period and reproduces an equal number of occurrences with an identical interarrival time. The main benefits of using this method are the followings:

1) Easy to code and fast running time
2) It allows to reuse historical data with same outputs

In view of these aspects, the thinning procedure will be used in this research to determine the customer demand.

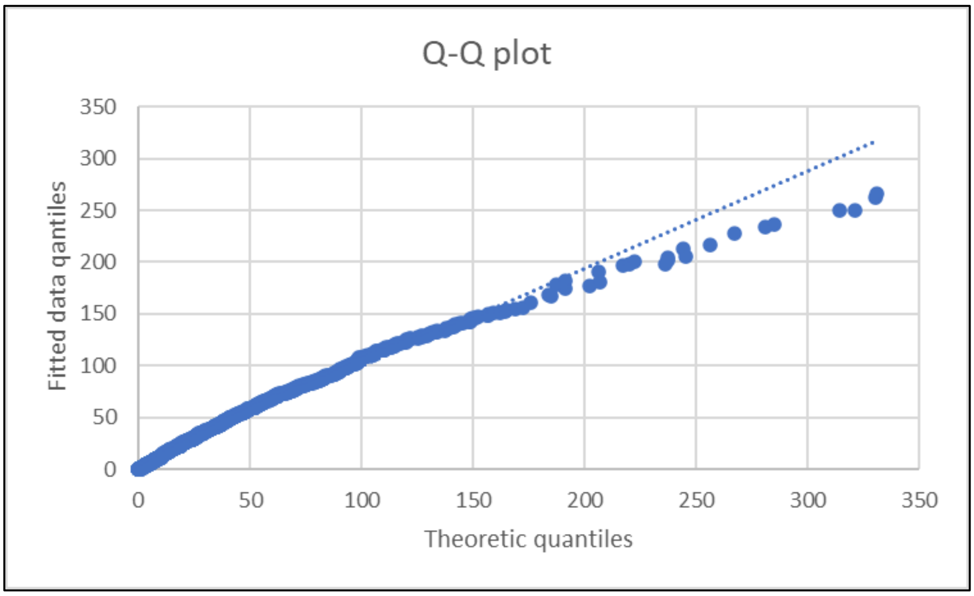


Figure 19. Q-Q plot for comparing the quantiles of the theorical and empirical distributions.

So far, the term '*orders*' has been used interchangeably with '*parcels'*, whereas there is a small difference: an order can constitutes of multiple parcels. Introducing such a feature in the generation of demand allows for a more realistic representation of real demand. The approach designed is to assign for each country a probability that an order has one, two, three, etc. parcels. Historical data on the orders were collected and processed as follows:

1) For all the involved countries, a whole number was assigned to every order in accordance with the number of parcels.
2) The records were distributed on a histogram and the probability that an order contains k parcels was calculated as

$$P(order = k\ parcels)_c = \frac{\sum \#\ of\ Orders\ (k\ parcels)_c}{\sum Total\ orders_c}$$

where c = Countries, k = 1,2,…,6.

The histogram below shows an example on how these probabilites are distributed.

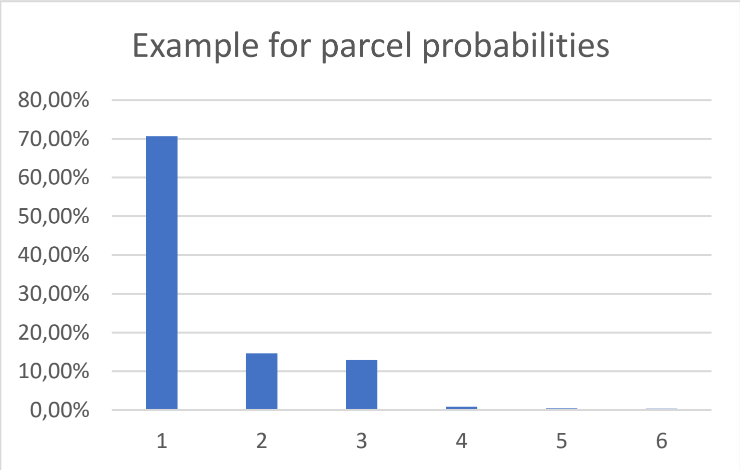


Figure 20. Probabilities of number of parcels per order.

4.2.2 Backlogs

As already mentioned in Section 4.1, if backlogs are generated, they directly influence the throughput in the warehouse and in the case that these are not emptied soon, they can compromise the productivity in the upcoming days and generate extra costs for the business.

Since the forecast of demand is used by the warehouse as input for planning the working, the initial idea was to determine the backlogs given the actual demand and the forecasted one. Developing a forecasting model is not in the scope of this project, which means that linking the backlogs to the forecast is not a recommended solution. Nevertheless, a backlog probability can be assigned to the warehouse shifts, accordingly to the scenario that is tested. For example, if in a given day there is a high mismatch between the forecast and the real demand, in the model these circumstances are reflected in a higher backlog probability. Two variables will be used to incorporate the backlog effect:

- Backlog Y/N: this probability determines if backlog will occur or not during a shift. Again, this probability does not impact if backlogs are already arising because of capacity issues.
- Backlog %: this probability decides the fraction of standard order volumes that is backlogged if the event of having backlog is realized.

The quantitative nature of the parameter will be discussed in the Design Of Experiment chapter.

Other inputs and parameters

Besides the daily demand and the generation of backlogs during the day, there are other parameters used in the model that will have an impact on the outcomes. Some of these are fixed and cannot be modified, such as the cut-off times for specific delivery modes. The remaining parameters will be analysed in more detail in Chapter 5.

4.3 Model outputs

The last step to conclude the model description consists of describing the metrics designed to assess the simulation outputs. To provide the business a better understanding of how the model evolves over time, the measures are calculated at the end of each day and summarised in descriptive statistics for each simulated scenario. For instance, knowing that the performances in a single day are low, this can be extremely relevant from the business perspective. The metrics of the three dimensions will be analysed in the following order: service level, costs, and sustainability.

4.3.1 Service Level

The role of this class is to determine the quality of service delivered to the customers. In this case it translates in measuring the percentage of orders that are being dispatched according to the first scheduled time. Each day, the service level (SL) will be measured as

$$SL = \frac{\#\ of\ orders\ dispatched\ on\ time}{\#\ of\ ordered\ expected\ to\ be\ disptatched\ on\ time}$$

The focus of this formula is on the *on-time* expression, which means that the dispatch of backlogs accumulated the previous day will not influence the dispatch rate for the current day. For instance, if the warehouse accomplishes to fulfil 800 orders, where 200 are backlogs but that day 700 new orders were scheduled, the service level will be calculated as follow:

$$SL = \frac{(800 - 200)}{700} = \frac{600}{700} = 0{,}857$$

This logic likewise applies to all the segments and type of delivery options. This KPI is only measured at the warehouse level as the performances in the carriers' distribution centres are expected to be the same.

4.3.2 Sustainability

As mentioned before, the analysis on the sustainability dimension has been restricted to the carbon footprint, more specifically on the CO2 emission. Following the guidelines of a previous work conducted at Beerwulf regarding its supply chain impact on the environment (Nieuwesteeg, 2021), the objective in this section is to define a metric that estimates the emissions generated by delivering a parcel from the warehouse to the customer location. As already mentioned earlier in this chapter, the emission calculation is applicable solely to the same-day delivery option since standard home delivery suffers from many obstacles. Since the carbon footprint is a sensitive topic within the logistic environments, collecting data directly from Beerwulf's LSPs was not a feasible option. Hence, an alternative approach was designed. First, the vehicle classes used by the LM providers were determined either through interviews or based on the documentation available in the company. Following the class categorization available in Ragon (2021), the vehicle for same-day delivery has been identified with the 5-RD (Regional Delivery) class. This step allows having an estimate on the emission rate, which is usually measured in CO2 grams per ton per kilometre. The second step was indeed to calculate the distances between any subsequent stages in the outbound process, from the warehouse to the customers. Again, these data were not available for this project, but Google Maps was used instead. Ultimately, as the emission rate is weight dependent, defining the total weight loaded onto a truck is required. To accomplish that, the average parcel weight was retrieved and discussed with the team to ensure it consisted in a valid assumption. In this way, the number of parcels loaded can be multiplied by the average weight to get the total weight. Here are the parameters used for this metric:

Parameters	Description
ER_{sdd}	Emission Rate of same-day vehicle expressed in CO2 g/ton*km
D_{ij}	Distance between two locations in the outbound
$\overline{W}$	Average weight of a parcel
W_{empty}	Vehicle curb weight (without load)
W_t	Total weight loaded on a truck
N	Number of parcels loaded
$CO2_{p,ij}$	CO2 emissions generated by a parcel between stages i,j

The total weight is calculated as:

$$W_t = W_{empty} + N * \overline{W}$$

and the grams of CO2 generated by transporting the product between two locations is

$$CO2_{ij} = W_t * ER_v * D_{i,j}$$

where on a parcel level it becomes

$$CO2_{p,ij} = \frac{(W_{empty} + N * \overline{W}) * ER_v * D_{i,j}}{N}$$

This equation basically calculates the CO2 emission per parcel considering both the distance and weight load of the truck.

A scenario where vehicles are travelling with half of their capacity will determine a higher CO_2/parcel compared to a full loaded vehicle. In reality, this conclusion is not always correct since the impact of the speed, traffic, etc. on the carbon emission are factors that must be taken into account. In this case, this implication will be disregarded from the calculations since it is not possible to access such data.

4.3.3 Costs

The last dimension to be included in the solution design involves the economic dimension. Multiple factors contribute to the costs for delivering a parcel to the customers. The costs in the warehouse for fulfilling the orders are not dependent on the delivery mode, therefore these costs will not account for the delivery costs. Regarding the AT-FR-DE segment, there are no costs to be attributed as this segment is not in the scope. For the other segments, a fraction of the costs will depend on the service level: delays in the standard home delivery are not generating extra costs since the customers will only get a discount if the delay is substantial (low occurrence); for same-day delivery, each customer who will not receive the order within the scheduled date, he/she will be reimbursed based on the extra costs paid for the delivery. To compensate for the extra costs generated by eventual reimbursement, the company is interested in exploring the possibility to charge the customers with an extra fee on the cost paid to the last-mile carrier. In the table the parameters used for the analysis.

Parameters	Descriptions
SC_{sdd}	Shipping costs paid by the customer to benefit from the same day delivery. From a different angle, this cost also expresses the refund amount offered to the customer in case the delivery date is not honoured.
N_b	Number of same-day orders that are backlogged at the end of the day
EF	Extra fee that customers pay in addition to the cost agreed with the carrier
N_d	Number of same-day orders that are dispatched on-time
C_v	Fixed cost for the vehicle used for the shipment warehouse-distribution centre
CF	Cash flow produced at the end of the day per parcel

Next to these costs, for same-day delivery there are also costs associated with shipping the orders from Beerwulf warehouse to the first carrier distribution centre. In this case, the amount paid per shipment is fixed as it mainly depends on the vehicle size. At the end of the day, all these costs combined can either generate a loss or a profit. Below the final expression for the monetary flow resulted from the same-day option.

$$CF = \frac{C_v + EF * N_d - SC_{sdd} * N_b}{N_d + N_b}$$

4.4 Simulation model

The final step to conclude the model definition is to present the simulation model. For the sake of completeness, the description of the simulation model covers all the steps necessary for performing a full experiment. In Figure 21, a diagram of the processes in the simulation model is given. The simulation of an experiment starts off with retrieving the configurations that are intended to be tested. The model checks if the number of requested runs is reached (Criteria 1). If so, the simulation terminates and new experimental configurations are computed. If not, then the simulation proceeds and the virtual structures of the warehouse's shifts are initiated. If the number of simulated days exceeds the run length (Criteria 2), the simulation of a new day does not occur and a new run will be performed. In case the threshold is not reached, the actual simulation takes place. Two parallel flows are created: one for the current configuration and one with the addition of the same-day delivery. Customer demand is generated for the whole day and orders are assigned to the shifts according to the allocation policies. After the orders have been distributed to the warehouse's shifts, the model checks if it is a working day (Criteria 3). In case the warehouse is closed, no dispatch can occur, therefore the system moves to the next day. On the contrary, when the warehouse is open, the orders are sorted and shipped based on the dispatch policies. A last check determines if orders are still in the queue and have not been dispatched (Criteria 4). In case of backlogs, the delayed orders are assigned to the next available shift. If all the scheduled orders have been successfully dispatched, the queues are emptied of all orders. For both circumstances, the perfomances on the three levels are calcuated and eventually a new day can be simulated.

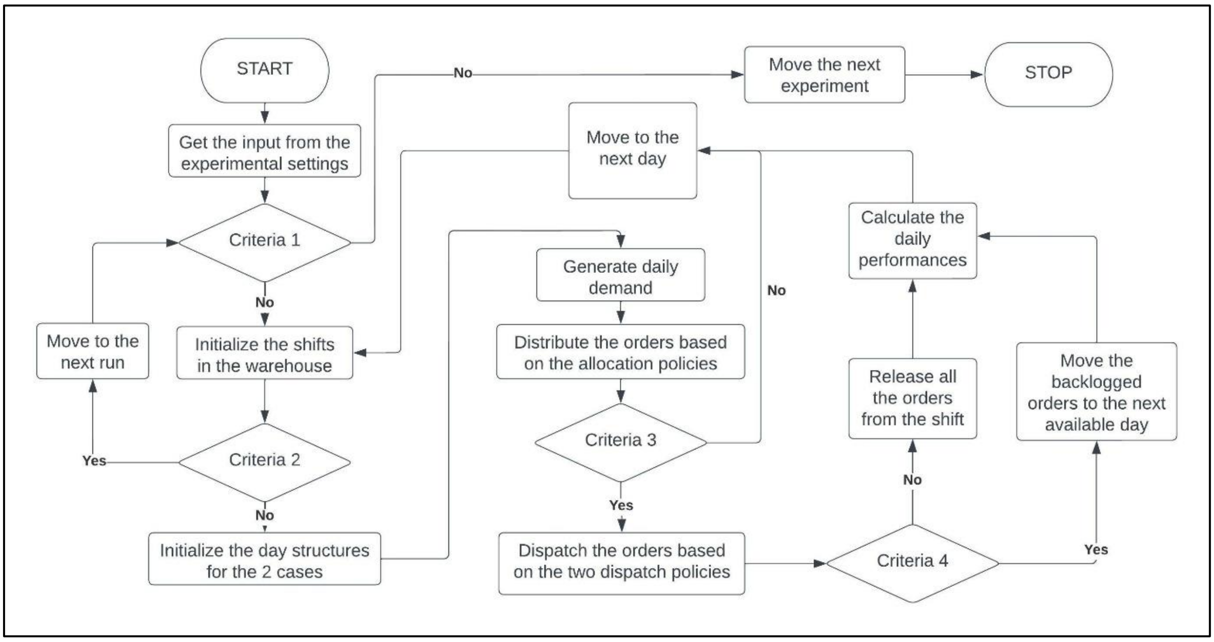


Figure 21. Simulation model for performing a single experiment.

4.5 Validation and Verification

To prevent inconsistent outputs, the model was validated and verified along the coding stage. To accomplish that, the code was divided into modules and tested in sequence. The first step was to make sure that the orders generated in a day where first distributed according to the allocation policy, then dispatched based on the rules of the dispatch policy, and ultimately translated into the model outputs. The major obstacle encountered during the coding process was the allocation of orders to the right shift, especially in the NL warehouse where there were three different demands (two related to the standard home delivery and one from the same-day delivery) and two working shifts. Feedback provided during the validation meeting were recorded in a log file. This document was not used only for this project, but also to disclose interesting points worth of discussion with future partners.

4.6 Conclusion

The fourth chapter focused on the key aspects required for developing a robust simulation framework where the integration of same-day delivery could be investigated. The research question assigned to this chapter is:

'*How to design a simulation model representative of Beerwulf's distribution network for both cities?*'

In the first part of the chapter, the current logistic setup for both cities are examined. The process of how orders are received in the warehouses and assigned to different shifts is mapped, as well as the dispatch policies adopted for shipping the orders. Then, the two new configurations embedding the same-day delivery option in both segments are proposed, and the main differences are discussed. Since the order generation process and the occurrence of backlogs are key inputs for this study, a separate section is dedicated to them. Since Beerwulf does not offer a set of metrics applicable to the purpose of this research, new measures are developed, with the contribution of the literature resources reviewed in the third chapter. The parameters involved in the equations for determining the model performances are briefly touched in this chapter, as they will be presented more extensively in the next chapter. The last part of the chapter consists of merging all the proposed steps into a simulation model, the foundation for coding the computer model and proceed with the experimental phase.

5 Design Of Experiment (DOE)

The previous chapter has introduced the simulation model to test the implementation of a new delivery mode. The next step is to show the structure of the experiments and determine the requirements for the validity of the results. In Section 5.1, the parameters utilized to define the experiments are listed, including eventual relationships among them. As anticipated in Chapter 4, customer demand and backlogs are core inputs for this study. Therefore, a more quantitative description for the two parameters is provided in Section 5.2. To ensure the quality of the simulation, the parameters typical of a simulation such as the warmup length, the number of replications, and the process to determine them are defined in Section 5.3. The last part of the chapter is dedicated to the characterization of the experiments, elaborating on the different approaches taken based on the segments.

5.1 Parameters definition

The first activity in the DOE process was presenting the parameters to the stakeholders in the organization in order to make them familiarize with the context. The goal of these meetings was to align on the parameters developed in the conceptual model and spot any gaps that could have compromised the flexibility requested in the experimental phase. The reader may argue that this step should have taken place before the implementation on the coding environment. However, some additions were made along with the coding as pilot runs already revealed a narrow margin for testing different scenarios. Indeed, two sessions were planned with the team where the parameters were examined and implemented accordingly. In the table below the parameters used in the simulation are listed.

Table 3. Parameters used to define the experimental settings.

Parameters	Description
$\boldsymbol{CapMax_{std}}$	This parameter represents the maximum number of parcels that the warehouse is capable to process in one shift. This capacity is sized on the vehicle capacity designated for the pickup of standard delivery orders. This parameter is measured in parcels.
$\boldsymbol{Cap_{sdd}}$	The vehicle capacity that will be used for dispatching same day orders. Contrary to the previous parameter, this value does not influence the warehouse capacity and it only restricts the number of parcels that can fit in the same-day vehicle.
$\boldsymbol{BL_{Y/N}}$	The probability of backlogging standard orders at the end of the day. Example: $BL_{Y/N} = 20\%$, the warehouse records backlogs once every 5 working days.
$\boldsymbol{BL_{\%}}$	If backlogs are occurring because of the $BL_{Y/N}$, the $BL_{\%}$ determines the fraction of orders scheduled in a shift that will be backlogged. This probability is only applicable to the standard orders as the same day orders are only constrained by the vehicle capacity.

COT_{sdd}	The cut-off time until when the customers can opt for the same-day delivery option. This parameter is measured in hours.
W_{empty}	The weight of an empty truck used for shipping same-day orders from the warehouse to the distribution centre of the last mile carrier. This factor is measured in kilograms.
C_v	The cost to arrange a shipment for the same day order truck, calculated in euros. This parameter is the same as the one used in the calculation for the cash flow KPI.
ER_{sdd}	The CO2 emissions generated by the truck used for same day delivery, expressed in g CO2/km*t.
DS_{sdd}	The likelihood that the customer will select the same day as a delivery option, calculated in percentage over the daily volumes.
SC_{sdd}	The shipping cost that the customer will pay extra for selecting the same day delivery option, measured in euros. This parameter can also be referred as reimbursement/refund costs, depending on the context.
EF	The extra fee that the customer is charged on top of the last mile delivery cost agreed with the LM carrier to ship the goods from its distribution centre to the customer location.
Day	The first day from which the experiment will start. This is expressed in a dd/mm/yyyy format.
$\overline{W}$	Average parcel weight.

The first task consisted in identifying potential relationships between the parameters to prevent designing scenarios not likely to occur in the real life. The proposition of same-day delivery is founded on the attractiveness perceived by the customer. With the current delivery offer, the customer does not have to pay for the delivery since it is already included in the product price. Therefore, to make the customer opting for premium delivery, the benefit must be tangible. From the table above, four parameters have been detected being correlated with each other: 1) cut-off time SDD (COT_{sdd}), 2) shipping cost (SC_{sdd}), 3) extra fee (EF), and 4) SDD prob (DS_{sdd}). The same-day option is already attractive itself but it also trades-off with the costs that the customer must pay for the premium service. All these considerations lead to the following logic: "the lower the price of the same-day delivery, together with a longer time window for selecting this option (determined by the cut-off time), the higher the chances that the premium option is selected". After an internal brainstorming session, it has been agreed to develop two scenarios for this group of parameters, namely an *attractive* and *non-attractive* offer. The reason for taking two opposite scenarios is to shape the boundaries where the real-life proposal is likely to lie. In the table below, an example of the values selected for the two scenarios in the UK is given. The directions and colours of the arrows in each cell represent the relative benefit for the customer. It can be argued that the second proposition is profit-driven, as the extra fee paid by the customer could eventually generate profit for the business. However, supplementary costs are expected to arise throughout the implementation or concretely, to pay back the customers when the order will not be delivered according to the planned date.

Table 4. Example of the values simulated in the UK for (non-) attractive propositions.

Offers	SDD cut-off	Reimbursement cost	Extra fee	SDD probability
Attractive	14.00h ↑	5 € ↓	1 €	20% ↑
Non-Attractive	11.00h ↓	7 € ↑	3 €	5% ↓

Both vehicles' capacities were set to a fixed number of parcels per truck. With respect to the truck for the standard order segment, its capacity is not likely to change in the future as this parameter was agreed in the contract with the supplier. For the same day truck, the decision of having a fixed capacity was partially driven by the limited offer of vehicles available with the current supplier, together with the fact that again this capacity is decided upon in contractual terms. This choice constraints also the following parameters as they all depend on the type of truck: empty truck weight (W_{empty}), the truck costs (C_v), and the CO2 emissions (E_{sdd}).

A parameter that was extensively discussed was the probability of having backlogs in a shift, the $BL_{Y/N}$ probability. Data related to this parameter were not available on a daily level, but only weekly. Translating the performance from a week to a day level implies equal probabilities of queuing backlogs in the warehouse across weekdays. Warehouse's workers suggested a different approach for modelling the $BL_{Y/N}$. Mondays usually have a higher probability of incurring into backlogs, whereas on Fridays backlogs are almost never occurring. This behaviour is explained by the forecast performance since Monday volume prediction covers almost three days of demand. In view of these consideration, the $BL_{Y/N}$ has been modelled as

$$BL_{Y/N} = \frac{p}{x}$$

where *p* is a fixed probability and *x* is a whole number that represent the weekdays, with Monday = 1 and Friday = 5. Below in Figure 22, an example of the $BL_{Y/N}$ distribution with p = 0.2.

Two situations have been proposed for this parameter:

1) $BL_{Y/N\ low,}$ where the likelihood of having backlogs determined by unpredictable circumstances is considerably low.
2) $BL_{Y/N\ medium,}$ where planning and operational issues are happening more often.

The two values have been determined based on the personal experience of the people involved in the design sessions. The first case is typical of either low volumes in the warehouses or good forecasting performances from Beerwulf side. The latter can be associated with unpredictable peaks in customer demand or problems at the warehouse level. Especially during the COVID-19 pandemic, this has turned into a sensitive parameter when people who were scheduled in a shift were calling themselves sick.

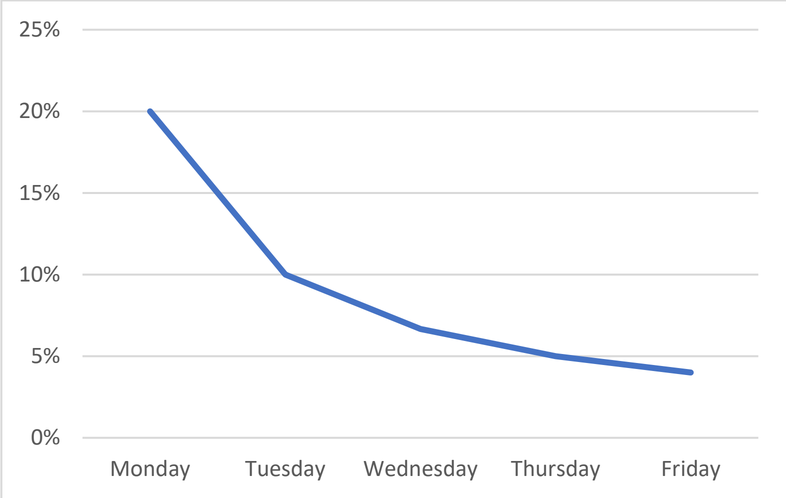


Figure 22. Probability mass function of the backlog probability variable.

Looking at the $BL_{\%vol}$, this quantity was set to a fixed number, as again data on a daily level were not available. However, it was noticed that the fraction of orders that is backlogged in a day does not fluctuate significantly so it would not make sense to create a day-dependent distribution for this parameter. Ultimately, the customer demand was investigated. As many other e-commerce businesses, Beerwulf is also subjected to seasonal demand. It is common knowledge that during peak periods, LSPs have a tendency to score lower performances, usually compromising the success of a delivery. Therefore, it becomes crucial to assess the performances of same-day delivery in a low and a high demand period. As the demand generation process is based on historical data, the $\boldsymbol{Day}$ parameter is used to identifies the day from which the experiment will start.

5.2 Verification of Parameters

This section covers the parameters' verification to check if the model implemented in the coding environment reflects the conceptual model. Also, some of the parameters were tuned to reflect realistic performances of the model. For those factors, the tuning procedure is provided.

Order arrival process

As already shown in Chapter 4, the customer demand can be described by a Poisson process. As the source of data is based on the purchasing dates and not on the actual dispatching dates, we assume that customers are always purchasing the product for the earliest available date. In this regard, a comparison between the actuals dispatched orders and the model outputs was performed. The average absolute deviation registered was 10%, an acceptable distortion that also reflects possible demand fluctuations. This finding also confirms the customers purchasing behaviour, where in most of the cases they place an order for the earliest available date. This result was presented to a broader audience and approved. In Figure 22, a comparison between the model output and the actuals volumes dispatched in the UK warehouse is shown.

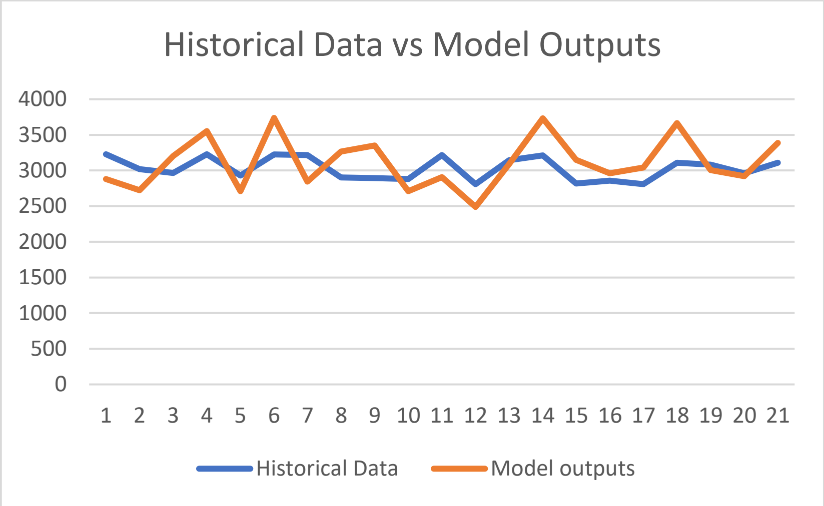


Figure 23. Comparison between actuals volumes dispatched and the ones from the model of the UK case.

5.3 Warm-up period, Run Length and Replications

Warm-up period

When the simulation starts, there are no orders in the system, which means that there are fewer chances to run into backlogs in the first days of the experiment. The queues are gradually starting to be filled with new orders and the system reaches a status from which the performances are valid. In this regard a warm-up period must be determined and to accomplish that, some pilot runs are performed based on realistic scenarios. All three metrics were analysed for this part. The simulations are performed on the UK model for 3 weeks, starting with a Monday (the fact that the x-axis only reflect 19 days is because Saturdays and Sundays are not included as the warehouse is closed on these days).

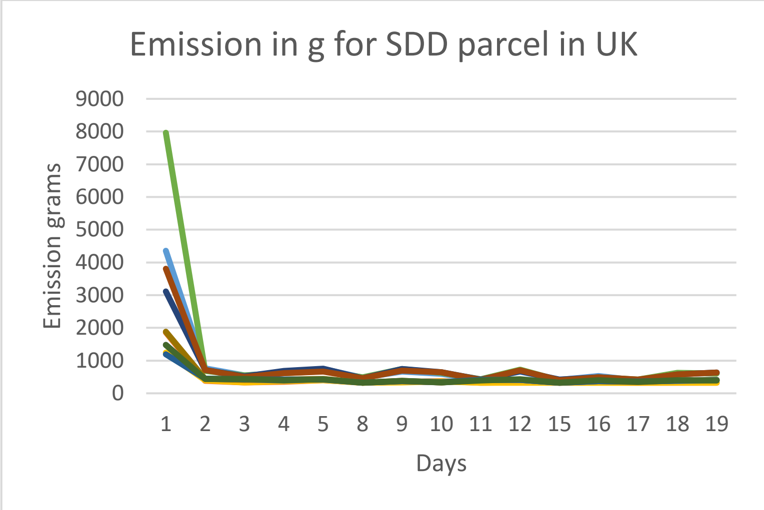


Figure 24. Emissions performances of different scenarios for the UK case.

For the emissions per parcel, it can be noticed that the first two days are showing higher values compared to the other days. This is the result of having a little amount of SDD orders when the simulation starts. From this perspective it could be reasonable to take two days as a warmup period. At the same time, analysing the behaviour of the dispatch rate for SDD, it is visible that in the first 5 days the profiles of different scenarios are overlapping. This is again attributable to a low number of orders shipped in the first week. Similar behaviour is reflected in the SDD shipment costs. The collected information determines a warm-up period of 5 days, being the minimum number of days to ensure that the three KPIs are representative of the system performances. On the experimental level it translates into anticipating by one week the staring day of the simulation to make sure to have the processes already busy with some orders. At the same time, the daily performances will be measured from day 6 onwards, which is the second Monday encountered during the simulation.

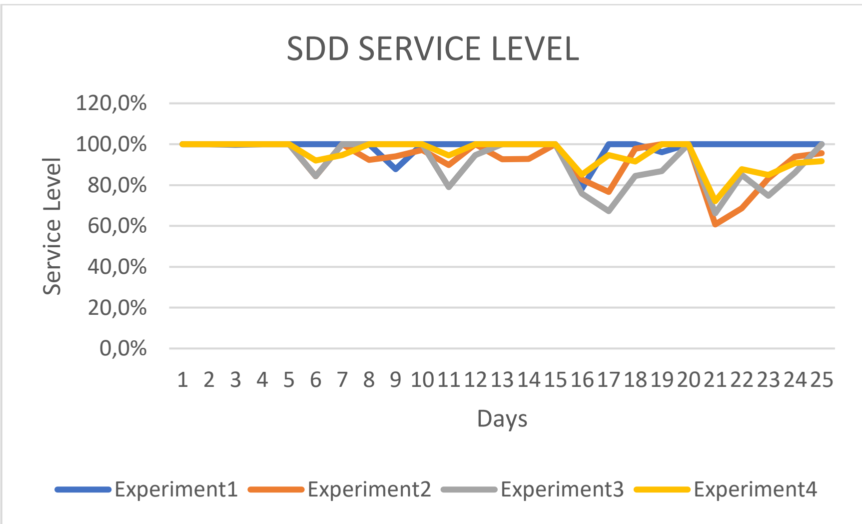


Figure 25. Service level evolution for SDD in the UK case.

Run Length

Another important aspect in the simulation environment is connected to the run length, which establishes in this case the number of days for which each scenario will be simulated. This parameter is linked to the steady state of the system but in this case the goal is to target periods of the year and measure the performances obtained. In light of the decision regarding the warmup period, it was agreed with the company to assess the results in a period of at most 4 weeks, since in the e-commerce sector, peak periods are usually shrunken in a time window of at most one week. This happens because of marketing strategies, where the deals are only available for a short period and the customer feels pressured to buy the products.

To conclude, considering both the warmup time and the 4 weeks required for the assessment, each scenario will be tested on a period of 5 weeks, where the performances will be recorded only from the second week onwards.

Replications

For the number of replications, the approach described in Law's book (2014) was followed. First, a realistic scenario was set, and 16 replications were generated recording the perfomances of each run. A confidence interval was build for each of the three KPIs with the progresion of the runs. Being α the level of significance of the confidence interval, the minimum number of replications required must satisfy $\xi < \gamma^{I}$, where

$$\xi = \frac{t_{n-1,1-\alpha/2} * \sqrt{S^2/n}}{\bar{X}} \qquad \gamma' = \frac{\alpha}{1+\alpha}$$

In Appendix C, a detailed overview on the results is provided. For the service level SL and the E_{sdd} , the condition was already satisfied after the second replication. However, the targeted error for the CF was only achieved after 6 runs, determining consequently the number of replication for each simulated scenario.

5.4 Experimental settings

In Section 5.1, the parameters used as input for the simulation have been described. The final step before proceeding with the simulation is to give them also a quantitative nature. Below, the parameter values are provided, followed by a short description. In Appendix D, all the settings of the simulated scenarios can be found summarized in a table. For now, the variables will be discussed per market.

UK

$CapMax_{std}$. For this parameter, the value depends on which period the scenario is tested. In case of a low demand period, this value is by default 1200 parcels, meaning that with the four shifts available per day at the UK warehouse, 4800 parcels can be dispatched at most in a single day. In case the scenario is tested on a high demand period, this parameter is set to 1300 parcels, capping the daily capacity up to 5200 parcels.

Cap_{sdd}. The capacity for the same day delivery truck was a combination of company requirements and carrier fleet availability. It was agreed that at most 500 parcels could be dispatched every day from the UK warehouse. All the decisions regarding the SDD truck are not subjected to a different demand period as arranging different trucks sizes is not feasible.

C_v. The price paid per day for the SDD transportation comes along with the decision about the capacity. In this case, the price was set to 500€ per shipment. This cost embodies both the distance to travel from the BW warehouse to the carrier distribution centre near London, and the loading/unloading costs.

ER_{sdd}. This value follows the specifications set for the same-day vehicle, resulting in a rate of 85,3 CO2g/km*ton.

W_{empty}. The information regarding the weight of the SDD truck was retrieved from the same document used to determine the emission rate and it is expressed in kilograms. For the UK this value was set to 3100 kg.

$BL_{Y/N}$. The probability that in a day some standard orders will be backlogged was determined through the identification of possible causes for backlogs. In the worst-case scenario, this probability can be up to 20%, as a combination of forecast errors on BW side and issues occurring in the warehouse. This percentage is reduced to 5% when the risk of incurring into backlogs is minimum. Setting a 0% risk is not realistic as backlogs can always occur. Once more, this probability is day dependent, thus these probabilities refer to Mondays.

$BL_{\%vol}$. The percentage of the volumes backlogged in a day for the standard orders that are not subjected to the max capacity was set to 10%. For this parameter, the volumes backlogged on a weekly level were compared to the weekly demand, resulting indeed in a 10%.

SDD Attractiveness. The remaining four parameters will be treated jointly as they are related with each other's. One set of these parameters consists of the cut-off time for the same-day delivery option (COT_{sdd}) and the percentage of customers that will opt for same day delivery (DS_{sdd}). The reason why the two parameters are correlated is connected to the maturity of the SDD implementation. In the initial stage, the business does not expect that many customers will select this option since an additional fee could potentially discourage the customer. In a more mature stage, the business assumes that more customers will be attracted by the SDD proposition and therefore the volumes will increase. For the UK case, the values of these two cases are shown in the table below.

	Cut-off time $_{sdd}$	*SDD selection*
1	11.00 h	5%
2	14.00 h	20%

The other set of parameters includes both the SDD shipment costs (SC_{sdd}) and the extra fee added to the shipping cost as a potential revenue for the business (EX). The 3 combinations of these parameters are provided in the table below.

	Shipping Cost$_{sdd}$	**Extra Fee**
1	4€	0€
2	6€	2€
3	7€	3€

NL

$CapMax_{std}$. For the Dutch warehouse, this parameter translates into two values, one for the NL segment and one for the AT-FR-DE segment. However, tracing back the historical logistics decisions on the period where the model is tested, it was seen that an extra carrier collection was arranged for both segments, resulting for this case in at most 2400 parcels per day, whereas for the other period the standard value was used, 1200 parcels per segment. These logistics decisions are reflected in the simulation as well: 2400 parcels for the high demand scenarios and 1200 for the low/medium scenarios.

$Cap_{sdd.}$ As the NL market is not as big as the UK one, the capacity for the SDD vehicle was set to 120 parcels. Similarly was with the UK model, this parameter does not change across the simulated scenarios.

C_v. The transportation cost for the SDD shipment follows the decision on the above one, being 190€ per shipment. Like the UK model, this cost takes into account the distance to be travelled to the carrier distribution centre and the loading/unloading costs.

ER_{sdd}. The emission rate for the NL same day delivery truck is retrieved from the European Transport Emission report mentioned before, resulting in 75,5 CO2g/km*ton.

W_{empty}. As the capacity is lower for the NL case, also the vehicle is lighter. For this parameter, the value is set to 1500 kilograms.

$BL_{Y/N}$. With respect to NL warehouse performances, the same process was followed as the one for the UK. The only difference is that in this case there are two shifts, which eventually could not be correlated with each other. Insights from the warehouse showed that the likelihood is the same for the two

segments but that does not mean that if in the morning backlogs are registered, the same will happen in the evening. The two values calculated are 5% and 15%.

$BL_{\%vol}$. The percentage of volumes backlogged is different per segment. For the NL market, this number was set to 10%, whereas for the AT-FR-DE market it is set to 15%. It was noticed that this discrepancy is attributable to the forecast performances as forecasting the daily volumes for a single market is less complicated than predicting orders for 3 markets.

SDD Attractiveness. The logic behind the cut-off time for same day delivery selection is similar to the UK model. The only exception is that the highest percentage of the SDD selection is reduced to 15% as the fraction of customers who were interested in this proposition is slightly lower compared to UK customers. The values are showed in the table below.

	Cut-off time $_{sdd}$	***SDD selection***
1	11.00 h	5%
2	14.00 h	15%

Regarding the other two parameters, the decision about shipping costs and extra fee is the same since the three options are already covering extreme scenarios. Exploring circumstances where the company asks its customers a higher fee or, worse, compensate the shipping fee at its own expenses, would have not yielded useful insights to the business. Below the three scenarios for this set of parameters are given.

	Shipping Cost$_{sdd}$	**Extra Fee**
1	4€	0€
2	6€	2€
3	7€	3€

Before moving to the next chapter with the results' analysis, some remarks on the combinations examined will help the reader to understand how the scenarios were generated. Making use of a full factorial design is not recommend for the purpose of this project as not all the combinations are realistic or feasible. Next, evaluating a full range of values for the extra fee, the cut-off time, intermediate points for the SDD delivery selection, etc. would only result in an increase in the number of experiments without provided a lot of extra value to the research. For instance, simulating that the fraction of customers opting for the SDD proposition is 10%, could be extrapolated as an intermediate solution from the experiments with 5% and 20%.

So far, the demand periods were referred to as either *high demand* or *low/medium demand* periods. The high demand period for the UK started the 31st of May 2021 and ended the 5th of July 2021. During this period, the UEFA Euro 2020 was taking place, seeing the England national football team advancing in the competition until the finals. This success was driving up the demand for Beerwulf. This effect was not registered in The Netherlands as their team was eliminated in an earlier stage. For the Dutch model, the peak period was identified between the 1st of November 2021 and the 6th of December 2021. During this period, the country celebrated *Sinterklaas*, one of the most important holidays in the Dutch heritage. Next to that, two more recent holidays were celebrated in the same period, *Black Friday* and *Cyber Monday*. During this period, Beerwulf has offered special deals to their customers increasing the demand and the pressure on the logistic network. The low/medium period has been defined with the same range for both models. The start date is set to 13th of September 2021, and the end date to the 18th of October 2021. Usually, the customer behaviour after the summer period changes a lot, as beer is very much perceived as a "*summer treat*".

In Appendix D, all the simulated scenarios are provided in two distinct tables based on the case.

5.5 Conclusions

Chapter 5 has presented the experimental setup designed for this work. The goals of this chapter were: 1) identify the model requirements to guarantee the validity of the simulation outcomes 2) shape and translate the consumer behaviour into quantitative ingredients to feed the simulation model. Since the same-day delivery is not yet available for Beerwulf's customers, it was not possible to determine the customer attitude with respect to this delivery mode. Therefore, data collected from the customer survey about the delivery modes were used instead. Replicate the exact volumes dispatched in the warehouse was not feasible as the customers do not always request the delivery for the day after. After verifying the distribution of customers ordering *k-day* in advance, it was concluded that the volumes of orders determined through the model were similar to the real-world figures. With respect to the backlogs, information on a daily level were not found. However, conversations with the warehouse revealed that there is a correlation between backlogs and weekdays, therefore the generation of backlogs was modelled accordingly.

6 Results

In this chapter, the results from the simulated scenarios are analysed. First, technical details of the machine used to perform the simulation are provided in Section 6.1. Next, a dashboard designed to assess all the relevant metrics of the simulated experiments is presented in Section 6.2, concluding the introduction part of this chapter. In Section 6.3, the experimental results for each of the analysed markets are discussed.

6.1 Computation method

The simulation model was implemented on Python, using Anaconda platform. All the experiments were conducted on a PC with an Intel Core i7-9750H processor, 16 Gigabyte RAM memory and Windows 11 64-bit installed. No restrictions were set on the computational time as each run was completed in 3 minutes and 33 seconds on average. On an aggregated level, all the experiments linked to a single market were performed in 5 hours and 45 minutes on average. The results of each experiment were stored in an Excel file, 2021 Version.

6.2 Analysis tool

In order to simplify the analysis process, an Excel dashboard was developed allowing to individually inspect the experiments and compare the performances across experiments. The dashboard was therefore divided into two sections. In Figure 26, the first part of the dashboard is displayed. In quadrant 1 (top left corner), the experiment number to be inspected is shown, generating a set of charts and statistics outputs for the KPIs identified in Chapter 4. The following charts were part of the dashboard: dispatch rate for standard orders [1], dispatch rate for same-day delivery [2], the cash flow per same day order dispatched [3], the emission per parcel dispatched [4] and the volumes of same-day orders [5]. All these charts show how the system evolves over time.

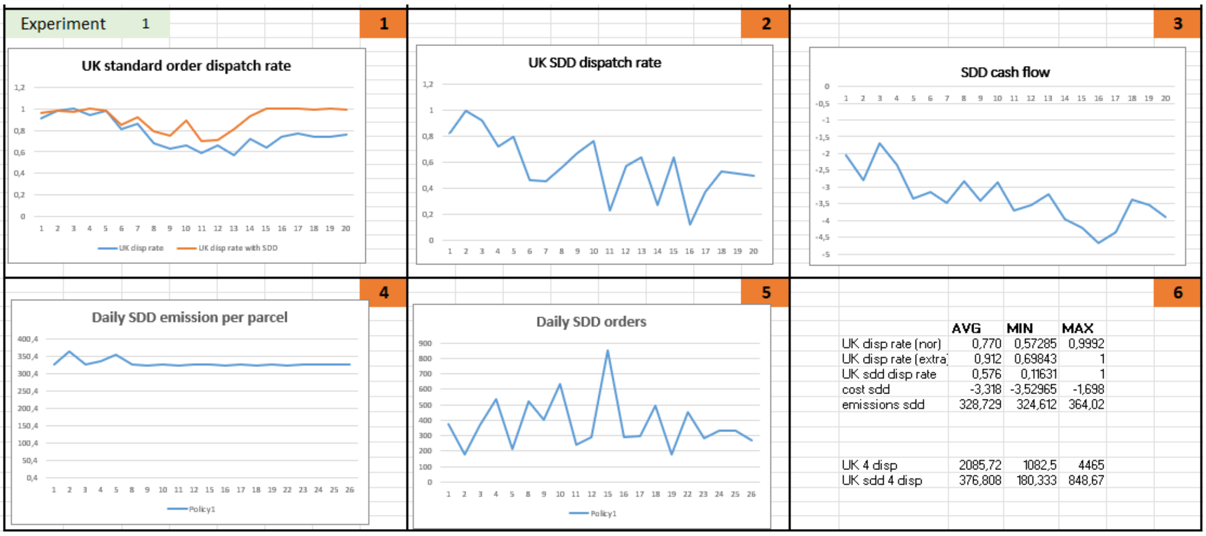


Figure 26. Dashboard for the analysis - Section 1.

The second section of the analysis dashboard was built to compare different scenario settings and eventually disclose performance patterns. The three charts display the performances of the SDD dispatch rate, the daily cash flow for SDD orders and daily emissions per SDD order dispatched. This section revealed to be useful throughout the DOE phase since it contributed to limiting the selection range for some parameters' values where infeasible areas were detected. In Appendix E, a picture of this dashboard section is displayed.

6.3 Result analysis

6.3.1 UK

The approach selected to analyse and describe the results from the simulation was to cluster the scenarios based on the performances obtained. The first dimension discussed is the service level, followed by the sustainability and financial ones.

Service Level

Group 1 – Low performances [1,2,3,4,7]

Average SL: 59.9%

In this group, the behaviour of the dispatch rate is very homogeneous, meaning that a drop was already recorded on the third day. These five scenarios were all tested in a high demand period. The dispatch rate keeps devolving with visible high fluctuations (Figure 27). In this case it can be stated that despite changes in the BL Y/N probability (from 5% to 20%), there is not much of an impact. Rather, the SDD probability and longer cut-off time play a major role, causing high volumes not to be shipped and resultingly backlogged. However, this also impacts the standard order operations, as the registered dispatch rate for these orders is slightly higher in case of SDD orders. This happens because SDD orders are balancing out the volumes that otherwise would fall under the standard orders operations. It can be seen that a steady status is not reached after 4 weeks. However, determining at which point the service level is recovering would not provide extra insights as this scenario is already concerning.

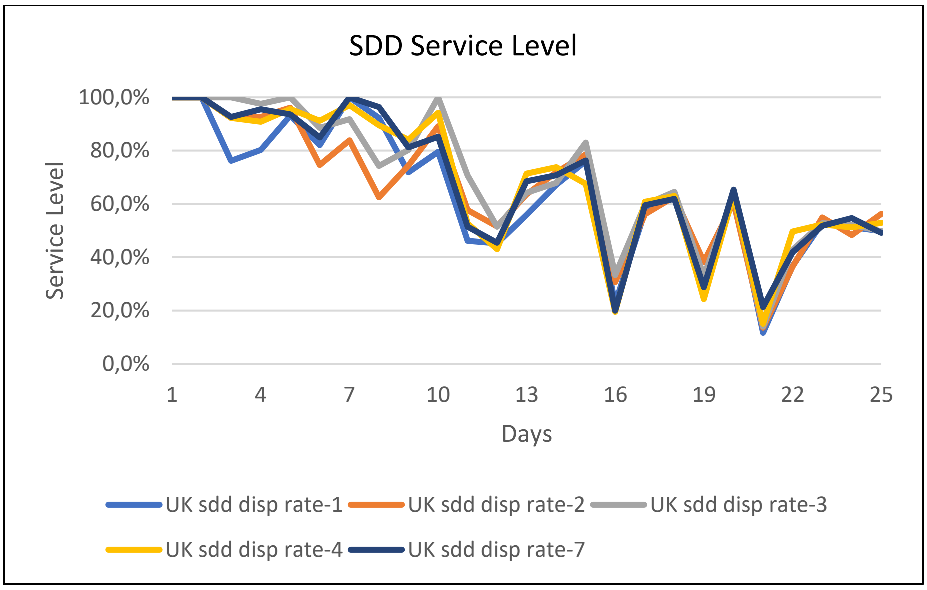


Figure 27. SDD dispatch rate for Group 1.

Group 2 – Very good performances [6,9,10,11,12,15]

Average SL: 93.0%

In this class, except for scenario 6, all the others belong to a low demand period (Figure 28). It can be noted that on day 16 (Monday), the performances are slightly dropping, suggesting that orders accumulated during the weekend could not be dispatched on time. The fact that scenario 6 has equal performances as the others is mainly driven by the low attractiveness of the same-day proposition for the customers (shorter cut-off and a lower SDD probability), whereas for the others, the SDD is more appealing to the customers.

For scenario 6, the relationship between the two delivery modes in the dispatch rate for standard orders is quite surprising (Figure 29). When the two delivery offers are available (orange line), the dispatch rate for standard orders is performing worse compared to when only one delivery option is available. Despite a share of the standard orders being shifted to the SDD option, the volume of standard orders to be processed is still largely affected by the SDD operations. Towards the end of the simulation, the case with two delivery options overtakes the performances of the current configuration as the volumes are smoothly diminishing.

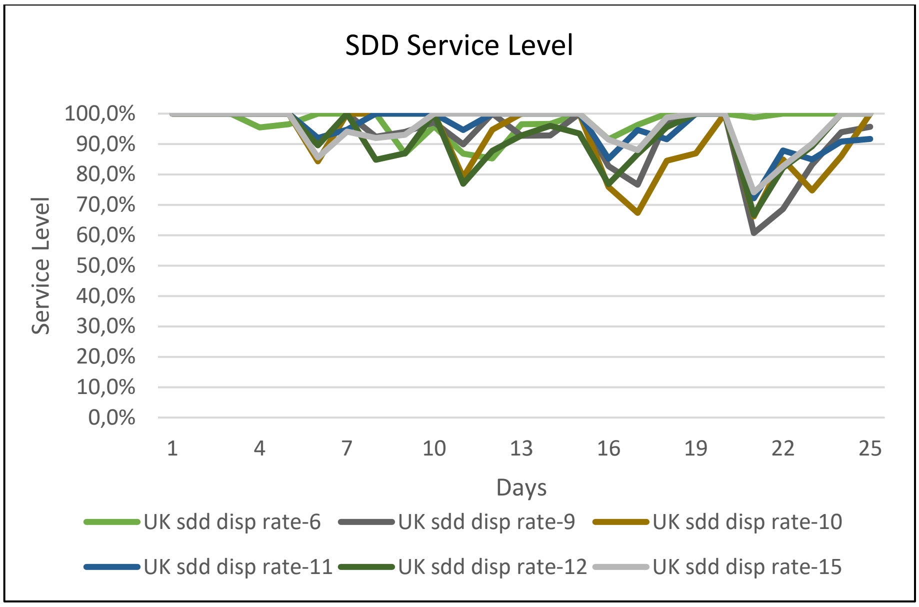


Figure 28. SDD dispatch rate for Group 2.

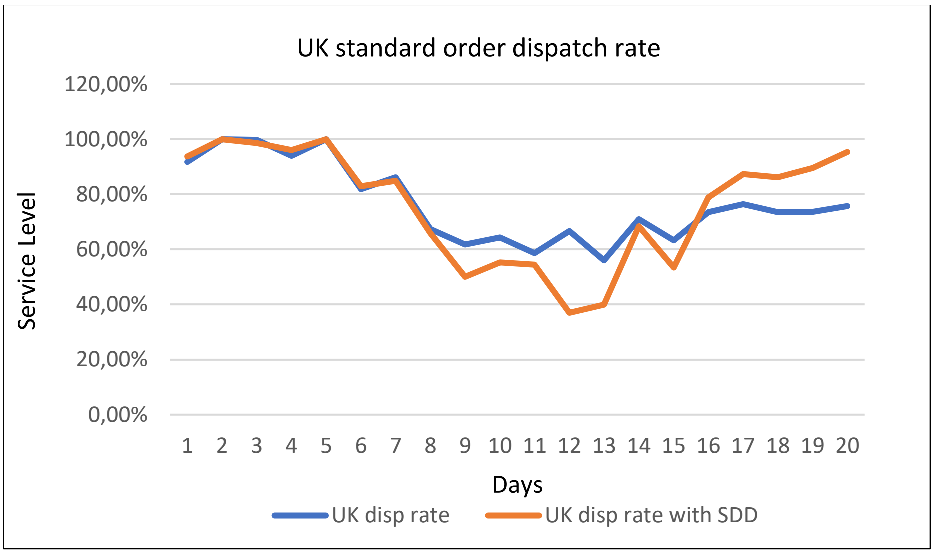


Figure 29. Performances on the standard order segment with and without the SDD.

Group 3 – Outstanding performances [5,8,13,14,16]

Average SL: 97.3%

The results for this class outperform the others, reaching a maximum of 99,9% in some cases (Figure 30). Despite 5 and 8 are scenario investigated on a high demand period, the low volumes observed for SDD explains the high performances, which again are stimulated by a low SDD prob and a shorter cut-off time. In other words, the attractiveness of the same-day proposition is low, determining low volumes and high service level. In the other scenarios, being already in a low demand period, the influence of the attractiveness of SDD is minimal. The same applies to the standard orders performances.

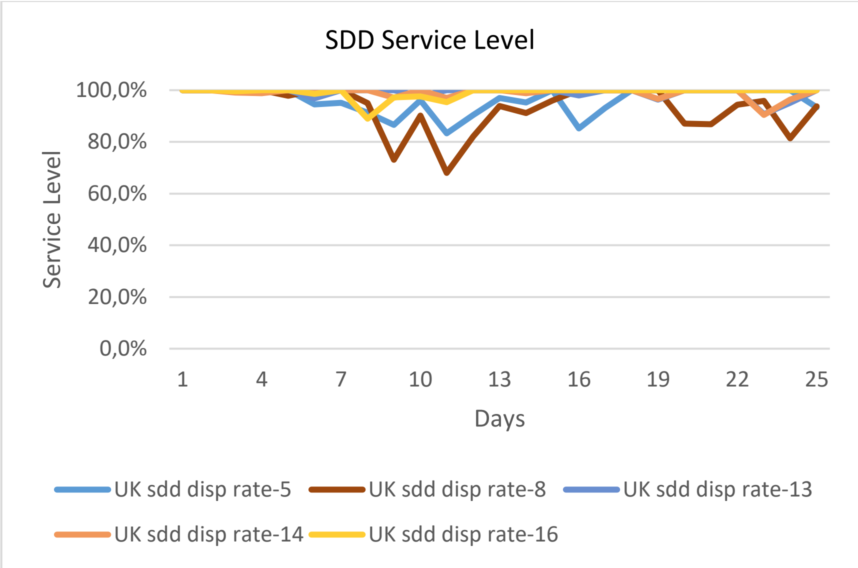


Figure 30. Dispatch rate results for Group 3.

Emissions

Group 4 – High emissions [13-14-16]

Average $CO2_p$ = 850g/parcel.

Beyond the high average emission per parcel, the standard deviation in this group was also considerable, with an average of 190g/per parcel. Furthermore, the maximum emissions reached in the daily performances is above 1 kilogram of CO2 per parcel shipped. All the scenarios in this category were simulated in a low demand period. The bad performances are explained by the little volumes transported with the SDD vehicle. Performances are showed in Figure 31.

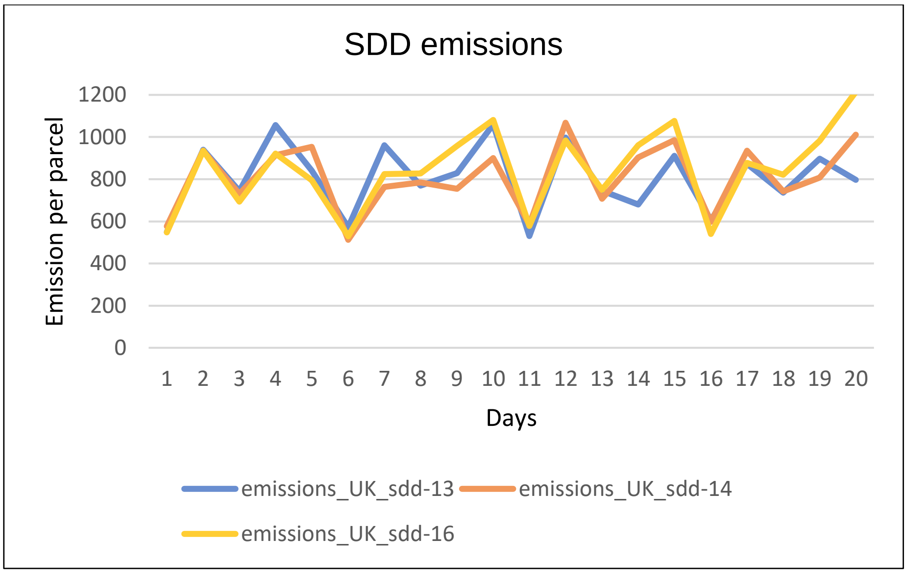


Figure 31. Emission performances of SDD.

Group 5 – Medium emissions [5,6,8]

Average $CO2_p$ = 615g/parcel.

The average CO2 emission recorded for this class is 615g/CO2, with a similar standard deviation similar to Group 4. Despite the high demand period where these scenarios are tested, the emissions generated are the result of modest SDD volumes.

Group 6 – Low emissions [1,2,3,4,7,9,10,11,12,15]

Average $CO2_p$ = 350g/parcel.

In this category, the CO2 emissions generated per parcel are significantly low. The average emission for this group is 350g/CO2, with a standard deviation of 26g/CO2. For all the scenarios in this cluster, the longer cut-off time and the high SDD probability have a positive effect on the carbon footprint. As it can be seen in the line chart below, there is straight line at the level of 324g corresponding with the performances of scenarios 1,2,3,4,7. The seesaw behaviour of the other scenarios is explained by the high volumes that usually occur on a Monday (lower emissions), smoothly decreasing throughout the week (higher emissions).

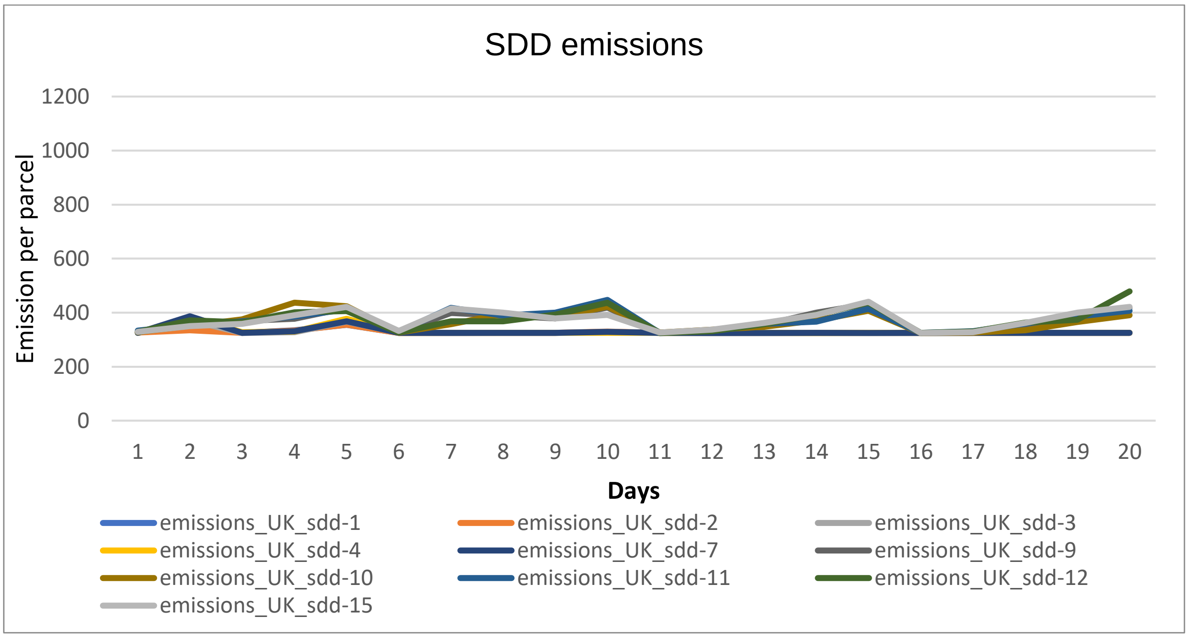


Figure 32. Emission results of Group 6 for SDD.

Costs

For the cost category, the clustering process is more complex as the performances are more dispersed (Figure 33). The first consideration is that scenarios 16-13-14 are visibly underperforming compared to the others, yielding results that ranges between -7,45€ and -10,25€ per order. In this case, the high costs are attributable to the low volumes. Similarly, scenarios 8-6-5 score values between -6€ and -4€.

What stands out is that the majority of the scenarios lies around the -2€/-3€ band. However, the root cause is different. For the scenarios tested in a high demand environment, the costs are mainly driven by reimbursing the customers because the delivery expectations are not met as the volumes are too high. In contrast, for the other scenarios the costs outputs are determined by the transportation costs which are spread across lower volumes.

Finally, the last three scenarios, 11-12-15, are better performing including one situation positive profit is generated for the business. In this case, the average SDD volumes are just below the truck capacity, determining a wider share of the transportation costs, with only a limited effect of the reimbursement costs.

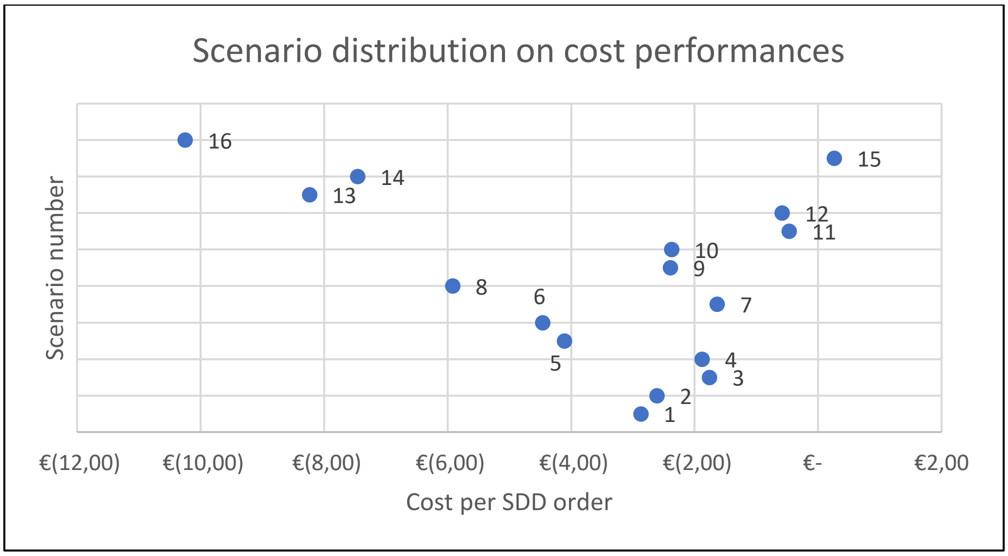


Figure 33. Dispersion diagram on the financial performances for the UK scenarios.

6.3.2 NL

Service level

Group 1 – Low performances [1,2,3,4,7]

Average SL: 66.8%

The scenarios belonging to this group are the same as the one for the UK model. If these setting are met in the real-world, 1 SDD customer out of 3 will not receive his/her order on time. The reason for such bad performances is again attributable to the limited capacity of the SDD truck that is not able to dispatch all the requested orders on time (Figure 34). In contrast to the UK case, the operations for the SDD delivery are impacting other markets, in this case the AT-FR-DE segment. Overall, it can be seen that when the SDD configuration is active, a fraction of the capacity in the morning shift is cannibalised by this premium option, especially on Monday and Tuesday where the volumes are higher.

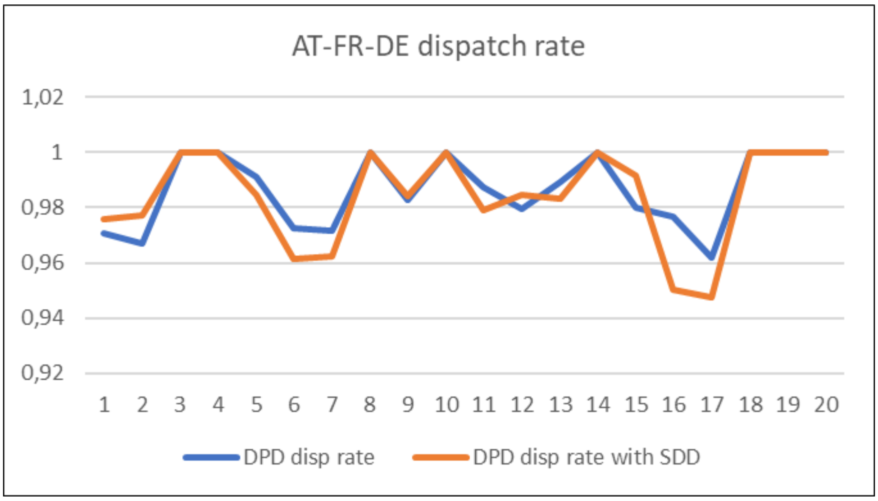


Figure 34. Dispatch rate for the AT-FR-DE segment with and without the SDD for NL.

Group 2 – Very good performances [6,8,9,11,12]

Average SL: 90.3%

The experiments in this group are performing better than in Group 1. Still, the service level offered to the customers is not excellent. The explanation does not lie in the $BL_{Y/N}$, since both values for this parameter are the same, rather it is related to the demand for the NL market. From the figure below it can be seen that there are evident spikes in the demand for the SDD profile, going beyond the capacity of the SDD truck (Figure 35). Consequently, it takes a few days to clean out the backlog accumulated, which in turn drives down the performances of the premium delivery. This phenomenon did not occur for the UK case since the demand profile is more stable.

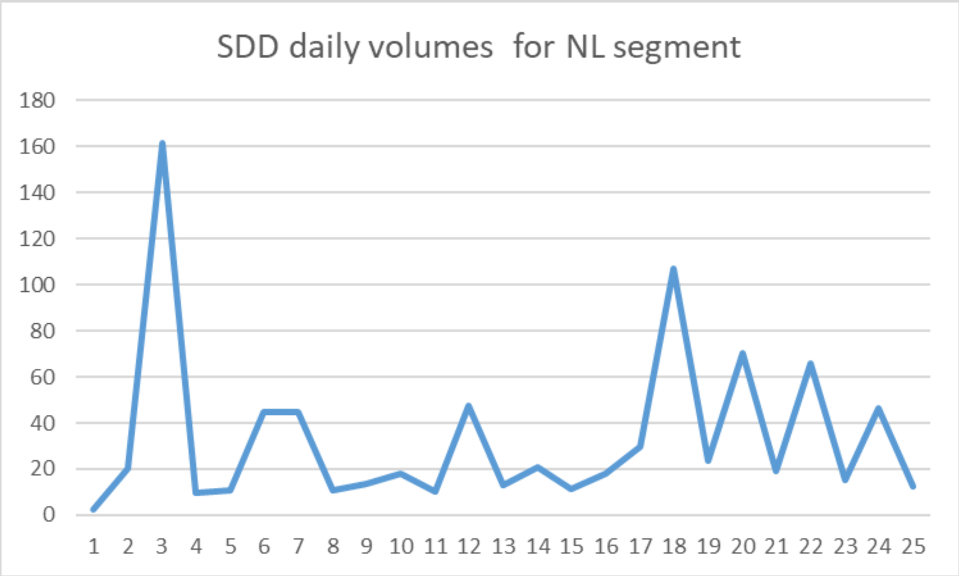


Figure 35. Daily demand registered for SDD in the NL market.

Group 3 – Outstanding performances [5,10,13,14,15,16]

Average SL: 97.0%

For the scenarios in Group 3, the SDD orders are almost always dispatched according to the planned date. The effect on the performances of the AT-FR-DE segment is limited, with a dispatch rate profile nearly overlapping with the one without the premium delivery option. The low volumes are mostly explained by a short cut-off time and a low probability that the customer will select the SDD delivery. A chart is not provided in this case as it is very relatable to the one displayed in Group 3 of the UK case.

Emissions

Group 4 – High emissions [13-14-16]

Average $CO2_p$: 402,2g/parcel of CO2.

The scenarios belonging to this class are the same as the ones recorded for the UK model. The low volumes in the demand for SDD determine a high emission rate per order, with an average of 402,2 g of CO2 emitted. All the scenarios in this category are simulated in a low demand period.

Group 5 – Medium high [5-6-8]

Average $CO2_p$: 217,3 g/parcel of CO2.

Group 5, in contrast to Group 4, has only experiments simulated in a high demand period. Still, the emissions are significant, averaging to a 217,3 g of CO2. The explanation is similar to the UK case: a small SDD probability and a short cut-off determine low volumes for the SDD option.

Group 5(+) – Medium low [9-10-11-12-15]

Average $CO2_p$: 119.2 g/parcel of CO2.

The introduction of this new group was driven by the fact that there is a neat distinction in terms of performances in the medium emission group, showing two separate classes. All the scenarios in this class are tested in a low demand period and have a longer cut-off time together with a higher SDD probability (Figure 36).

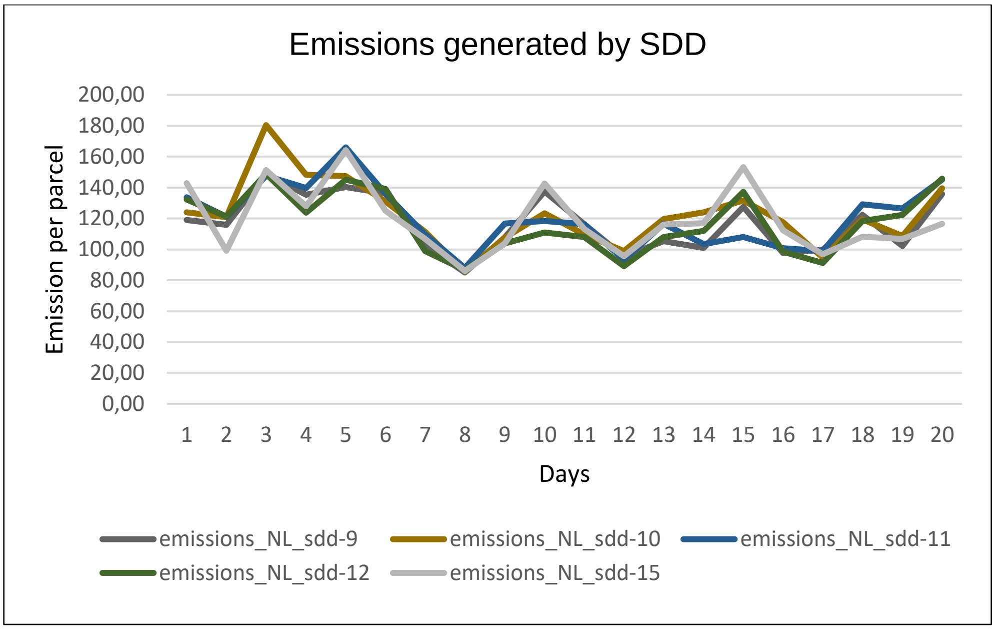


Figure 36. CO2 emissions generated per order by SDD option.

Group 6 – Low emissions [1-2-3-4-7]

Average $CO2_p$: 89.4 g/parcel of CO2.

To conclude on the emission KPI, the last group consists of the same scenarios as the ones for the UK case. The average emission rate is 89.4 g/CO2, with also a small standard deviation of 5.8g/CO2, confirmed by a stable emission profile. Again, these performances are driven essentially by the demand profile rather than the settings of the SDD attractiveness.

Costs

For the NL model, it can be seen that the scenario performances are not as mixed as in the UK case, making the clustering process more intuitive. On the top left corner of figure 37, scenarios 16-13-14 stand out with their poor performances. In this case the explanation lies in the transportation costs that are spread across small volumes, resulting in an average daily cost for BW of more than 20€ per order. Another cluster is represented by scenarios 8-6-5 with still a very expensive result of 10,95€ per order.

Most of the scenarios are, however, in the range between 5€ and 0€, with not a single scenario resulting profitable for the business. As already explained in the UK section, some of these scenarios (1-2-3-4-7) are mostly affected by the low dispatch rate for SDD. As a consequence, the business must reimburse the customer for missing the expectations. The remaining scenarios are driven by a mix of reimbursement costs and transportation costs, cutting off the eventual profit produced by the SDD proposition. On Figure 38, an example on the different monetary profiles taken from Scenario 12.

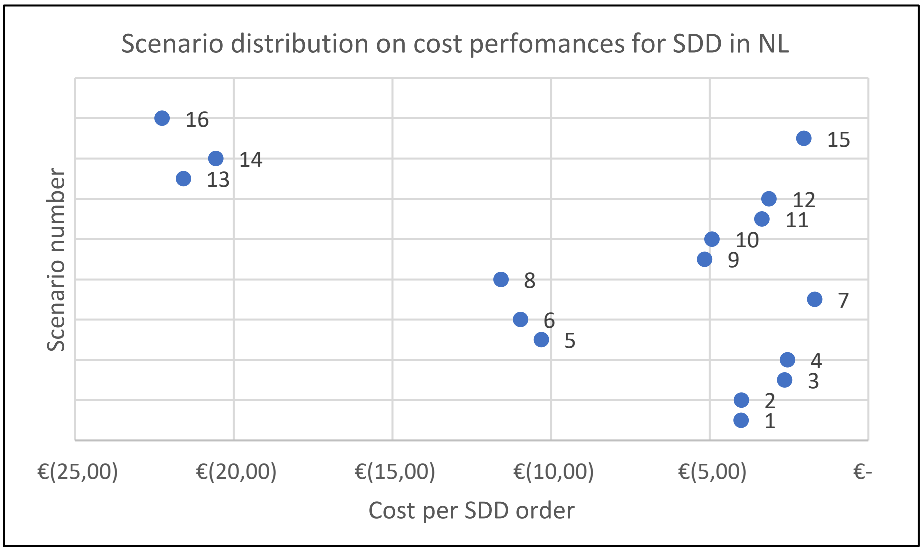


Figure 37. Dispersion diagram on the economic performances for SDD.

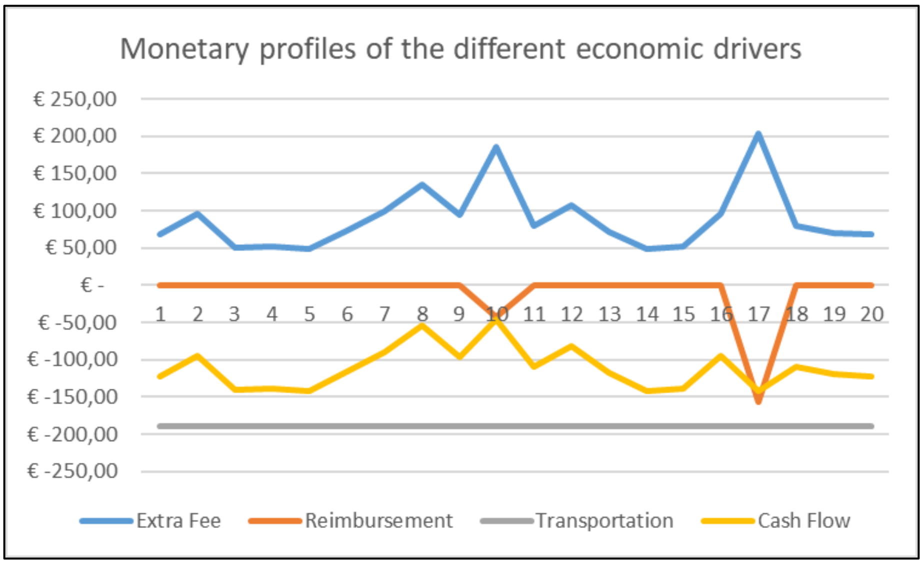


Figure 38. Daily evolution of the different economic drivers for SDD.

6.4 Result discussion

This final section of Chapter 6 aims to summarize the results obtained from the two models and elaborate on the insights of the proposed scenarios.

Regarding the service level delivered to SDD customers, three service classes were identified, one performing considerably worse than the other two (see Figure 39). As already pointed out in Section 6.3, the root cause was identified in the mismatch between the SDD truck capacity and the SDD demand. Even though the SDD demand started to decline after the 4th week, a recovery period from the low service level was not observed. Surprisingly, the standard orders segment benefited from the volumes shift on the SDD mode since less volumes are handled in the standard segment. The performances of SDD in the lower band can be considered unacceptable from a business perspective. First, delivering to the customer a poor service level affects the brand image. Second, the monetary compensation does not always pay off the customer to the point that he/she will place another order in the future. The other two classes are similar in terms of scores, where one is almost always meeting customers' expectations. The two classes can also be denominated as *customer-centric* solutions. An interesting aspect in the NL case is connected to the volume's spikes occurred in the low demand period that were temporarily dropping the performance. This effect was not noticed in the UK case as the demand profile was more stable there. For these two classes, the effect on the standard order performances is limited.

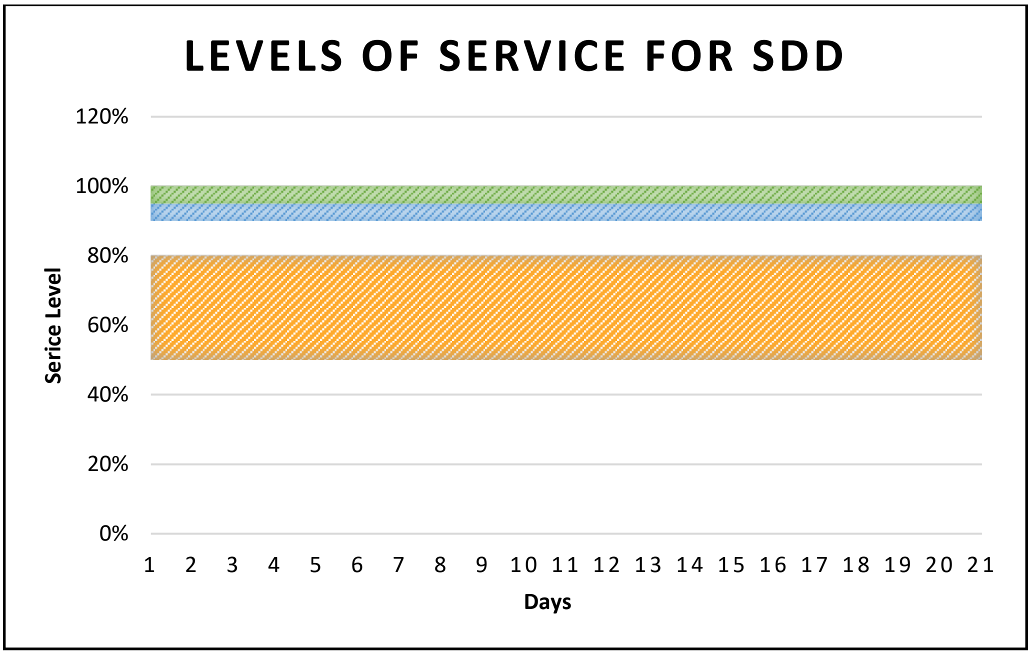


Figure 39. Service level classes identified in the simulation.

On the emissions side, the results have showed that there is a high correlation between the CO2 emissions per order and the dispatch rate. For the scenarios performing low on the service level, it was observed that the emission rate was also low, as the load in the SDD truck was maximized. On the contrary, scenarios with excellent performances were scored poorly on the emissions, as the share for distributing the emissions was limited. The output of the two models cannot be compared with each other on an absolute level since 1) the distances travelled by the SDD vehicles are significantly different, and 2) the vehicle type belongs to different classes, both in the emission rate (g/ton*km) and empty weight. The latter has quite an impact if the number of parcels shipped is minimal since emissions are still generated by the truck.

The discussion on the financial side is more articulated than the previous two. For both countries it was observed that when the number of SDD parcels to be dispatched is considerably below the truck capacity, this negatively affects the business. The reason is that the transportation costs are distributed among only a few orders, and still, a potential extra fee next to the shipping costs does not compensate for the transportation costs. In similar cases, the recommendation would be to *turn-off* the SDD option as it only harms the business financially.

In the NL case, an interesting phenomenon occurred in relation to the spikes in demand. In the situation when the number of orders for SDD registered in a single day highly exceeds the truck capacity, it could take up to 2 days to clean the backlog, which results in having to reimburse all the customers that are affected with delays in the meantime. In such episodes where the same-day volumes are hard to forecast or when they are significant lower compared to the truck capacity, it is advisable to not enable this premium option. Even though reimbursing the customers mitigates their disappointment from a delayed order, it should not become a standard activity for the business since it is time consuming and does not guarantee a zero risk for churns.

Some scenarios reported similar economic performances, with only a little loss per parcel on average. Nevertheless, a deeper look into the daily performances revealed interesting insights. In one case, the SDD volumes were not sufficient to fill the truck, reaching only 70%-75% of the truck capacity. Under these circumstances, the cost per parcel is only driven by the transportation costs. In the other case, the SDD volumes exceed the truck capacity with 5%, with an optimized allocation of the transportation costs, but with an additional cost derived from the reimbursements. The main learning from the two situations just described is that the performances can be similar at first sight, but in one case the SDD expectations are always met, meaning a higher service level, whereas in the other case part of the demand is backlogged. It goes without saying that the first scenario is preferred to the second one.

Only one scenario registered a potential profit for the business, namely scenario 15 for the UK. The settings of this scenario can be considered somehow *optimistic* but that was indeed the purpose. The high attractiveness combined with a high shipping cost are factors colliding with each other, unless the business manages to offer the customers extra 'attractiveness' to the proposition, for instance on the return flow (return in 24 hours), on a fidelity program, etc. An interesting aspect with this scenario setting is that the profit was only registered in a low demand period. The value of such an experiment reveals to the business that the SDD proposition can turn into a profitable solution if tuned correctly.

6.5 Sensitivity analysis

From the experiments analysed in Section 6.3, almost all the proposed scenarios did not provide solid insights to convince the business that the same-day delivery can turn into a profitable intervention. A sensitivity analysis was performed to determine to what degree the input factors impact the simulation outcomes. The UK market was chosen to carry out the investigation as it represents the biggest market for Beerwulf. Also, a wider spectrum for the inspected input was available.

One of the constraints set for the model is the fixed capacity of the same-day vehicle. This limitation derives from the lack of flexibility on the operation level for arranging collections with vehicles of different sizes. Therefore, the capacity for all the experiment was set to the midpoint of the carrier's fleet availability as already mentioned in Chapter 5. For the sensitivity analysis, this restriction was lifted and extremes values for SDD capacity were explored, namely 200 and 1000 parcels. Besides the truck capacity and characteristics of the vehicle, all the other parameters have been tuned as Experiment 3 (see Appendix D), which was simulated on a high demand period.

As expected, the performances on the service level are correlated with the capacity available. To benchmark the outcomes of the simulation, the performance of the experiment with 500 parcels has been added to the chart. In Figure 40, the performances of the three levels are displayed. When the SDD capacity is 1000, the customers' expectations are almost always met, with the exception for a small drop on the Monday of the third week (Day 11). The behaviour of the case with only 200 parcels is significantly worse in the beginning, but it almost overlaps the behaviour of 500 parcels with the progression of the days, delivering to the customers a low service level.

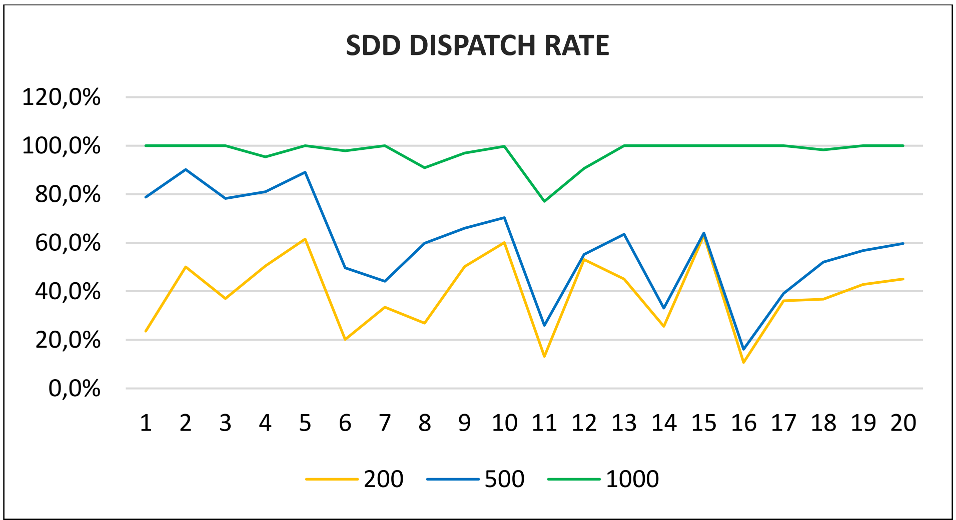


Figure 40. Dispatch rate with variable SDD capacity.

With respect to the carbon footprint, the impact of using a bigger vehicle since the weight of the empty vehicle is not proportional to the load that can be carried. The CO2 emissions per parcel recorded for the larger vehicle are almost twice as higher that the smaller one, albeit the capacity is on a ratio 1:5. More interesting are the performances on the financial angle, which are displayed in Figure 41. When the capacity is 200, the average loss per order is -2,55€, mainly driven by the reimbursement costs occurring due to the delays already proved by the service level. For the case with 500 parcels, the performances are slightly better on an aggregate level, 2,15€, but in the second part of the simulation, they are even worse than the previous scenario. Even though the capacity is higher, still the demand cannot be fulfilled, and the transportation costs are also higher. Performances for the larger vehicle are quite singular. The average cost per parcel is -0.92€ per order, outperforming the other two scenarios. The root cause can be identified in the little number of delays recorded in this scenario. The transportation costs are higher, but they are partially compensated by the positive effect of having less backlogs.

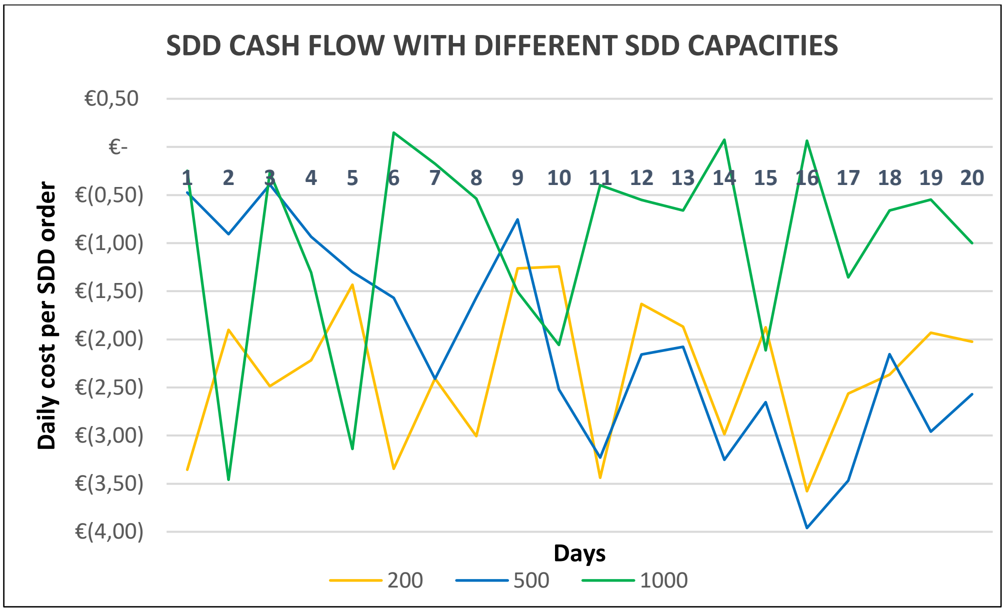


Figure 41. SDD cash flow with different SDD capacities.

This effect leads to the next *what-if* analysis, which is related to the risk for the business to charge the customers with different extra fees. The risk emphasizes the potential higher reimbursement costs that the business has to pay back to the customer. For this investigation, the capacity was fixed at 1000 parcels, and the extra fees examined are: 0,1,2, and 3 euro.

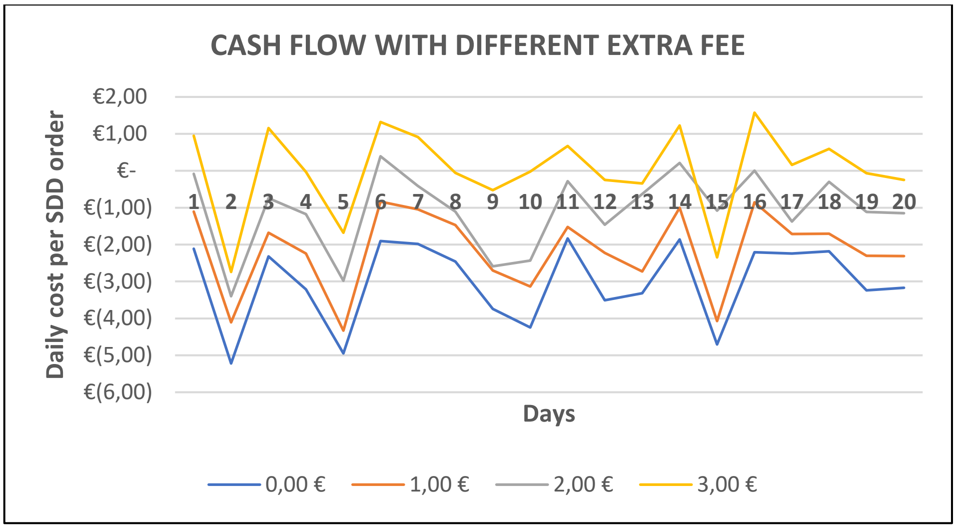


Figure 42. SDD cash flow with different extra fees.

The results of the four simulated scenarios reveal that charging the customer with a higher fee can generate profit for the business, even when the higher capacity of the SDD truck is used (Figure 42). In other words, it makes sense for the business to take the risk for a signing a contract for a high-capacity vehicle to ensure that the majority of the SDD demand is always shipped on time. In the scenario where the extra fee was set to 3,00€, the average revenue per parcel registered was 0,11€.

The proposed sensitivity analysis has investigated the effect of selecting vehicle with different characteristics. For all the 16 scenarios evaluated in Section 6.3, the capacity was set to 500 parcels, being an intermediate solution that could trade off both high and low/medium demand periods. The sensitivity analysis has targeted a high-demand period since it represents the most interesting and challenging season for Beerwulf. The first insight derived from the analysis is that using vehicles with capacity of 200 and 500 had similar performances in the service level, despite the significant difference in capacity. On the contrary, the vehicle with capacity 1000 was resilient to the peak in demand, delivering an average service level of 92,1%. The second insight is related to the economic side. Even though the vehicle with capacity of 1000 is almost twice as expensive as the one with 500, the shipping cost per parcel are much lower when the vehicle with highest capacity is implemented. Ultimately, it was proved that applying a higher extra fee to the shipping costs asked to the customer was resulting in a profitable scenario for the business. The sensitivity analysis has showed that the business should consider opting for a high-capacity vehicle in peak periods, even though when the truck could not be fully loaded. Also, asking the customer a higher extra fee can cover both potential backlogs and the transportation cost. However, the impact on a low demand period was not evaluated which leaves room for further investigation with a smaller truck capacity and different fees options.

7 Conclusion and recommendations

Chapter 7 contains the conclusion of this study, discussing the achievements accomplished through this project, and the limitations encountered throughout the development. The chapter concludes with some recommendations for further research.

7.1 Conclusion

The goal of this study was to develop a model for introducing a premium last mile delivery next to the standard one and assess its performances under three facets: service level, sustainability, and costs. The focus was restricted to two markets, the Netherlands and the United Kingdom, as these two are substantially different from each other both in the market structure and from a logistics point of view. The integration of same day delivery on the two markets was developed according to the current warehouses' structures, trying to propose a new operational scheme that would reflect a realistic implementation. The performances of the new delivery mode were investigated through a simulation study, embedding a degree of stochasticity.

Eight scenarios were designed for each market and tested in two periods with different seasonal demand patterns. The results of the low demand period showed an overall excellent service level offered to the SDD customers, registering performances between 89.7% and 100.0%. On the contrary, the carbon footprint of the new delivery mode is not as remarkable as the service level. In the experiments where only a few customers are selecting the SDD mode, the emission are shared only among a few entities, making same-day delivery not attractive from an environmental perspective. This was also reflected in the financial dimension where the costs per order reached an expenditure of 22,3€/order in one case. In the instances where the SDD was more attractive, the CO_2 emissions revealed acceptable values. Still, the economic impact is not as good as expected, meaning that a negative cash flow was recorded for all the tested scenarios. Only one scenario in the low demand period disclosed a promising path towards the new delivery mode, with a balanced trade-off across the three dimensions investigated. As already mentioned in Section 6.4, the appealing scenario combines a high attractiveness with a margin of profitability for the business. The recommendation for the organization in a low demand period is to make the SDD proposition as attractive as possible whilst maximizing the truck load. If these requirements are not likely to be met, it is advisable not to add this delivery mode into the current last mile delivery scheme.

In contrast to the low demand period, a more heterogenous picture is visible in the high demand period. When the high demand profile for the standard delivery is also reflected in the SDD proposition, the truck capacity selected for the same day is not sufficient to cope with the demand, delivering to the customers a poor service that ranges between 57.6% and 69.4%. In such circumstances, the optimal

allocation of the transportation costs is offset by the reimbursements that need to be paid to compensate customers affected by delays. Nevertheless, the full truck dictates a low carbon footprint per order, making these scenarios the most sustainable amongst all. Interestingly, when the two delivery options are active at the same time, the service level of the standard order flow is higher to a certain extent, compared to the current configuration with one delivery option. If the business recalls that there is a risk in exceeding the SDD capacity or that the demand volume is highly unpredictable, both the service level and the cost dimension have proved the SDD option not being that attractive.
In the scenario where despite the high sales realized in the standard orders, the SDD option does not appear to be attractive to the customers, the service level for the premium delivery provides values between 86.7% and 96.7%. As already observed for the low demand period, the low volumes negatively impact both the costs and the emission generated per order. It is therefore advisable to *not activate* the same day delivery option if similar circumstances are expected to occur. For the high demand period, it can be concluded that none of the scenario investigated seem to bring extra value to the business. On this particular case, a sensitivity analysis was performed to explore the effect of using vehicles with opposite characteristics, mostly noticeable in capacity and costs. The smallest vehicle available from the carrier's fleet scored similar performances to the one used in the core experiments, whereas the larger vehicle, despite its expensive costs, resulted in a superior service level and cost profiles. Lastly, a wider range of extra fees was tested. The results proved that the business should not fear the risk of applying a high extra fee, since eventual reimbursement costs faced in a short period were offset by the profit generated in the period before and after the peak.

To conclude, the proposed scenarios suggest the business to exclude the same day delivery option in its future strategies if the room for vehicle flexibility is limited. However, one goal of this research was indeed to identify boundaries for implementing the same-day delivery, both on the logistics and business sides. The results do not leave out the possibility for considering intermediate conditions that would eventually make this delivery mode attractive in Amsterdam and London. Same-day delivery has demonstrated to be very sensitive to a rigid logistics environment, especially when tactical decisions constraint the business to a long-term strategy.

7.2 Limitations and recommendations

The results of this research were restricted by a number of limitations. There is room for further investigation in future research. In this section, the limitations of the study are presented, and recommendations for future research are provided.

Limitations

The first limitation in this study is related to the geographic sphere, or better, the cities that have been selected for this thesis. The necessary criteria in order for a city to be selected were mostly driven by the volumes of sales generated by a city, and the ones with higher volumes have been selected. Another requirement for the city was the availability of the same day delivery option from the current last mile partner. In the UK case, the long distance between the warehouse and the carrier distribution centre has somewhat compromised the outcomes, especially in scenarios with smaller volumes. It could be of interest to explore other cities that present similar logistics characteristics but that are closer to the warehouse, determining then lower transportation costs and emissions.

The second limitation is connected to the first one and it involves the vehicle characteristic selected for the same day delivery. In this case, the decision was taken considering both the carriers' fleet availability and an intermediate capacity, in order to ideally be able to accommodate both low and high demand volumes. The results have proven the contrary though, showing that a fixed capacity is not advisable. However, alternatives to overcome this problem can be found. For instance, Beerwulf could look for a flexible delivery truck plan, where the truck capacity can be agreed depending upon the forecast. If this is not achievable, another solution could be to investigate combinations of city demand and truck capacity and then determine which requirements fit best. This would also mean that only selected cities would benefit from the same day delivery option, with may lead to the risk of receiving complaints and disapproval from customers not included in the offer.

With respect to the sustainability outcomes, this research did not succeed in providing a comparison between the current state and the new delivery option to the business. Originally, the mission was to determine the carbon footprint of the standard delivery option but throughout the modelling phase, some barriers hampered the estimation of the CO2 emissions:

1) A fragmented network. While mapping the different stages for the standard delivery option, it was acknowledged that there are many intermediate stops between the warehouse and the customers' houses, especially in the UK, where multiple transportation providers participate in the Beerwulf outbound network. In this context, it becomes difficult to retrieve the data for each segment, especially when the shipments are not dedicated to Beerwulf only.
2) Data availability. Another difficulty encountered in determining the environmental impact of standard home delivery relates to the limited freedom of the last mile carriers to share data with external partners. If the previous point was mainly about the complexity of the transportation environment, the restriction on sharing data is more of a legal matter. Indeed, during the conversations held between Beerwulf and the carriers, it was pointed out by them that information regarding the vehicles' characteristics, the emission rates, the average length of the

last mile routes, are sensitive and could play in favour of the competition or put other customers at risk.

Knowing these limitations, it was agreed with the business to disregard the sustainability assessment for standard home delivery and focus on same day delivery. Still, the recommendation to the business is to invest in the relationships with the carriers to make sure that such information could be shared or at least estimated. In the e-commerce sector, the green ambitions are becoming a matter of competition and informing the customers about the environmental impact of an order could play a decisive role towards both the consumers and the landing of prospective green regulations.

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Appendix A – Simulation methodologies

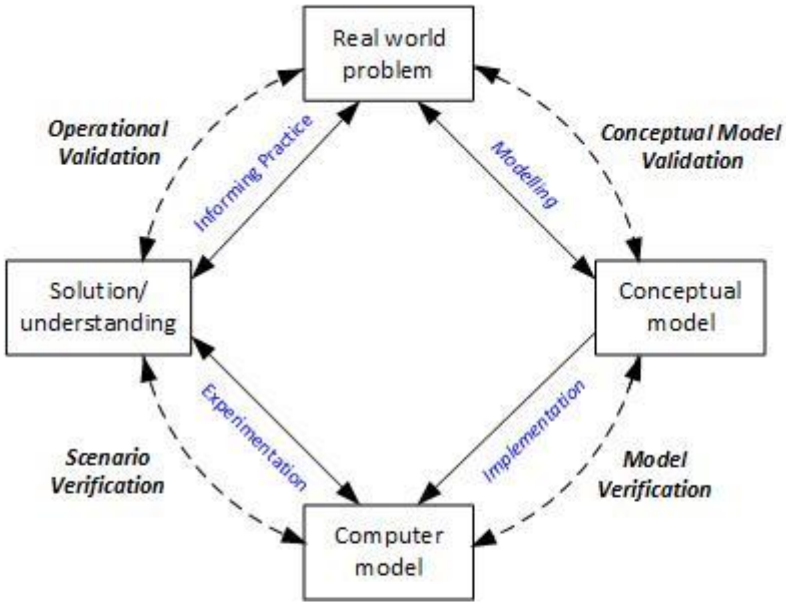


Figure 43. Robinson (2004) simulation framework.

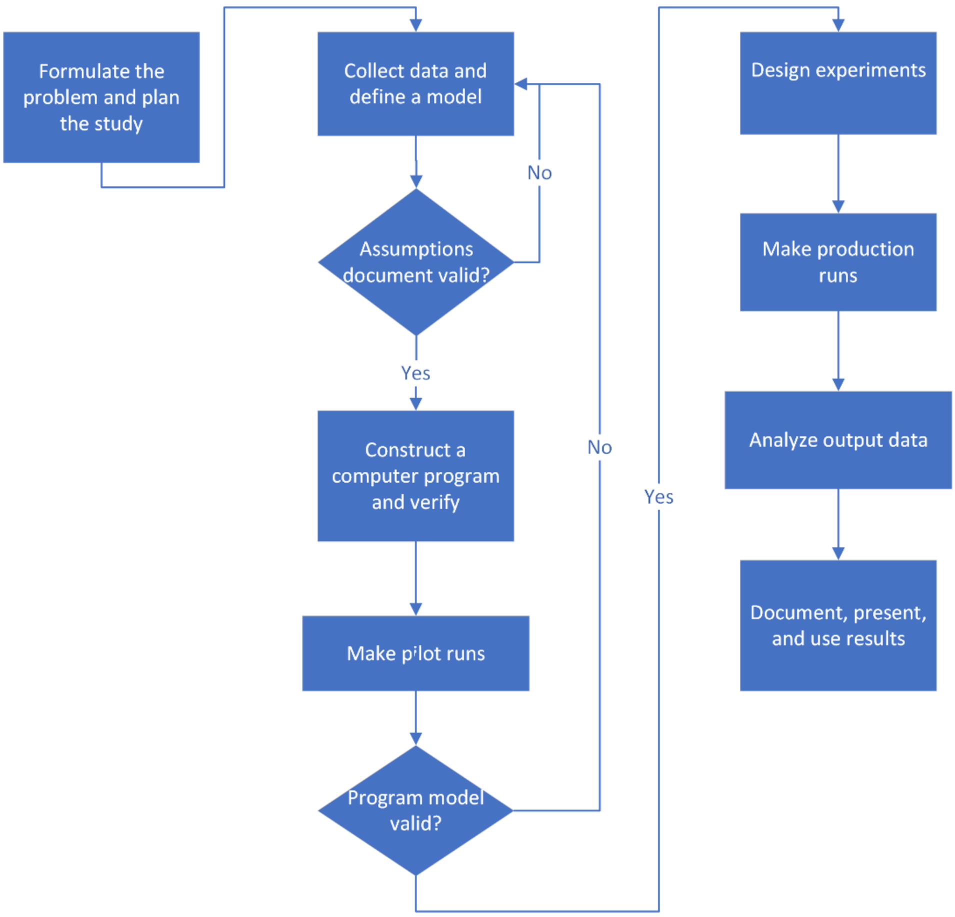
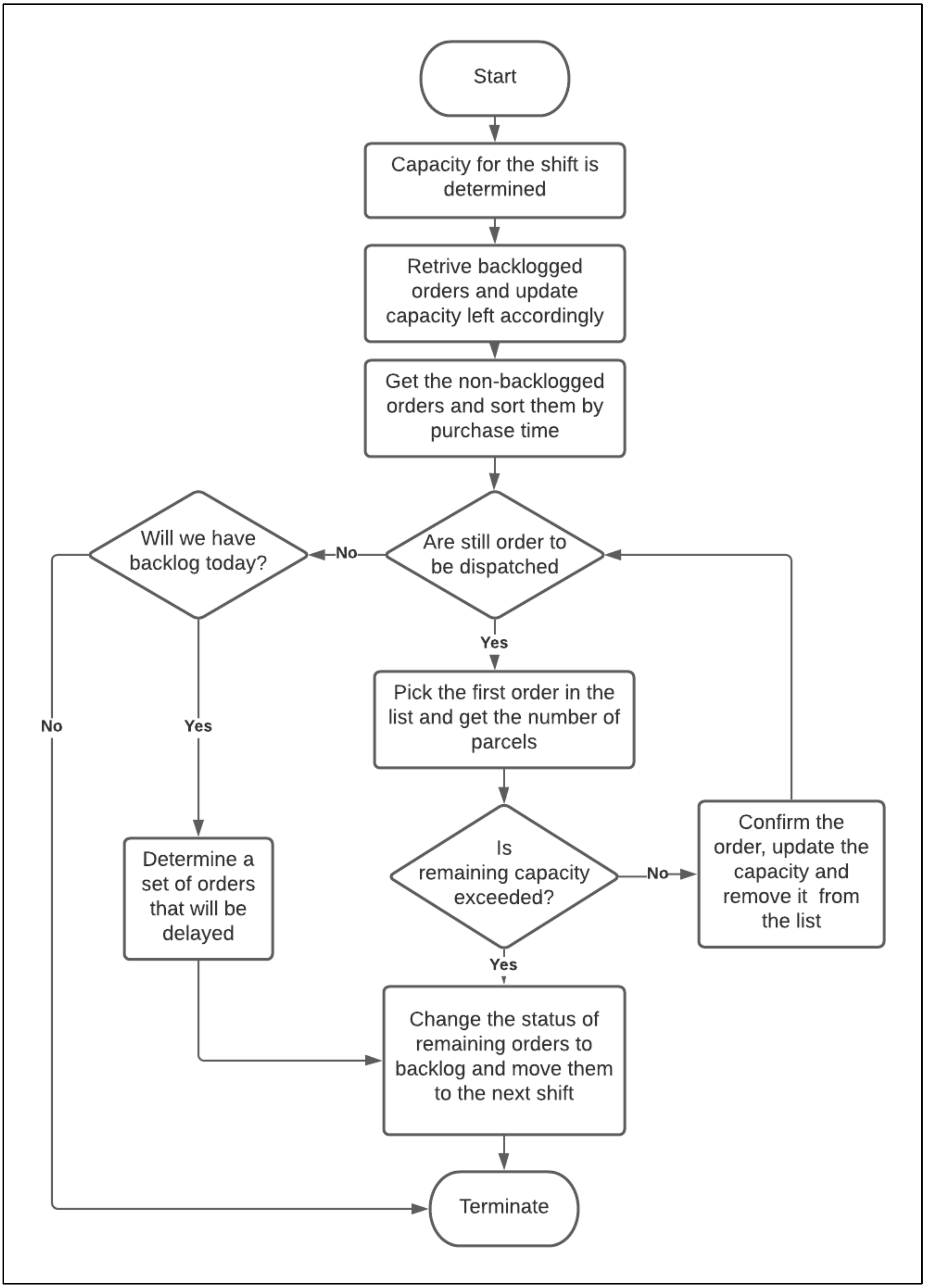


Figure 44. Law (2013) simulation framework

Appendix B – Flow chart of the dispatch policy for the current setup



Appendix C – Detailed version of the replications results

Table 5. Replications analysis on the service level KPI.

Run	SL	$\bar{X}$	VAR	t-value	ξ
1	0,974095				
2	0,977428	0,975762	0,000006	12,706205	0,021670
3	0,988356	0,979960	0,000056	4,302653	0,018750
4	0,981218	0,980274	0,000037	3,182446	0,009930

Table 6. Replications analysis on the cash flow KPI.

Run	CF	$\bar{X}$	VAR	t-value	ξ
1	462,531429				
2	462,856464	462,693946	0,052824	12,706205	0,004461
3	470,430411	465,272768	19,977374	4,302653	0,023602
4	442,230057	459,512090	146,059875	3,182446	0,043486

Table 7. Replications analysis on the emissions KPI.

Run	E_{sdd}	$\bar{X}$	VAR	t-value	ξ
1	-3,715366				
2	-3,653603	-3,684485	0,001907	12,706205	0,107397
3	-3,811696	-3,726889	0,006348	4,302653	0,051924
4	-3,825539	-3,681200	0,029745	3,182446	0,071738
5	-3,399795	-3,681200	0,029745	2,776445	0,062988
6	-3,564145	-3,661691	0,026080	2,570582	0,047550

Appendix D – Experimental settings

Features	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CAPACITY NL	2400	2400	2400	2400	2400	2400	2400	2400	1200	1200	1200	1200	1200	1200	1200	1200
CAPACITY SDD NL	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
CAPACITY AT-FR-DE	2400	2400	2400	2400	2400	2400	2400	2400	1200	1200	1200	1200	1200	1200	1200	1200
BL % NL	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
BL % AT-FR-DE	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
BL Y/N NL	20%	5%	20%	5%	20%	5%	20%	20%	20%	5%	20%	5%	20%	5%	20%	20%
BL Y/N DPD	20%	5%	20%	5%	20%	5%	20%	20%	20%	5%	20%	5%	20%	5%	20%	20%
CUT OFF SDD NL	14	14	14	14	11	11	14	11	14	14	14	14	11	11	14	11
REIMB COST	4	4	6	6	6	6	7	4	4	4	6	6	6	6	7	4
EXTRA FEE	0	0	2	2	2	2	3	0	0	0	2	2	2	2	3	0
SDD PROB	15%	15%	15%	15%	5%	5%	15%	5%	15%	15%	15%	15%	5%	5%	15%	5%
EMISSIONS NL	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
EMISSIONS SDD NL	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5	85,5
COST TRUCK SDD	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190
EMPTY WEIGHT	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
DAY	01/11/2021	01/11/2021	01/11/2021	01/11/2021	01/11/2021	01/11/2021	01/11/2021	01/11/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021

Figure 45. Experiments' settings for the NL case.

Features	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CAPACITY UK	1300	1300	1300	1300	1300	1300	1300	1300	1200	1200	1200	1200	1200	1200	1200	1200
CAPACITY SDD UK	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
BL % UK	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
CUT OFF SDD UK	14	14	14	14	11	11	14	11	14	14	14	14	11	11	14	11
REIMB COST	4	4	6	6	6	6	7	4	4	4	6	6	6	6	7	4
EXTRA FEE	0	0	2	2	2	2	3	0	0	0	2	2	2	2	3	0
SDD PROB	0,15	0,15	0,15	0,15	0,05	0,05	0,15	0,05	0,15	0,15	0,15	0,15	0,05	0,05	0,15	0,05
BL Y/N UK	0,2	0,05	0,2	0,05	0,2	0,05	0,2	0,2	0,2	0,05	0,2	0,05	0,2	0,05	0,2	0,2
EMISSIONS UK	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
EMISSIONS SDD UK	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3
COST TRUCK SDD	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
EMPTY WEIGHT	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
DAY	24/05/2021	24/05/2021	24/05/2021	24/05/2021	24/05/2021	24/05/2021	24/05/2021	24/05/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021	13/09/2021

Figure 46. Experiments' settings for the UK case.

Appendix E – Section 2 of the analysis dashboard