Design of the input and output cargo flows for a Fast-Track at Amsterdam Airport Schiphol

Master Thesis

K.M. Schuppener
Design of the input and output cargo flows for a Fast-Track at Amsterdam Airport Schiphol

Master Thesis

by

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Preface

This thesis is the final step for the degree of Master of Science in Transport, Infrastructure and Logistics (TIL) at Delft University of Technology. The purpose of the master thesis project is to apply the theory and knowledge gained in the two year programme to a real life problem. At the moment of choosing a company and topic there was little doubt: It needed to be at a key logistics hub. Having moved from Costa Rica to the Netherlands to complete my master studies precisely because of its leading role in logistics, I feel extremely blessed and grateful to have had the opportunity to perform my research at Amsterdam Airport Schiphol.

This research has been conducted for the Cargo Department of Schiphol Group from March until December of 2016. During this period, the airside and landside distribution processes were studied in order to propose a set of designs that would facilitate a seamless flow for a Fast Track. These designs were tested making use of a simulation model and its results analysed. As a strategic project, there were several difficulties regarding data availability and in particular, designing for such uncertain scenarios. Additionally, the learning curve of the simulation software proved to be challenging and tested my patience. I believe these challenges were successfully overcome and as a consequence, I am now a better engineer. I am proud of the finished product and believe that, by testing the different variables and optimal point between a push and pull system, valuable knowledge has been created for Schiphol but also for other parties in the supply chain.

I would like to specially thank my supervisor at Schiphol, Hendriena Ritsema, for her support and trust in this period. She allowed me to figure out my way while always providing valuable advice and guidance. The Cargo team also made my internship time extremely pleasant and without realizing it, allowed me to learn from the Dutch culture as well. I am also thankful to my committee and the help each one of its members provided. Alexander, for teaching me how asking the right question can change everything; Jafar for his enthusiasm and advices and finally, Mark for his commitment and thorough feedback. This work could not have been completed without you.

This has truly been an amazing experience and I appreciate every single person who took the time to answer my extensive and frequent questions, give me a tour or simply, allow me to give into my curiosity. Having an airside tour, walking next to the baggage conveyor system, exploring a cargo handler’s warehouse and being allowed on a freighter are moments I will never forget.

Lastly, I would like to thank my family who in spite of being far, are always present in my life through their messages, prayers and love. This achievement is for you and your unconditional support throughout the difficult times and your sincere joy in the good ones. There are no words that can express my gratitude and debt to you. Christian, for being there always, enduring the long nights and intense weekends. Thank you for encouraging me to the end and being part of this adventure with me. And my friends, for being my family away from home and giving me more sanity than you will ever know.

K.M. Schuppener
Schiphol, December 2016
Executive Summary

The economy in the Netherlands is shaped by logistics and specifically, two major hubs: the Port of Rotterdam and Amsterdam Airport Schiphol. As such, Schiphol is of vital importance both on a national and regional level. With the ambition of becoming Europe’s cargo preferred airport, the airport is focused on achieving operational excellence on ground. However, past research has shown that there are key issues preventing it from reaching this goal. Some of these are truck waiting times, long throughput times for shipments and warehousing efficiency at the 1st line. In addition to these, the need to have spare capacity for future growth compels Schiphol Cargo to revise the current business model. The concept of a Fast Track (FT) or cross dock facility is one of the research topics, however, certain knowledge gaps remain. These are related to how the transport process and actor configuration at airside and the truck scheduling and planning at landside can contribute to a higher throughput. Current research goes into the specifics of each factor, not going in depth in the inter-dependencies among these. This leads to the following research question:

*How can the input and output distribution processes of a fast track (FT) at Amsterdam Airport Schiphol facilitate a seamless flow in the context of a multi-actor environment?*

The scope is that of import cargo flows that arrive as Build-Up-Pallets (BUP) and configuration variables pertaining to the distributions and the FT interface. First, a distribution process analysis is performed for the three main processes: airside, handling and landside. Through it, the critical characteristics of the processes are defined and a better understanding of the system and its inter-dependencies reached. Subsequently, a literature review is conducted in order to define the critical design variables. These are: arrival and departure pattern at airside and landside, the number of dock doors, temporary storage and airside handler configuration. Having completed the previous assessment, the theoretically viable alternatives are created and assessed. As Table 1 shows there are 4 designs based on the existence of storage and system configuration. In addition to this, the airside configuration is considered in its two alternatives: Multiple handlers and single 3rd party handler. It is at this point that the departure pattern is linked to the push/pull configuration and to the ability of the FT to perform the truck allocation. In this way, a FT with a non-restricted departure pattern will behave in a push way, creating truck shipments based on destination groups and optimizing thus the truck load. On the contrary, a restricted one will behave as a pull system, respecting the original shipments of the Road Feeder Network (RFN) even in cases of Low-Truck-Loads (LTL).

Table 1: Experimental Plan - FT designs

<table>
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<th>FT Design</th>
<th>Temporary Storage Size</th>
<th>Departure Pattern</th>
<th>System Configuration</th>
<th>Storage Utilization</th>
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<th>Multiple Handlers</th>
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Table 1: Experimental Plan - FT designs

The performance evaluation of the different FT designs can be accomplished through the use of a verified and validated simulation model. The configuration variables are: Airside and Landside dock doors, storage size, storage size utilization, handler configuration and the Truck Notice Time (TNT). These are used in order to create the different designs while the KPIs serve as a measure of the success in meeting the requirements of the design. The KPIs are split into airside, FT and landside. Airside criterion is Airside Lead Time, whereas for the FT it is Throughput (TP) and Lead Time (LT). At landside the criteria are: Truck Load Factor, Turnaround time, Waiting time and Truck reduction. Thorough verification and validation tests are performed to ensure that the model is able to respond to real life questions.

The simulation is executed with a run length of 672 hours and 25 replications in order to ensure unique statistical results. The configuration of the variables that are fixed across the designs is: 10 airside dock doors, 5 landside dock doors and 2 hours TNT. The experimental plan presented in Table 1 will be followed with the goal of understanding whether different designs are statistically equivalent or not. In addition to this, it is
necessary to understand how large the differences truly are since "finding that an effect is significant does not tell you about how large or important the effect is" (Lane, 2015). In order to do so, hypothesis testing is used as part of an extensive statistical analysis. In all cases, the null hypothesis $H_0$ is that means are equal and there is no effect of the designs on the KPIs.

1) Handler Configuration at Airside
Design A is selected as the "base case" and tested in both handler configurations for the three demand scenarios (i.e. current demand, conservative and optimistic growth). In total, 6 runs are performed and a handler configuration is selected. The analysis shows that Lead Time (LT) results as one of the critical KPIs, improving between 0.32 and 0.65 hours and reducing the variability significantly. The effect on the other KPIs is not relevant or non-existent at worse. Based on this, the configuration that yields better results and draws nearer to the premise of facilitating a seamless flow to the FT is that of a multiple handler configuration.

2) Fast Track (FT) Design Alternatives
The remaining FT designs are run (i.e. B, C and D) on the conservative demand scenario. The results show that LT and LT Airside are affected by the existence of storage. Both designs with storage (A and B) are statistically equivalent. As Figure 1 shows, the existence of storage greatly reduces variability. Another take away is the fact that the current system configuration (i.e. storage size 75) is not able to cope with a 50% increase in demand. As a matter of fact, the LT increases from approximately 1.6 hours for the base demand to around 4. Throughput (TP) also showed that storage is an asset since it increases the output by at least 10 BUPs per hour. The push/pull configuration does not affect the TP.

The landside indicators show that the truck turnaround time increases as the truck load decreases. This is expected since more trucks need to be called in order to expedite the same BUPs. The pull configuration generates smaller truck loads than their push counterparts, which is logical since truck loading is not maximized. This proves to be related with the storage size as well, as the results from Design A show. In this case, when the system moves to push, the number of trucks required to expedite the existing cargo generates congestion and increases thus turnaround time. All designs achieve a reduction in the amount of trucks of at least 50%. The dock doors also show a statistically significant difference between storage configurations. The dock utilization variability for FT designs with storage is considerably lower. Based on this, the distribution alternative that is recommended is FT Design B. The benefits of this design are related to an overall reduction in variability, an increased throughput and the improvement on landside operations. The shortcomings are related to some of the model assumptions and the fact that it is not able to cope with a substantial demand increase.

In conclusion, the input and distribution processes of a FT need to be designed in a way that variability is reduced and issues or disturbances arising in one end of the chain do not permeate in other areas. In fact, airside operations proved to strongly modulate LT, which is why a storage area is considered a must. Airside operations need to be as fast, lean and stable as possible. It is considering this that a multiple handler configuration is advised. Nonetheless, if the engagement of the cargo handlers is not substantial, a 3rd party configuration should be implemented. On the landside process, it is vital to ensure that the time trucks spend at the dock is composed only of loading time. As limited resources, dock doors serve as the last regulators of flow, which is why their capacity ought to be spent only on value added activities. Currently, cargo handlers have mostly no say in the truck allocation, however, for the FT to be successful that needs to change. The decision-making power needs to rest in the FT operator so that the dynamism of the push/pull logic can be sustained. In this way, the storage utilization limit can be fine tuned according to the needs of the operation. This adjustment determines the ensuing performance in terms of truck load and turnaround times. For larger storage areas, this threshold should be lower in order to prevent congestion due to a large number of trucks being called in these "peak" moments. These improvements would contribute not only to a seamless flow but also to the sustainability of the cargo operations at Schiphol. It is recommended for Schiphol Cargo to implement this concept by engaging with the relevant stakeholders and using this research as a validation of the possible gains of a push/pull FT with collaborative trucking. This can lead the conversation and negotiation with the parties towards the planning and implementation of a pilot.
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- **9.2.1 Contribution to science**
- **9.2.2 Contributions to society**
- **9.2.3 Contributions to the industry**

### 9.3 Recommendations

- **9.3.1 Recommendations for Schiphol Cargo**
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- **A.2 Dimitri Brink - Business Unit Manager Panalpina-13th June 2016**
- **A.3 Gerard Kervezee - Chief Commercial Officer Dnata- 20th June 2016**
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List of Abbreviations

The abbreviations used on this report are the following:

- AAS - Amsterdam Airport Schiphol
- ACN - Air Cargo Nederland
- AMS - Amsterdam Airport Schiphol’s IATA Code
- ANOVA - Analysis of Variance
- AWB - Airway Bill
- BUP - Build Up Pallet
- BWM - Best Worst Method
- CPD - Central Pick Up and Drop Off Point
- CVRP - Capacitated Vehicle Routing Problem
- ETA - Estimated Time of Arrival
- ETV - Elevating Transfer Vehicle
- FT - Fast Track
- FTF - Fast Track Facility
- FIFO - First In First Out
- FIFS - First In First Served
- FTL - Full Truck Load
- HWB - Houseway Bill
- IATA - International Air Transport Association
- JIC - Joint Inspection Centre
- JIT - Just in Time
- KPI - Key Performance Indicator
- LIFO - Last In First Out
- LT - Lead Time
- LTL - Low Truck Load
- RFN - Road Feeder Network
- SLA - Service Level Agreement
- SVRP - Stochastic Vehicle Routing Problem
- TP - Throughput
- ULD - Unit Load Device
- VOT - Value of Time
- VRP - Vehicle Routing Problem
- VRPTW - Vehicle Routing Problem with Time Windows
List of Definitions

In order to aid the reader and avoid confusions, this section will present key terms, their respective definition and from which point of view these are considered.

- **Airsides**: The movement area of an airport, adjacent terrain and buildings or portions thereof, access to which is controlled (ICAO, 2013).

- **Air Transport Movement**: A landing or take-off. In scheduled traffic it means a movement in commercial traffic according to an official timetable. In non-scheduled traffic it means a non-scheduled movement in commercial traffic (charters, relief services, etc.; taxi flights excluded) (Schiphol Group, 2016).

- **Consignee**: Final receiver of the shipment (Rezaei et al., 2016).

- **Consignment**: One or more pieces of goods accepted by the carrier from one shipper at one time and at one address, receipted for in one lot and moving on one air waybill or shipment record to one consignee at one destination address (ICAO, 2013).

- **Consolidation**: A consignment of multi-packages which has been originated by more than one person, each of whom has made an agreement for carriage with a freight forwarder. Conditions applied to that agreement may or may not be the same as conditions applied by the scheduled air carrier for the same carriage. Usually a consolidation implies the issuing of a master air waybill to which are linked several house air waybills and a cargo manifest (ICAO, 2013).

- **Efficiency**: In this context, the ratio of the handled tonnage per square meter at a cargo handler’s warehouse. Measured in t/m$^2$ (Districon, 2012).

- **Freight Forwarder**: Arranges the transport of the freight from shipper to origin outstation or from destination (Rezaei et al., 2016).

- **Landside**: The area of an airport and buildings to which both travelling passengers and the non-travelling public have unrestricted access (non-restricted area) (ICAO, 2013).

- **Productivity**: Rate of output per unit of input.

- **Shipper**: Owner or supplier of the freight. It is also called ‘consignor’, its ultimate goal is to send shipment to the consignee (Rezaei et al., 2016).

- **Throughput**: Rate of production or processing of a system. In this context, BUPs processed in a FT and loaded on the correct truck.
Introduction

1.1. Globalization and trade

The term globalization is used frequently when referencing supply chains and the rise of a global economy. However, it is important to know what it stands for. According to Boskov and Lazaroski (2011) globalization “refers to the growing interdependence of countries resulting from the increasing integration of trade, finance, people, and ideas in one global marketplace”. The main elements of it are precisely international trade and investment flows, which explains the surge in global transportation. Even though it can be traced back to post World War II times it accelerated exponentially after the 1980s due to new technological developments (i.e. Internet, containerization, etc.) and the deregulation of markets.

This constant growth lasted for several decades: The 90s were followed by a strong rise in the 2000s. However, the United States sub-prime mortgage crisis in 2008 triggered a sharp decline. The crisis caused a ripple effect in other markets. On a global level, the volume of exports fell by 12% while even the gross domestic product (GDP) suffered a 2% drop. In terms of value, it represented a staggering decrease of 22%. Even though in 2010 the growth rate finally rebounded (14% in volume), trade growth has been unable to match the former growth (World Trade Organization, 2015). A sum of factors like the increase of oil prices, political instability in oil-producing countries and the European debt crisis have contributed to a slower growth.

It is precisely this expanding global trade that creates the need for world transport. According to (Zhang and Zhang, 2002) the air cargo volume grows at a rate between 1.5 and 2 times the GDP growth. Freight rates and volumes are thus directly related to the trade growth of regions. In 2008, world transport exports reached US$ 891 billion. However, after a decrease of 22% during 2009, the sector has barely been able to recuperate. It was not until 2013, that exports surpassed the pre-crisis level, tallying US$ 906 billion (World Trade Organization, 2015). According to Boeing (2015), the world air cargo traffic will grow 4.7%. This forecast is similar to the one provided by IATA (2015) at 4.1%. The key routes will remain: Asia-North America and Europe-Asia, growing faster than the global average stated above. Developing markets in Africa will also contribute to the growth.

Even though the growth of air cargo is a component of the global transport, it is a specific segment of goods that make use of this mode. Statistics by IATA (2015) give an indication of this: In 2014 51.3 million metric tonnes were transported by air, representing more than 35% of global trade value but less than 1% of volume. This shows that commodities transported by air have high values per unit or require speed and reliability above cost. The World Bank (2015) quantifies the difference in cost as being normally priced 4-5 times higher than road transport and 12-16 times than sea transport. The rate can vary from $1.50–$4.50 per kilogram and usually the value of air cargo is above $4.00 per kilogram (World Bank, 2015). Typical products shipped by air are: Pharmaceuticals, live animals, electronics consumer goods, fashion garments, perishable goods and emergency shipments like spare parts or documents. The express delivery services offered by e-commerce giants can also only be provided through air freight. Approximately 340 billion letters and 6.7 billion parcels are sent annually (World Bank, 2015).

However, new developments like Just-In-Time (JIT), e-Commerce or higher passenger demand have not translated directly into revenue for the sector. Factors like a decrease in sea shipping rates of almost 75% since 2012, a low fleet utilisation of 43.5% and a flat demand for air transport, have caused a reduction in revenue of more 3% in the last 10 years (The Economist, 2016). The sector is going through a tough competi-
1. Introduction

In a challenging period where an industry-wide optimization is required, there is a need to modernize processes, improve quality and reliability and increase the services offered (IATA, 2015). The IATA Cargo Strategy mentions data integration, process integration and supply chain partnerships as key factors towards success.

1.2. The air cargo logistic chain

As stated in the previous section, the current economy requires global supply chains. The air cargo supply chain combines different actors in locations across the world so that goods can reach their final destination (ICAO, 2013). Cargo often shares routes with passengers however its requirements have little to do with terminal services or transfer ease. On the contrary, factors like pallets build up and break down, cost of transshipment and handling and temperature or humidity assurance are critical for cargo (Zhang and Zhang, 2002). Additionally, airports are required to offer a certain infrastructure and be connected to a certain network that can facilitate inter-modal transportation to the hinterland.

In order to understand the scope of this project and the involved stakeholders, the air cargo logistic chain will be explained. Based on the definition provided by ICAO (2013) and referencing Figure 1.1, it is clear that all parties have a shared responsibility. The process is initiated by the seller/shipper (or consignee) and the buyer/importer. These two parties have a commercial relationships that requires the exchange of goods via air transport. The shipper is responsible for ensuring all customs requirements are met, which will often occur through a hired broker or agent. If this agent also offers the coordination of transport services and door-to-door solutions, it is called a freight forwarder. Freight forwarders aggregate cargo received from different shippers based on its destination and brings it to the respective hub (i.e. sea-port and airport) for further transportation (Chan et al., 2012). In this specific case, they serve as the link between shippers and airlines, performing the booking and rates negotiation.

Figure 1.1: Air Cargo Supply Chain (ICAO, 2013)

Once at the airport, goods are received by cargo ground handlers who are subcontracted by the airlines or freight forwarders in case these do not possess the required facilities. The airline pays a specific fee and makes sure to include the demanded quality levels on its Service Level Agreement (SLA) (Burghouwt et al., 2014). Due to their location, which is usually airside or between air and landside, serving as a border, cargo handlers perform the following activities (ICAO, 2013) (Burghouwt et al., 2014):

- **Warehouse handling**: Collection of cargo for export flows, distribution of cargo for import flows and build up and break down of pallets. Additional services are: preparation and tagging of cargo, X-ray scanning of outbound cargo, clearing customs and on-airport storage\(^1\).
- **Ramp transport**: Transportation on airside, specifically to and from the aircraft to the warehouse.

\(^1\)Off-airport storage is performed usually by forwarders
1.2. The air cargo logistic chain

- **Ramp handling**: Loading and unloading of the aircraft.

  It is worth noting that warehouse handling is a task which is more open for a liberalised market. Specially in Amsterdam Airport Schiphol, a wide range of players operate. There are several types of players involved in freight handling, which according to Burghouwt et al. (2014) are:

  - **Self handling airlines**: Specially at their home base airlines tend to perform their own handling in order to improve reliability and efficiency. Due to the volume this becomes profitable for the airline.
  
  - **Airport operators**: In certain cases, airports offer their own handling services. An example of this is Fraport, the cargo handler or Frankfurt airport.
  
  - **Independent handlers**: These third party companies are global players active in multiple airports. Usually contracts with airlines are "multi-station", which means the airline hires the handler for several airports. In the case of Amsterdam Airport Schiphol all handlers, except for KLM Cargo, fall under this category.
  
  - **Freight forwarders**: Some make use of their first line warehouses (adjacent to the airside) in order to load/unload their respective cargo.

  The activities performed by the cargo handlers are critical in ensuring a fast throughput. The overall time for cargo operations normally depends on the following factors: customs clearance and cargo inspection procedures, efficiency of cargo handlers and the layout of the storage facilities (World Bank, 2015).

  After the aircraft has been loaded and transportation has been performed, cargo handlers take charge at the destination airport. The required procedures are followed so that the cargo can be picked up at the warehouse. From here it is usually transported by truck to a forwarder's warehouse or in special cases, directly to the consignee.

  All of these actors work directly in the Schiphol area or around it. They can be differentiated by their role but also by the position they have with regards to the airside. A differentiation is made between 1<sup>st</sup> line, 1.5 and 2<sup>nd</sup> line facilities. 1<sup>st</sup> line warehouses have direct access to airside and are normally assigned to cargo handlers. 1.5 line facilities have indirect access to airside through a special gate. These warehouses are used by freight forwarders. Lastly, 2<sup>nd</sup> line facilities are warehouses located on the airport's ground used by freight forwarders and trucking companies.
2. Problem definition

2.1. Problem statement
In order to fully understand the problem, it is important to have the context of Schiphol Group and its mission clear. This section will address Schiphol’s Group objective, the cargo department’s specific goals and the developments surrounding these.

2.1.1. Schiphol Group’s objective
The ambition of Schiphol Group is to become Europe’s preferred airport. It strives to maintain and further develop the position of Mainport Schiphol as a multimodal hub. By looking not only at how competitive the airport is but also at the competitiveness of the region, the international business climate and the strong network of KLM and the SkyTeam, the following strategic themes are defined (Schiphol Group, 2015b):

- **Top Connectivity**: Develop capacity through supporting home carrier and its partners, liberalizing sustainable capacity and welcoming new airlines (belly and freighters). Facilitating the use of the belly capacity is another component of this theme.
- **Excellent Visit Value**: Offering the best quality for airlines and other cargo actors. Achieving operational excellence on ground and becoming a leader in innovation and technology.
- **Competitive Marketplace**: Attractive business and visitor locations where knowledge can be shared and combined. Continue the development of Schiphol as a cargo distribution hub by strengthening current strategies and expanding additional verticals.
- **Development of the Group**: Expansion of international activities, promotion of an innovative environment and improved synergy within the group.
- **Sustainable and Safe Performance**: Conduct business in a socially responsible manner, weighing people, planet and profit aspects. Invest in good relationships with stakeholders.

Even though all strategic themes are related to the success of the cargo industry at Schiphol, the main strategic theme for this research is “Excellent Visit Value”. Based on it, specific goals and activities have been devised, as shown on Figure 2.1 (Cargo Department, Schiphol Group, 2016). The main topics are: Achieve operational excellence on ground and Leadership in innovation and technology. It is specifically on the first one that this project will contribute to.

According to a presentation provided by Ritsema (2016) past research has shown some key issues in the current operations of the cargo industry at Amsterdam Airport Schiphol. These are: Waiting time for trucks, long throughput times for shipments, warehousing efficiency at the 1st line and the pickup and distribution of cargo done by numerous handlers, resulting in multiple visits.

2.1.2. Developments
There are several key developments that affect the way in which Schiphol Cargo plans and expands the existing cargo hub. Schiphol’s Masterplan 2025 aims at investing on a growing volume of passengers and their
2. Problem definition

comfort. The facts make for a compelling case: Schiphol is reaching its capacity limits, the passengers’ perception of quality suffers from it and competitors are investing heavily, both in Europe and in the Middle-East (ACN, 2015).

In order to maintain the competitiveness and reach its objective of becoming Europe’s preferred airport, central security systems were implemented and capacity will be expanded. According to ACN (2015), the changes on the security systems are critical towards reduced waiting times for passengers, both Schengen and non-Schengen. This allows airlines to have more reliable departure times and enhances the passenger experience. This project was completed in July 2015.

On the other hand, the expansion of capacity will be done through the construction of a third terminal (Zuid) and a new pier, the A-pier. In order to build this, the current Vrachstation 1 from KLM Cargo will be removed. Eventually, two more piers (A’ and A”) will also be built. This part of the Masterplan started in 2013 with the rebuilding, expansion and renovation of the existing terminals and piers (ACN, 2015). As it can be seen, there are no plans to build any new runways and the increase in capacity is solely based on more efficient processes and the creation and expansion of Schiphol Centrum.

As a direct consequence of the Masterplan, cargo activities and facilities will have to be relocated to Schiphol South-East. Figure 2.2 shows the required relocations. Initially, KLM Cargo will have to relocate the processes performed at the Vrachstation 1. Following this, Vrachstation 2 and 3 will be relocated as well. On the final stage, the area where Dnata, WFS and Freshport are will follow. According to research by (van Doorne, 2013) platform capacity will not be a concern. However, 1st line area will indeed pose an issue since there is not enough airside space to provide all handlers with the existing conditions. In addition to this, Schiphol Group expects the cargo volume to increase to 3 million tonnes per year against the current 1.6 million tonnes. As it will be shown in the next chapters, it is difficult to imagine cargo volumes at AAS rising to 3 million tonnes. However, even in a more conservative demand increase, Schiphol Group has a clear understanding of their limited 1st line space, which is why thorough research has been done on the topic. This will be detailed in section 2.2.

2.1.3. General problem statement

Based on the context and developments it can be stated that Schiphol Cargo’s general objective of:

“Continuously increase the competitive position of Schiphol within the European cargo market and become Europe’s preferred cargo airport”

is at risk due to the limited 1st line capacity available in the South East area. Additionally, the need to have spare capacity for future growth compels Schiphol Cargo to revise the current business model and logistics concepts used currently by the parties active at the airport.
2.2. Previous research

Due to the existing problematic, several researchers have gone into the details of possible solutions and design alternatives. The investigation has been thorough, however, on this section, only the most relevant results will be discussed as the foundation for this research.

2.2.1. Cargo of the Future

The first research on this topic was performed by van Doorne (2013) in order to understand what the feasible alternatives for a more efficient use of warehousing and transportation modalities exist. The outcome of the research shows that the ramp demand will not be a concern (demand of 26 ramps vs. the available 32) but 1st line area will indeed be a bottleneck. By assessing the following three alternatives, he lays the base for further researchers.

- 1st line aircraft handling with 2nd line warehousing.
- 1st line aircraft handling with collaborative 2nd line warehousing.
- Collaborative warehousing by all parties except AF-KLM Cargo.

Results show that removing the warehousing function from the 1st line is very effective, as long as the area is used to its full potential. Hybrid construction also proves to be profitable, allowing AF-KLM Cargo to obtain their preferred space on the 1st line area and creating a shared 2nd line facility for the other handlers. Pending research according to van Doorne (2013) should go deeper into the costs and benefits, juridical and liability aspects, alternative configurations for 1st line facilities and locations for the cargo handling.

2.2.2. Central Pick Up and Drop Off Point (CPD)

The fundamental idea of a CPD was discussed during an air cargo conference in Munich in 2013. The concept is basically taken from other industries like city distribution and sea ports (Lubbe, 2015). It has several advantages like: centralised location for loading and unloading of trucks, eliminates multiple truck visits, reduces shipment throughput time, truck visits and waiting times and costs. It relieves the congestion of the air cargo facilities. On the other hand, however, by adding an extra link on the chain, it could cause delays, cargo damages, increased complexity and extra storage. It would also eliminate the possibility of differentiation amongst cargo handlers since the facility is shared or managed by a third party. Figure 2.3 shows the CPD concept and how flows change due to its implementation.

Following up on van Doorne (2013), Lubbe (2015) and de Wit (2014) looked into the design of the CPD in terms of functions and which location would optimise the cargo flows between airstside and the CPD. van der Donk (2015) on the other hand, looked at whether or not the CPD could be developed and function effectively in the existing cargo logistics chain. The research carried by Lubbe (2015) shows that the preferred conceptual
2. Problem definition

Figure 2.3: Current and CPD flows (Ritsema, 2016)

design for the CPD would include build up and break down and destination (de-) consolidation. Additionally, a fast-track handling CPD with airside access should be included. However, the expected space limitations are not solved fully by simply building a CPD.

de Wit (2014) looked into the potential of a CPD to accommodate the future cargo flows of 3 million tonnes of cargo. The results show that 50% of the flows are appropriate for handling in the CPD, however, the introduction of it will cause poorer performance of the overall system due to truck waiting times and the lack of information sharing among parties. Regarding the location, she assessed three alternatives:

1. Off-airport CPD: Flows still go through the 1st line facilities which increase the required area.
2. Off-airport CPD with Bypass Gate: Scores well on the use of capacity, however, it is not realistic to assume all ULDs can be picked up at the gate.
3. On-airport CPD: Not a realistic design since it requires 79,000 m². Under the existing Masterplan, that area is not available.

Based on the above, de Wit (2014) proposes to use a combination of an off-airport CPD and an off-airport CPD with a Bypass Gate. The latter could provide a fast system for ULDs that can be picked up directly by the CPD shuttle service and if required, the 1st line warehouses can still be used for handling activities.

Finally, van der Donk (2015) proposes the following critical design variables for the CPD: The proximity of the CPD to AAS, the level of obligation or stimulus for usage, the range of services offered, the ownership, the responsibility of operating it and the model of costs and gains sharing. Based on this, the preferred CPD design is one with an airside and a landside facility. The airside facility would be handled by freight forwarders jointly, while the landside one by ground handlers. This design has a positive influence on the cultures and beliefs of the key stakeholders and fulfils the design criteria. The implementation of it would reduce truck movements by 4% to 13% (35,000 to 135,000 truck movements yearly).

2.2.3. Process improvement and collaboration

Specially in a multi-actor environment like that of Amsterdam Airport Schiphol, collaboration is of critical importance in order to reach any improvement, either in quality or efficiency. It is for this reason that Pieters (2014) takes a look at how Schiphol can, on its facilitator role, improve the quality of the air cargo supply chain. It does so by analysing two perspectives: System and Actor. By understanding the system’s issues the author is able to identify which ongoing projects (ACN-card, E-freight and E-link) have the potential of solving them. Additionally, by appraising the broad network of actors (6 cargo handlers, 150+ trucking companies and 80+ freight forwarders) Pieters (2014) is able to identify the low degree of cooperation among these actors. Even though there is a desire to work together, commercial interests, the economic environment and the low willingness to invest in local systems, make the cooperation nearly impossible.

Schiphol should thus act as a process manager for innovations and implementation and focus on: Interoperability of the E-link with systems at the several actors, protection of core values of companies involved, security and quality of information, better naming and framing of E-link advantages, transparency and an increase of ACN card adoption.

Equally insightful is the research conducted by Ankersmit et al. (2014) at Air Cargo Nederland (ACN) where he defines to which extent the logistics operations of truck movements between the freight forwarders and
the cargo handlers can be improved, by applying horizontal collaborative concepts. He performs a qualitative and a quantitative analysis divided into four main parts (Ankersmit, 2013):

- **Assessment of current transport collaboration and global air cargo system use developments at major air cargo airports**: The benefits from horizontal collaboration are: transport costs, transport performance, sustainability, effective/efficient use of resources, stabilisation of cargo flows and improved relationships between stakeholders. ULD shipments and loose cargo result as the most suitable type of cargo to include in collaborative transport. However, it is clear that the way of doing business is based on single company strategies, which reinforce congestion and increase handling times. A combination of vertical and horizontal collaboration is required in order to efficiently manage the transport needs of several forwarders from one specific handler.

- **Managerial implications regarding horizontal transport collaboration**: The extent of collaboration depends on many aspects. Some of these are: technical shipment transport requirements, drivers for transport collaboration, company facilitators, companies' ability and willingness to support both collaborative and single company transport and the ability to segment the collaboration for specific shipments. Figure 2.4 captures these aspects and the relation between the actual and potential collaborative transport.

- **Case study simulation**: Cargo flows are assessed separately for loose cargo and ULDs. As a result, the model requires a minimum of 50% of shipment volume of the three involved companies to be transported in a collaborative way in order to have fewer costs. In the case of loose cargo, costs can be cut by 20% to 70%, while truck movements by 20% to 40%. In contrast, it increases throughput time between 1 to 3 hours, which can be reduced to 30 minutes by limiting the amount of combined cargo when waiting. Based on this increase, it can be concluded that import collaboration on loose cargo has potential, whereas, for export, it might increase times in an unacceptable way. In terms of ULD transport, collaboration only shows a minor impact on transport movements and throughout times. And yet, it can reduce transports costs between 5% to 40%. It is worth noting that waiting policies for ULD were not assessed under this model and a simple as-soon-as-possible policy was used.

- **System perspective of loose cargo transport collaboration with the Schiphol air cargo system**: Loose cargo represents the largest share of cargo handled at Schiphol (60% to 70%). The average weight of these type of shipments is 300 to 400 kilogrammes per shipment. The potential for collaboration on loose cargo depends on: number of forwarders within Schiphol area at a specific handling facility, the frequency and weight of loose cargo shipments at a handling facility for a specific forwarding company, the location of the forwarder in relation to the handler and the possibility to combine ULD and loose cargo shipments flows.

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**Figure 2.4: Conceptual model for the assessment of transport collaboration potential (Ankersmit, 2013)**

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**2.2.4. Fast Track Facility (FTF)**

Building upon the research performed by van der Donk (2015) who advises for an airside CPD in addition to the landside one, Kallen (2015)'s research explores the design space for a 1st line facility which increases...
the 1st line productivity and can be integrated in the multi-actor cargo supply chain at Schiphol. A so-called Fast Track Facility (FTF) makes use of the cross-dock concept to create a terminal, on the 1st line, which is used for cargo transhipment. The cargo going through it does not require build up or break down since they are transported on Unit Load Devices (ULD), either in the form of pallets or containers. On export, they are destined for the same flight, and on import, the same freight forwarder. These ULDs are referred as Build Up Pallets (BUPs). The concept of the FTF is to bundle BUP flows from different clients. According to Kallen (2015), the contribution of the FTF is the facilitation of cargo volumes due to an increased productivity and an increase in Schiphol’s attractiveness as a cargo hub.

The process followed in the transportation of goods handled through a Fast Track Facility starts at the aircraft stand with the loading the BUP on the transportation equipment (dollies or transporters). The choice for the equipment is made at the handlers facility once the distance to the aircraft is known. If the aircraft stand is close to the handler’s facility and customs check is not required, then the cargo is loaded on transporters and moved to the specific storage spot in the handler’s warehouse. If the cargo requires the customs check, it is taken directly to customs and from there on, to the handler’s facility. Once at the handler’s, the distinction between ULDs and BUPs is made. Paperwork is checked and if there is compliance, BUPs are placed on the fast track. The BUP is rolled to a buffer zone bypass and, based on the information of the truck arrival, placed either on the buffer zone, tilted off the track to a storage spot off-track or pushed through to the assigned dock for the truck loading. The stored BUP will be placed on the track again or rolled to the dock once the truck arrival time approaches. Once loaded, the truck will transport the load to a 2nd line facility.

It is important to note that a basic requirement for a successful cross-dock is a seamless flow. This results in a low variance in the arrival and service processes in the system. In terms of the input, it is assumed that a first come first out (FIFO) method for import cargo is used and that the required split between BUPs and ULDs is done at airside, before reaching the FTF. The storage system at the facility functions as a buffer aiding in peak management, however, the truck system responsible for the output of the FTF is also required to function smoothly (Kallen, 2015). This research urges Schiphol to support the existing Milkrun efforts. A Milkrun is simply when trucks combine shipments from different clients and thus performs its route with an increased load factor. A consequence of this is less congestion and faster overall transhipment times. Supporting software with the necessary information (pick up and drop off time windows and dock allocation) should be implemented.

Kallen (2015) proposes thus, based on the FTF requirements and the most important design variables, two alternatives: Manual and Automated. Through a simulation, a comparison between both options and a simplification of the actual situation is achieved. According to the author: "Compared to the current BUP transhipment system, both interpretations of the design space contribute to AAS productivity and result in a decreased lead time. Both alternatives are able to handle at least 2.75 times the current estimated BUP throughput." And yet, in terms of required area, it is clear that the automated one has a better performance. This design has a capacity of 550 pallets per day, which can be stretched with an extra layer to more than 606 pallets per day. This would come at a cost of 0.3 million euros. The layout of this preferred alternative is shown on 2.5

![Figure 2.5: Layout and Profile Automated Design Alternative (Kallen, 2015)](imageurl)

The outcome of the research performed by Kallen (2015) shows, however, that even with the maximum capacity of 606 pallets per day, the productivity would only reach 42.5 ton/year/m². This translates into a shortfall of nearly 3 ton/year/m². In terms of time, a lead time under 2.5 hours is ensured, with an average of 1.5 hours. All of this is, of course, dependent upon the adoption of the actors in the chain, which is why Kallen (2015) also looked at the institutional design and based on interviews and literature, proposed one that
stimulates the use of the FTF, as it can be seen on Table 2.1.

Table 2.1: Suggested institutional design FTF (Kallen, 2015)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Institutional Design Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>Schiphol Real Estate</td>
</tr>
<tr>
<td>Operator Responsible</td>
<td>Neutral 3rd party Forwards Handling Priority Requirements: Schipol</td>
</tr>
<tr>
<td>Costs and Gains</td>
<td>Forwarder:</td>
</tr>
<tr>
<td></td>
<td>- Pays FTF operator per use</td>
</tr>
<tr>
<td></td>
<td>- Gains from decrease in truck movements and lead time</td>
</tr>
<tr>
<td>Schiphol Stimulant</td>
<td>Initial investment terminal building and equipment</td>
</tr>
<tr>
<td></td>
<td>Initial price subsidy per pallet</td>
</tr>
</tbody>
</table>

2.3. Knowledge gaps

As mentioned in Section 2.2 there have been numerous researchers tackling different facets of the general problem. In order to solve the problematic that rises due to the Masterplan, Schiphol cargo developed a comprehensive research plan. van Doorne (2013) looked into the ramp and 1st line capacity, concluding that the latter is indeed limited and will become a bottleneck. Lubbe (2015) analysed the processes that should be performed at a CPD, with de Wit (2014) assessing the corresponding truck movements between 1st line cargo handlers and the CPD. Based on this, she proposed the location for the CPD. van der Donk (2015) developed the business model on a set of different scenarios. Kallen (2015) developed the fast track for import BUPS, while Schoenmaker (2016) looked into the options to increase handling capacity on the 1st line under footprint constraints. In parallel, Pieters (2014) assessed the role Schiphol Group can take in order to improve the quality of the chain and assessed specifically the truck waiting times. Similarly, Ankersmit (2013) evaluated to what extent truck movements between handlers and forwarders can be improved through horizontal collaboration.

Figure 2.6: Research on the relocation of cargo to Schiphol South-East
Figure 2.6 shows the designed system composed of airside, 1st line facilities for cargo handlers and fast track, 1.5 and 2nd line facilities for freight forwards and also on the 2nd line, the CPD. The check icons represent previous research and filled knowledge gaps. Export flows going through the FTF are represented in grey because, according to Kallen (2015), these are not feasible. If the actor environment were to change and the demand for export BUP would increase, then it should be reconsidered. Red cargo flows represent the import BUPs that go through the fast track. This section of the problematic has not been investigated yet and constitutes the knowledge gaps in the research. Based on this, two knowledge gaps are identified:

**Gap 1: What is the transport process and actor configuration at airside that meets the fast track's needs for higher 1st line productivity?**

The design for a fast track assumes a seamless transport flow, however, it does not go into detail on when and where the decision is made regarding which cargo goes to the fast track and which one goes straight to the CPD or other 2nd line facilities.

Additionally, there is no proposal in terms of the actor configuration. Currently, there are 6 cargo handlers (excluding KLM Cargo) who are active at Schiphol. The subsequent coordination among these and the possible priority treatments are at this point unknowns.

**Gap 2: How can the truck scheduling and planning at landside contribute to a higher fast track throughput at Amsterdam Airport Schiphol (AAS)?**

Even though there is a Milkrun initiative among certain players at Schiphol, the consideration of what such a design would look like in the case of a fast track is non-existent. As authors like Buijs et al. (2014) and Van Belle et al. (2012) state, research on cross dock concepts goes into detail on the specifics of each factor, not going in depth in the inter-dependencies among these. Future research that integrates several problems in one approach, like the combination of truck scheduling with the routing of the trucks, is encouraged by Van Belle et al. (2012). An example of the factors that influence each other is: routing schedules, trucks deadlines, arrival times at cross docks and truck loading. The scientific value of this research is thus apparent.

### 2.4. Research questions

Based on the above, it can be stated that the objective of this research is to analyse the transport process between the aircraft and the fast track and the distribution from it to 2nd line facilities. Through this analysis, a deeper understanding of the critical variables will be achieved and based on it, a conceptual design for the stated networks advised. The main research questions for this research is:

*How can the input and output distribution processes of a fast track at Amsterdam Airport Schiphol facilitate a seamless flow in the context of a multi-actor environment?*

The following sub-questions are formulated in Table 2.2 in order to answer the main research question:

<table>
<thead>
<tr>
<th>Research Sub-questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are the characteristics of the current distribution processes?</td>
</tr>
<tr>
<td>2. What are the requirements in terms of input and output of the FT?</td>
</tr>
<tr>
<td>3. Which distribution and cross docking design variables have a critical influence on the functioning of the FT?</td>
</tr>
<tr>
<td>4. What are the theoretically viable alternatives to design a distribution process that facilitates higher FT throughput?</td>
</tr>
<tr>
<td>5. What are the required actor configurations under the presented alternatives?</td>
</tr>
<tr>
<td>6. What are the recommended distribution alternatives under a number of scenarios for the FT?</td>
</tr>
<tr>
<td>7. What are the benefits and shortcomings of the recommended alternatives?</td>
</tr>
</tbody>
</table>

### 2.4.1. Project scope

The cargo flows within the scope of this research are the import ones, which arrive as a Build-Up-Pallet (BUP). The design and results of the previous research will be taken into account to determine the requirements of the fast track.
As this research builds on previous work by other authors some restrictions are present. For instance, the fact that the FT will be situated at Amsterdam Airport Schiphol South-East and that its design has already been devised. This means that certain variables concerning the internal operations of the FT like the shape and levels of the terminal, the transhipment direction, as well as the required equipment and resources are out of the scope. However, it is important to state that variables concerning the FT, which are part of the interface between the assessed distribution systems and the FT itself, will be analysed.

Finally, distribution will be assessed only on airside whereas on landside the scope includes only the terrain of the FT. The specifics on landside include the arrival process, dock allocation, loading and departure. Two truck types (i.e. RFN and AMS) are included and each of these is split into several destination groups. Even though gaining insight into the distribution on the airport’s hinterland is valuable, there are numerous barriers to doing so. Thus and after consulting with experts on the topic, the landside distribution is considered out of scope.

### 2.5. Methodology and approach

In order to devise an appropriate set of design alternatives, a methodology that incorporates innovation, stakeholders engagement and a high degree of development, the Delft Design Guide is consulted. According to van Boeijen (2013), “designing is an activity that is supposed to lead to new possibilities and an embodiment of those possibilities”. It is clear that possibilities are also uncertainties, which is why as a designer there is a need to incorporate and offset these.

The basic design cycle by Roozenburg and Eekels (1995) is applicable to all design problem, independent of their nature, which is why it will be used in this research. As Figure 2.7 shows, it is composed of the following main steps: Analysis, Synthesis, Simulation, Evaluation and Decision. The analysis is the first step, in which the intended behavior or function of the new process or product is defined. So, it is not only necessary to include technical aspects but also the context around the issue (i.e. social, economic, market). It is in this phase that the problem statement and the criteria that the solution should meet are defined. This criteria or ‘performance specification’ will be improved later in the process. Following this, the synthesis is where the design proposal is created. This is done based on human creativity and the combination of separate ideas and factors. However, this design is not a definitive proposal. It is only provisional design, and its value will become clearer on the next step. It is then, during the simulation that the deductive process occurs. As van Boeijen (2013) states: “Simulation is forming an image of the behaviour and properties of the designed product by reasoning and/or testing models, preceding the actual manufacturing and use of the product.” The simulations can be based on actual data or it can be based on generalisations from experience. Even if the results may not precise, it provides a way of obtaining expectations on the properties of the designs. The fourth step is evaluation and as it names says, it is in this step where the value or quality of the design is compared to the desired properties. It is normal for differences to exist, which is why it needs to be defined if these are acceptable or not. Finally, the decision step is where the designer chooses to either continue and actually elaborate the design proposal or to iterate on the design proposal and improve it. Going back to the synthesis step is quite frequent and even in certain cases, all the way back to the analysis to re-define the formulation of the problem. As it can be seen, it is an iterative process, where cycles are repeated and steps interconnected with each other.

Based on the research question and sub-questions mentioned in Section 2.4, an initial planning can be formulated, as seen on Table 2.3. The research approach is shown in Figure 2.8. The associated numbers correspond to the research sub-questions. As it can be seen there are two design rounds. On the first one, the proposed FT by Kallen (2015) is assessed based on literature and the critical design variables re-defined as required.
Table 2.3: Research Methodology

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Topic</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>Literature review, Interviews</td>
</tr>
<tr>
<td>2</td>
<td>Problem Definition</td>
<td>Literature review, Interviews</td>
</tr>
<tr>
<td>3</td>
<td>Literature Review</td>
<td>Literature review</td>
</tr>
<tr>
<td>4</td>
<td>Distribution Process Analysis</td>
<td>Process flow diagrams, Field Research and Interviews</td>
</tr>
<tr>
<td>5</td>
<td>FT Design Revision</td>
<td>Literature review, Interviews, Workshop</td>
</tr>
<tr>
<td>6</td>
<td>Design of FT and Distribution Alternatives</td>
<td>Literature review, Historical data, Interviews</td>
</tr>
<tr>
<td>7</td>
<td>Discrete Event Simulation</td>
<td>Literature review, Discrete Event Simulation</td>
</tr>
<tr>
<td>8</td>
<td>Research Discussion</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Conclusion and Recommendations</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.8: Schematic research approach
In this chapter, the relevant literature will be laid out and explained. This serves as a vital step towards building a successful FT and Distribution design and will serve as a base and reference in Chapter 5: FT Design Revision. First, the concept of a Cross Dock is explained in Section 3.1 following by a shorter definition of Truck scheduling and planning (Section 3.2). After this, the theory on distribution and Vehicle Routing Problems will be detailed in Section 3.3. Finally, the concepts of Push and Pull are explained and translated to the context of Schiphol in Section 3.4.

3.1. Cross-Docking

The concept of cross-docking is based on the transfer of incoming goods directly to outgoing vehicles for distribution. In a traditional distribution center, goods are received and stored. Once it is requested by the customer, warehouse personnel performs the picking and packing for shipping. From this process the basic functions of a warehouse can be derived: receiving, storage, order picking and shipping. As a part of the ever growing need for cost reduction, the two most expensive functions of warehousing (i.e. storage and order picking) have been eliminated and thus, the concept of cross-docking arises (Van Belle et al., 2012). Contrary to a normal setting, under a cross-dock one, goods are already assigned to a customer in advance or upon reception (Gue, 2007). This facilitates sorting, consolidation and the generation of FTL instead of LTL (Rodrigue et al., 2013). According to Yu (2002) the process at a cross dock facility is typically: i) Cargo arrives on the receiving docks, ii) Cargo is scanned and verified at the receiving docks where in some systems cargo is also weighed, sized and labeled there, iii) Cargo is placed on the sortation systems, iv) Cargo is processed to the appropriate location on the shipping docks and v) Trucks load the cargo at the shipping docks and then leave. This difference in operations between a traditional distribution center and a cross dock can be seen in Figure 3.1. On the left side of the figure, the concept shows the transshipment function with no storage, while on the right side, a comparison between the truck movements is shown.

The definition of cross-docking can vary based on the author’s perspective. Some put a bigger weight on the consolidation of shipments in order to reduce transportation costs, whereas others focus on transshipment. For this research, the definition stated by Van Belle et al. (2012) will be used:

Cross-docking is the process of consolidating freight with the same destination (but coming from several origins), with minimal handling and with little or no storage between unloading and loading of the goods.

It is worth noting that one of the main challenges of a cross-docking operation is the synchronization of incoming and outgoing vehicles. A perfect and flawless synchronization is practically impossible to achieve, which is why a storage buffer is required. Authors agree on the fact that the storage should be for a short period of time (i.e. less than 24 hours) (Van Belle et al., 2012) (Rodrigue et al., 2013). Some of the benefits of cross-docking are: better synchronization with the demand, more efficient use of transportation assets (FTL vs. LTL), reduction of inventory and warehousing costs, reduction of order cycle time, increased responsiveness and flexibility of the distribution system and improved control of distribution (Yu and Egbelu, 2008) (Van Belle et al., 2012) (Buijs et al., 2014). As Rodrigue et al. (2013) argues, cross-docking can be of benefit in different aspects of the supply chain. In the case of manufacturing it can support
JIT assembly, for distribution it helps with consolidation of inbound products, for transportation it aids in achieving FTL instead of LTL batches and for retail it is concerned with receiving from multiple suppliers and sorting to different stores. It is for this reason, that cross-docking is a widely used concept in logistics and has seen a considerable rise since Walmart first applied it in the 1980s.

The simplicity of the concept should not lead readers to believe there is only one type of cross-dock. There are distinctions based on the number of touches or stages, customer assignment moment (i.e. pre-distribution or post-distribution cross-docking) and even on the location of the cross-docking terminals. In the case of the distinction based on touches, there are several configurations. The one-touch configuration (i.e. pure cross-docking configuration), in which the products are received and loaded directly in an outbound vehicle; two-touch configuration where products are staged on the dock until loading and multiple-touch, where products are received, staged and reconfigured for shipment before loading.

In addition to this, and according to the study conducted by Van Belle et al. (2012), the characteristics of a cross dock can be split into:

- **Physical:** *Shape* as described by letters (e.g. I, L, U, ...). *Number of dock doors*, which ranges usually in size from 6 to 8 to more than 200 doors. *Internal transportation*, which can be executed manually, automated or as a combination of both.

- **Operational:** The *service mode* determines the degrees of freedom in dock door allocation. If it is an exclusive mode of service, dock doors are exclusively for incoming or outgoing trucks (normally the case in I shaped terminals). For mixed modes, incoming and outgoing can be processed at all doors. A combination mode is also possible. The *dock holding pattern* is also critical. There are two strategies: The first, in which the truck is either fully loaded or unloadeed and leaves only after completion of the task. The second, also called *pre-emption*, in which case the truck loading or unloading is interrupted and the truck removed from the dock to make room for another one. The truck would wait until a dock becomes available and then the task can be completed.

- **Flow:** The *arrival pattern* of the shipments is critical. In this case, the incoming traffic would consist of dollies and transporters. The pattern can be concentrated or scattered. Likewise, the *departure pattern* of the trucks can be restricted or not. If restricted, trucks would leave before a certain time, in order to avoid delays, even if the full load has not been loaded. In terms of the products, there are instances where *product interchangeability* exists. However, that is not the case at AAS since all cargo has a specific destination upon arrival at the FT. *Temporary storage:* For pure cross-docking, no storage is used, since goods are immediately loaded into the trucks. However, in practise, the cargo is temporarily stored on the floor of the assigned door or at a small warehouse. As mentioned by Kallen (2015) a storage buffer is usually required due to the fact that a seamless input and output flow cannot be guaranteed. However, if a flow can be depended upon, no temporary storage is also an option. In this case, the cargo is simply placed at the shipping dock until loading is possible.
3.2. Truck scheduling and planning

Even though a cross dock might seem like a relatively simple system to design and handle, there is a considerable amount of work and planning that goes into making it successful. One of the most critical operational tasks at hand is the coordination of receiving and shipping trucks to the appropriate docks in the proper sequences. According to Yu and Egbelu (2008), improper sequencing increases operation completion time. However, the need for this type of operational management is often forgotten and left for the cross-dock employees to be executed (Yu, 2002). In some cases that is the supervisor, but in others, as in Schiphol, the warehouse employees decide which trucks to give priority to and which ones to serve later (Pieters, 2014).

Yu (2002) conducted research on this topic keeping the internal operations of the cross dock out of the scope. This means that "the arrival sequence of the cargo at the shipping dock is the same as their unloading sequence at the receiving dock". According to the author, the critical variables that affect the operational strategies of the cross-dock are: Number of dock doors, dock holding pattern and temporary storage. As it becomes clear, this is fully aligned to that presented in the previous section (3.1). Van Belle et al. (2012) present the same critical variables, while adding the ones relevant for the internal operation of the cross-dock. In Section 5.2, a final list of critical variables will be presented.

The number of models that can be derived from the diversity of these variables can be plentiful. In his dissertation Yu (2002) arrived to 32 models by changing just 3 variables: Docking pattern, number of docks and temporary storage. In it, the goal of his research was to reduce the total operation time or makespan (i.e. from the moment the first cargo of the first truck is unloaded to the moment when the last cargo is loaded on the last shipping truck). In order to reach a solution, mathematical modeling proves to be limited due to the size of the problem. It is for this reason that a heuristic algorithm was developed with the idea of reducing the total number of products that pass through the temporary storage. The stated factors can be seen in Figure 3.2, where it is clear which ones are in and out of the scope of this research.

![Figure 3.2: Factors influencing the makespan. (Yu, 2002)](image-url)

3.3. Distribution

Even though logistics was originally used for military operations, nowadays, it functions as the backbone of the global economic activity. A key part of it is precisely distribution, which facilitates the exchange of goods from producers to consumers all across the world. Throughout the ages, transport means have changed: During the industrial revolution rail was center field, while in this decade, an intermodal approach is extensively used (Hesse and Rodrigue, 2004). In the case of this report, the supply chain scope is specifically that of the distribution surrounding the import of air cargo, which means that transporters and dollies are used for airside and trucks for landside transportation. According to Hesse and Rodrigue (2004) there are two main types of distribution: Point-to-point and corridor. In the first case, there are particular and specific one-time orders, which even if they do not compose a logistical challenge, increase costs considerably due to their LTL nature and the empty return problems. Corridors, on the other hand, offer more general services, often connecting hubs and gaining cost efficiencies due to FTLs and optimized routing. Gue (2007) adds another layer and splits corridors into its possible strategies: Warehouse and Cross-dock operations.

At the moment, and as it was assessed in the previous chapter, Schiphol’s airside operations are defined by a point-to-point nature carried by the cargo handlers. On the landside, the situation is harder to define.
Even though trucking companies try to create and manage corridors, each freight forwarder (or customer) optimizes their own chain solely. In an air industry like the one present at Schiphol, with more than 100 freight forwarders and 200 trucking companies, optimizing individually and not as a system, creates considerable inefficiencies.

In order to understand which distribution alternatives have a critical importance on the design of the FT, the **Vehicle Routing Problem (VRP)** is explained and its variants presented. VRP is a generalization of the famous Travelling Salesman Problem (TSP) used initially in the 1960s to identify the optimal route for petrol deliveries to gas stations (Kumar and Panneerselvam, 2012). It represents a range of problems in which "a set of routes for a fleet of vehicles based at one or several depots must be determined for a number of geographically dispersed cities or customers" (NEO Research Group, University of Malaga, 2013). The premises of the VRP are the following (NEO Research Group, University of Malaga, 2013) (Kumar and Panneerselvam, 2012) (Caric and Gold, 2008):

- **Objective:** Supply a number of customers known demands with minimum-cost routes starting and ending at a depot. Costs can be improved by reducing the total travelled distance or the fleet size.
- **Premises:**
  - All customers are served only once in a 1 day period.
  - Each customer $i$ has a non-negative demand $q_i$, where $q_i < Q$.
  - A fleet of $m$ identical vehicles of capacity $Q$ is based at the depot.
  - The fleet size $n$ is given a priori or is a decision variable.
  - There are no waiting times $W_i$ at the customers.
- **Solution:** A feasible solution is that of a set of routes which satisfy the demand and all begin and end at the depot. An optimal solution is both feasible and fulfills the objective of minimizing cost.

VRP is a combinatorial optimization and integer programming problem, which makes it a non-polynomial-hard (NP-hard) and is thus best solved using heuristics (Kumar and Panneerselvam, 2012). Figure 3.3 shows the typical input of a VRP and its solution. The complexity rises when real world problems are analysed, and it is for this reason that constraints are relaxed or added to the original VRP. Table 3.1 shows these variations and the respective change in premises. The underlined green variants are the ones applicable to the scope of our research.

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1. Size of problems that can be solved optimally is limited. However there are efficient algorithms for verifying proofs
2. Involving problem-solving by experimental and especially trial-and-error methods (Merriam Webster, 2016)

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Figure 3.3: From left to right: Typical VRP input, Solution to VRP. (NEO Research Group, University of Malaga, 2013)
Table 3.1: VRP variations. (Kumar and Panneerselvam, 2012) (Caric and Gold, 2008) (NEO Research Group, University of Malaga, 2013)

<table>
<thead>
<tr>
<th>VRP Variation</th>
<th>Additional constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVRP</td>
<td>Capacitated</td>
</tr>
<tr>
<td>MDVRP</td>
<td>Multiple Depot</td>
</tr>
<tr>
<td>PVVRP</td>
<td>Periodic</td>
</tr>
<tr>
<td>SDVRP</td>
<td>Split Delivery</td>
</tr>
<tr>
<td>SVRP</td>
<td>Stochastic</td>
</tr>
<tr>
<td>DVRP</td>
<td>Dynamic</td>
</tr>
<tr>
<td>OVRP</td>
<td>Open</td>
</tr>
<tr>
<td>VRPSF</td>
<td>Satellite Facilities</td>
</tr>
<tr>
<td>VRPPD</td>
<td>Pick-Up &amp; Delivery</td>
</tr>
<tr>
<td>VRPB</td>
<td>Backhauls</td>
</tr>
<tr>
<td>VRPTW</td>
<td>Time Windows</td>
</tr>
</tbody>
</table>

3.4. Push and Pull systems

In supply chain, the concepts of "push" and "pull" have been widely used to describe systems ranging from inventory management to manufacturing and distribution. There are different definitions and each author tends to focus on a specific aspect. It can either be the material control mechanisms, the policy applied for inventory management and production scheduling or even a "tale" made up by consultants. However, and as Pyke and Cohen (1990) point out, it is not useful to name an entire system as either push or pull since in reality, these are mixed in the decision making process. All systems have elements of push and pull.

According to Bonney et al. (1999): "Push means to take action in anticipation of a need, pull means to take action on request." It becomes obvious then that in terms of inventory management, push is focused on looking back while pull looks ahead. Additionally, the push and pull differentiation has to do with information and where the decision making occurs. Pull systems decentralize decision making, whereas push systems have a centralized process that determines requirements, lead times and feedback information (Pyke and Cohen, 1990).

But the theory is not so straightforward since defining which system works best in a certain process for a company depends on the competitive dimensions of it. These are price and cost, quality, dependability and flexibility. As Olhager and Östlund (1990) point out, it is impossible to excel in all dimensions simultaneously, which is why compromises need to be made. Either way, the goal of both systems is the same: delivering the right product in the right quantity at the right time and at the right quality.

However, since most of the research and literature focuses on manufacturing and inventory management it seems like distribution simply follows the strategy devised by headquarters. But as mentioned, most systems work on a combination of push and pull. Where these strategies can integrate varies greatly still a common point of integration exists. This is the customer order point, which is when a product is assigned to
a specific customer (Olhager and Östlund, 1990). In the case of the process under analysis, this could be the point in which cargo handlers know which shipments need to be expedited to a specific customer and picked up by a specific trucking company.

With the goal of generalizing the concept of the push and pull systems and transferring into the realm of analysis, the framework by Pyke and Cohen (1990) will be used. According to the author the how and where the decisions are made and who get to make them is critical in defining a system. For it the concepts of upstream and downstream are extremely useful in portraying these theories. Upstream locations are those closer to the origin, whereas downstream locations are closer to the end customer. So, in the case of Schiphol, upstream locations might be for example the producer of flowers booking the flight through its freight forwarder and downstream, the flower shop. Following from this, the material control decisions according to Pyke and Cohen (1990) and adapted to the study case of Schiphol are presented:

- **Batch Size**: This component defines the shipment order quantity or in this case, the shipment to be loaded in a truck. In a push environment, upstream locations define this, whereas in a pull system, it is done downstream. In this research, an upstream location is considered as the original booking with the airline done either by the customer or the freight forwarder. So, a push system would respect incoming shipment sizes, whereas a pull one would allow the trucking company to challenge this and change it according to their truck scheduling and route planning.

- **Timing**: Once the shipment size is determined, the question is when does it need to be shipped. Again, this could be defined either through the received contract or done downstream by the trucking company. For Schiphol, having a fully push system would prevent trucking companies from having the flexibility to plan their routes and optimize their resources (i.e. truck load, trucker available hours, etc.) However, a full pull system would also not work optimally since the customer needs an assurance of when the cargo will be delivered. It is for this reason, that for Schiphol a combined system of push/pull would be beneficial. In this way, the push component defines what the delivery date at the customer is and the pull component allows the trucking company to inform the handler the time range in which the cargo will be picked up.

- **Priorities**: This factor is particularly important for the role of the cargo handler or in future, of the FT. This decision introduces the challenge of defining in which order to process orders (i.e. load shipments in trucks). Is the handler allowed to change the First In First Served (FIFS) sequence? A push system has a strict defined sequence and grants no authority to the downstream facility to decide. However, for a case like Schiphol, and specially because of the different types of cargo handled, priority treatment should lay at the handler’s side.

- **Interference**: Related to the topic of priority treatment, there is interference where the issue of emergency expediting is addressed. This applies to outlier situations that may cause agitation in the system. This is not applicable to the case under study completely, due to the number of parties the handler deals with both upstream and downstream. So, it would be unable to coordinate with one single party but on the contrary, would have to go back and forth between customers and airlines. Despite this, the system could also not function on a full pull way, providing all authority to the downstream party (i.e. end customer or trucking company). Again, as a transshipment point that functions in a multi-actor environment, a combination of push/pull would be optimal. In this way, the FT would have the authority to negotiate with the party that is suffering the “emergency” and define which trade-offs it can take without impacting other parties and when it would need to go back and re-plan. What is key is ensuring that the process is coherent and standard across shifts and employees. By doing so, both trucking companies and customers can be guaranteed that no arbitrary decisions are made by tactical employees.

After having applied this framework on the air cargo supply chain at Schiphol, it is clear how difficult it is to conceive a system in which the cargo handler or the FT would have more authority and flexibility in the decision making process. As of right now, they work mostly in a pull way, following the availability of the truck company. There have been attempts to gain control and introduce push strategies, like creating slots for truck loading. This was implemented by Dnata for the Amsterdam area trucks and it has worked relatively well, however, in the case of the RFN trucks it has failed (Kervezee, 2016). How the cargo handlers or the FT for that matter can have more authority and take a more prominent role in the decisions made will be assessed throughout the report by considering the push/pull tendency of a system as a configuration variable.
This section analyses the air cargo industry at Amsterdam Airport Schiphol by first going over its generalities, including the industry perspective and that of Schiphol specifically, as well as the main actors and their relationship to each other. Secondly, the cargo flows within Schiphol are assessed. Finally, the import processes in its main components, airside, handling and landside processes, are analyzed.

4.1. Air Cargo at Amsterdam Airport Schiphol (AAS)

The economy in the Netherlands is shaped by logistics and specifically, two major hubs: Port of Rotterdam and Amsterdam Airport Schiphol. The latter has been playing a key role in the last 35 years and has become a key European hub for air cargo (Hakfoort et al., 2001).

AAS continuously ranks as one of the most important airports in Europe across categories (passenger, movements, and cargo). Based on the annual report "Traffic Review 2015" by Schiphol Group, it ranked as 5th in passengers with 58.2 million, which represents a growth of 6%. It only grew less than Madrid (+12%) and Istanbul (+8.7%). In terms of movements, it ranks as 4th with 451,000 movements per year only behind regional leaders London Heathrow, Paris Charles de Gaulle and Frankfurt. Finally, in the area of interest, cargo, it ranks as 3rd with a total of 1.6 million tons. It is important to clarify that even though it suffered from a 0.7% contraction, this was still less than the reduction seen in the benchmark airports in the region. Frankfurt suffered a reduction of 2.8% while Charles de Gaulle 1.6% (Schiphol Group, 2016e).

The reduction is in line with the difficulties experienced by the industry since the crisis of 2008, as mentioned in the previous section. Figure 4.1 shows the volumes per year and the associated growth rates based on data from Centraal Bureau voor Statistiek (CBS) (2016). As expected, there is a clear drop in 2008 and 2009 with a recovery starting in 2010. This reduction of approximately 20% in volume was compensated in 2010. However, annual growth rates after the crisis have still not matched the 4% average growth seen over the period 2001-2008. Optimism is present with the latest statistics, which for the period of January to April 2016 shows a growth of 7.6%.

Air cargo is characterized by its broad type of goods, from live animals to spare parts or vaccines. The literature shows that there are different ways of categorizing these goods. Table 4.1 by Kallen (2015) shows the categories to be used on this project. What makes possible the efficient handling of cargo, in spite of its unpredictability, is the fact that Unit Load Devices (ULD) are standardized. A depiction of the used equipment is shown in Section 4.3. Most of the shown categories can be qualified as fast since they are handled as Build-Up-Pallets (BUP). This means that the ULD is loaded in such a way that no breakdown needs to be performed. These are products that are suitable for it due to their required fast throughput time. As an example, approximately 20% of all cargo is either express or flowers van Doorne (2013). The exception to this would be live animals, which is why this category will not be further considered. According to interviews conducted by van Doorne (2013) to KLM, Menzies and Aviapartner (currently Dnata) roughly 30% of the cargo arrives on a ULD while a 70% are loose cargo.

In terms of the actors involved in the air cargo industry at Schiphol, it is important to identify some of the key players. Based on the work by Pieters (2014) and Ankersmit (2013) the following can be detailed regarding these actors:

- **Cargo Handler**: AAS has one of the most liberalized cargo handling market in Europe. Any company
that has a contract with an airline and can directly rent warehouse space to Schiphol Real Estate can start operations. Usually an open market is expected to increase quality while keeping prices competitive, however, due to the cost savings focus of airlines, margins have fallen considerably. On the export side, handlers receive 100% of their revenue from airlines, while on the import side it is 80%. The remaining 20% is paid by the forwarding agent (Burghouwt et al., 2014). The active handling companies are: KLM Cargo, Menzies, Dnata, Swissport, Freshport, WFS and Skylink.

- **Airline:** Cargo can be carried either in the belly of a passenger aircraft or on full freight planes. There are also specific airlines that focus only on cargo like Cargolux and Yangtze River express. Both types of transport are important in terms of volume. In 2015 full freighters represented only a 3.7% of the movements, however, they carried almost 60% of the 1.62 million tons handled at Schiphol. That same year belly freight volume grew by 3.7% while full freighters decreased by 3.5%. The trend is for a reduced use of freighters and better use of the existing belly capacity (Schiphol Group, 2016e).

- **Trucking company:** Trucks provide the connection between 1st and 2nd line warehouses in addition to the final leg transportation to consignee. Under the Road Feeder Network (RFN) they also provide the connection between airports. There are almost 200 active companies working at Schiphol. However, it is a consolidated market with 50% of the visit frequency performed by 8 trucking companies. This percentage might be higher since most companies chart independent truckers as well. Some of the bigger companies are: Jan de Rijk, Bos Logistics and Kuehne+Nagel.

- **Freight forwarder:** Contracted directly by the shipper, these companies show on the House Waybill (HWB) making them fully responsible for the load. The selection of route and airline is done by the forwarder. In the Schiphol area, there are around 100 active companies offering their services. Each of these tries to differentiate themselves based on quality, price, added services or destinations. Active at Schiphol: DB Schenker, Rhenus Logistics, Panalpina, CEVA Logistics and Kuehne+Nagel.

- **Integrator:** This party owns or leases directly all steps in the supply chain. They offer door-to-door transportation, including trucks, airplanes and warehouses for consolidating. Due to their size and volume, they are able to achieve economies of scale. DHL is an example of integrators at Schiphol.
4.2. Assessment of cargo flows for a Fast Track at AAS

It is also important to understand what the contractual relationships between these parties are, which is why the Figure 4.2 is presented. It is clear that even though the cargo ground handler is right in the middle of the chain, it only has a contract with the airline. Several authors like de Wit (2014), van der Donk (2015) and Pieters (2014) have identified this lack of contract or Service Level Agreement between the cargo ground handlers and the trucking companies as a source of inefficiencies.

All of these stakeholders are a part of the ecosystem of companies and parties active in the cargo industry at Schiphol. Even though Schiphol has 6 runways (5 long runways and 1 short runway), most of the cargo activities are concentrated along the Kaagbaan. As it can be seen on Figure 4.3, there are developed areas around three platforms: Bravo, Romeo and Sierra. These platforms are adjacent to the runway and are used as parking spots for the aircraft to unload and load cargo. There are different facility types as well, based on their main activity and their connectivity with airside. 1st line, 1.5 and 2nd line facilities can be identified.

1st line facilities have direct access to airside and are generally used by the cargo handlers to build up and break down ULDs. Cargo is also temporarily stored here while waiting for truck pick up and checks such as customs or in the case of perishables, the NVWA inspection. This space is particularly coveted and is thus very limited (Lubbe, 2015). Currently, only KLM Cargo, Dnata, WFS, Freshport, Menzies, Skylink, Swissport and DHL have this type of facility.

1.5 warehouses have indirect access to the runway, through a special gate. These are normally operated by freight forwarders, as is the case with Panalpina, Rhenus Logistics and Ceva Logistics. The access to airside allows forwarders to skip the handlers and have faster times and better quality. However, at the moment Ceva Logistics is acting as a 2nd line facility, which does not make use of the valuable access to airside.

Finally, 2nd line facilities are warehouses located on the airport’s ground used by freight forwarders and trucking companies. Here cargo is stored for longer periods of time, there are value added services like repacking or relabeling performed, as well as the expected consolidation and deconsolidation for further transportation to the hinterland.

4.2. Assessment of cargo flows for a Fast Track at AAS

The cargo handling processes can be split in export, import and transfer. Understanding the share of each flow is critical for any process design and improvement. As mentioned by Nsakanda et al. (2004), the main
flows go from airside to landside and vice versa. In addition to this, there are flows from airside to airside. Particularly at Schiphol, there are landside to landside flows, created by freight forwarders, in order to maximize the utilization of their facilities (Districom, 2012). Transit or transfer cargo will be defined in this report as: i) cargo that does not leave the aircraft, iii) leaves the aircraft but stays airside or iii) cargo that is transported from and to landside (Ankersmit, 2013).

However, since export flows were deemed to be not applicable for a FT by Kallen (2015) and transfer represents only a 10% of the volume, the focus will be only on import. An overview of the import flows and how they split along the process can be seen in Figure 4.4. 90% of the volume has a direct transport flow. Almost all of it (98%) is transported by means of a ULD or pallet; the remaining consists of bulk. According to the authors, a 20% of the cargo transported by ULD would be applicable for a FT.

This contrasts with the data obtained by Kallen (2015), who performed calculations based on experts estimates, existing volumes and average load factors for ULDs. According to the experts, a 35% of the cargo volume is imported BUPs. This is expected to grow in the future since forwarders are performing more and more build up and breakdown activities in their 2nd line. Using an average ULD load factor of 75% and an average ULD volume of 21 m³, the author estimates that 294000 tons of cargo are transshipped as a BUP in 2015. The equivalent would be 94000 BUPs per year, of which 78% corresponds to import flows. Extrapolating this to the expected total throughput of 3 million tons, around 176000 BUPs (i.e. 550000 tons) will require transshipment at Schiphol.

4.3. Equipment

In this section, an overview of the used equipment at the different processes is given. A distinction between the used vehicles and the transport units is made.

4.3.1. Transport units

Standardized transport units are used across different modes. Twenty-foot equivalent units (TEU) are common on sea, rail and road transport. Due to space constraints, this unit cannot be used for air transportation,
4.3. Equipment

Figure 4.4: Import Transport Unit Flows, (de Wit, 2014) and (Lubbe, 2015)

which is why another standard is used: Unit Load Devices (ULD). According to Rezaei et al. (2016): The most common ULDs are containers and big metal plates, on which freight can be bundled and tied down. These are used due to their advantages: Reduced time to load and unload trucks and lower transport and storage costs due to a more effective use of space. The disadvantages are that there are costs associated with palletizing freight, the need for equipment and its movement between hub and warehouse (Morabito et al., 2000). Additionally, if the cargo is not assigned to the same flight but was built in a mixed way (M-ULD), an additional step of breaking down is required (Rezaei et al., 2016).

In the case of pallets, these are made of aluminum and are used as a base to build up the cargo. Once the cargo has been built up, they are secured with nets and plastic if required. Skids are a type of pallet made out of wood and used for the transfer or end-haulage (Kallen, 2015). These units are depicted in Figure 4.5.

Figure 4.5: Transport Units. From left to right: Container, Pallet and Skid

4.3.2. Vehicles

The vehicles used to transport the cargo from aircraft to 1st or 1.5 line facilities and from it to the end customer. The most common vehicles are explained below, while Figure 4.6 depicts them.

- **Aircraft:** Cargo can be transported on 2 type of aircrafts: Passenger or Full Freighter. For passenger aircrafts, cargo is carried in the belly or if it is a combi aircraft, on both the belly and main deck. Combi aircrafts have a compartment in the cabin, allowing a mixed configuration. This type of aircraft can carry 30 to 40 tons of cargo and 280 passengers versus the more common type of aircraft with 11 tons and 428 passengers (de Wit, 2014).

- **Dolly:** Used to transport cargo to and from the handler's facility to the aircraft. A configuration with multiple dollies\(^1\) fastened to a dolly truck is called a dolly train (Kallen, 2015). The maximum length is 27.5 meters, including the truck (de Wit, 2014).

- **Transporter:** Used to transport between high-loaders and dollies or, in case it is close, directly to the handler's facility (van Doorne, 2013). They are individually powered, which means they do not need to be attached to another vehicle like the dollies.

\(^{1}\) Maximum of 5 to 6 dollies
• **Forklift**: Used to load and unload and for handling at the warehouse.

• **Road vehicles**: Used to pick up the cargo from the handler's facility and transport it to either 2nd line or out-of-airport warehouses. It can also be used under the Road Feeder Network configuration. Mega trailers with roller beds are mostly used since it facilitates quick loading and unloading of the ULD or pallets. Dimensions are: 13.4 x 2.44 x 3.00 metres, or the equivalent of 4 ULD pallets.

![Image of vehicles used in air cargo handling](image)

Figure 4.6: Vehicles used in air cargo handling. *From left to right, top to bottom: Belly cargo, Full Freighter, Dolly, Dolly Train, Transport and Forklift*

### 4.4. Initiatives at AAS

In order to become Europe's preferred airport, Schiphol constantly searches for innovations and collaboration among stakeholders. It is clear for Schiphol Group (2015d) that "Air cargo can only maintain its share of global trade if it keeps pace with the changing demands of users and regulators – and continues to justify its premium price point by delivering speed and reliability." It is for this reason that Schiphol Cargo has partnered with different key actors like Cargonaut, Air Cargo Nederland (ACN), TKI DINALOG and Customs. In this section, some of the key initiatives promoted by Schiphol Cargo in order to improve the efficiency of the air cargo supply chain are presented.

#### 4.4.1. ACN Card

The ACN Card was developed by ACN in partnership with SmartLOXS. It is a smart card where the information of the trucker and the trucking company has been previously saved and approved. In addition to this, it includes some bio-metrical characteristics of the user of the card (trucker), which ensures security compliance. Because of this, each ACN Card is person-specific. It is used by companies involved in the transportation of cargo at AAS, specifically, trucking and freight forwarding companies (SmartLOXS, 2016).
4.4. Initiatives at AAS

This card can be used at the check in and check out of the handler’s terrain, as well as at some freight forwarders location like DHL Global Forwarding, CEVA and Rhenus Logistics. If a trucker does not have an ACN Card he/she is required to register manually at the gate with a passport and the respective cargo documents. In addition to the identification information included in the card, the check in and check out times and location are also logged. This allows for companies to track the on-route compliance of a truck. It can also be used to transfer digital documents and responsibilities between the parties (Ankersmit, 2013).

According to SmartLOXS (2016) the advantages of the ACN card are: Faster access to handler’s terrain, faster and safer administrative processes and information for management regarding residence times, location and more. A study carried by Rouppe van der Voort (2015) shows an adoption of 93.5% of users. One of the possible reasons for a trucker to not get an ACN card is a low number of visits.

4.4.2. E-Link
This initiative is Schiphol’s answer to IATA’s e-freight program. The aim of both is the same: To improve efficiency by removing the paper out of processes and replacing it with electronic information. This industry-wide initiative involves all partners in the chain. Starting with the electronic Air Waybill (e-AWB) and including more than 20 documents, paperless trade is not only feasible but a must in order to improve efficiency. IATA’s vision is to achieve 80% of all trade lanes by 2016 and 100% by the end of 2017 (IATA, 2015).

At AAS, this collaboration is lead by Amsterdam Connecting Trade (ACT) and Schiphol Smartgate Cargo (public-private collaboration between Dutch Customs, ACN and Schiphol Group). By using the ACN Card coupling it with information about the arrival and quantity of cargo, parties can prepare their processes and capacity better (Rouppe van der Voort, 2015). Once the truck has gained access to the handler’s terrain, it automatically receives confirmation of a dock allocation. This, however, is still not fully implemented, which means the trucker still has to go to the office in order to present himself and get a dock allocated. By using eLink though he gets priority in the queue. Once at the dock, the driver swipes the card and uploads all shipment data in the handler’s system. By doing so, the required information and responsibility are transferred to the next party (Schiphol Group, 2016b). According to Schiphol Group (2015a), E-Link is being implemented by the community in the export landside process. The claim is that E-Link yields up to a 25% reduction in time for certain processes. Research by Rouppe van der Voort (2015) shows that the percentage of users is of only 3.6%. The expected reduction times are verified, reducing up to a 33% the required time compared to paper registration.

4.4.3. Schiphol Smartgate Cargo
In order to speed up the clearance of goods by Customs, Schiphol has developed a key international public-private partnership. Smartgate works by collecting shipment information in advance and storing it in a central database. This enables Customs to inform handlers and other parties whether the cargo requires inspection (red) or has been cleared (green). In addition to this, a new Customs Joint Inspection Centre (JIC) was inaugurated in July 2016 to further enhance the Smartgate initiative. Here cargo is scanned remotely at the forwarders’ and handlers’ premises, reducing the number of inspections and the time to perform them. In addition to this, other inspection services are located here, which turns the JIC into a one-stop-shop model. Through this collaboration, speed and efficiency are delivered, while fully complying with customs security requirements (Schiphol Group, 2015d).

4.4.4. Milkrun
The milkrun concept is a delivery method, in which the transport begins with the unloading of the empty containers and the loading of new cargo at the first stop of the route. The truck continues on its route, performing multiple visits, and repeating this process of empties and loading new cargo at each supplier. It finishes its route by reaching again its departing point (i.e. the manufacturing facility) (Chuah and Yingling, 2005). As its name indicates, it has its origin from the dairy industry, however, it has been widely applied to different industries were one vehicle needs to make several stops on a regular route. By defining a route and schedule, the pickup and drop off times become regular (Nippon Express, 2016).

As Figure 4.7 shows, a milkrun has multiple advantages by enabling economic transportation with a high, regular frequency with a reduced amount of trips. According to Chuah and Yingling (2005) “the savings in transportation come from opportunities that the transport cycle creates in picking parts from a cluster of suppliers in a close region.” It might seem like transportation costs are initially higher, which they are, but they are offset by the benefits of having a JIT delivery system. At Schiphol this type of delivery is applicable due to the proximity of the 1st and 2nd line facilities and the time pressure associated with air cargo.
4. Distribution Process Analysis

It is for this reason that the milkrun project started at Schiphol in 2015. The reality of the LTL for the majority of trucks at Schiphol and the long waiting times at the multiple visits performed served as a motivation for this project. In the proposed milkrun the truckloads of several forwarders are combined and dropped at various handlers facilities (Kallen, 2015). The space in the trucks is booked through an online Milkrun Portal. The expected benefits are fewer truck movements on the airside terrains and thus less congestion and faster delivery of cargo.

In 2015 two pilots were carried, with the last one achieving the participation of 11 parties (Menzies and 10 forwarders). Based on their results, 1200 tons were transported and 112 individual truck movements were saved (Kallen, 2015). The main challenge of this initiate is the required information sharing among parties, who in some cases might even be competitors. An increased collaboration and an improved communication would benefit the implementation of the Milkrun considerably. However, the outlook is positive: In May 2016 the Milkrun project and its members won Schiphol's Aviation Award for Cargo. According to an interview to Dimitri Brink (see Appendix A.2) and ACN (2016), the milkrun was able to reduce truck movements by a 40%, a 30% reduction in CO₂ emissions and an increase in average truckload from 2.5 to 5.2 tons. In addition to this, throughput time for loose cargo is guaranteed in 12 hours and ULDs in 8 hours after landing.

4.5. Process analysis at AAS

In this section, an overview of the import process is presented and the individual parts of the process (airside, handling and landside) are discussed. As it can be seen on Figure 4.8 the import process begins with the landing of the aircraft. The responsible cargo handler performs the unloading of the aircraft and, based on the distance of the stand to their respective facility, chooses the transport equipment. If the distance is small, a transporter is used, otherwise, dollies are used. Next, the cargo is taken to customs if required and after this transported to the handler’s facility. Here it is stored while waiting for pick up. A confirmation is sent to the trucking company with the assigned time slot for pickup. It is worth mentioning that time slots are used only for import flows, whereas export ones, due to their variability, have no fixed appointments (Rouppe van der Voort, 2015).

Once the trucking company receives the confirmation, routes are planned and trucks sent to the respective locations. When the truck reaches the handler’s gate it needs to check in. The method will vary based on whether or not the trucker is in possession of an ACN Card. If the trucker has one, it only needs to scan it at the entrance. Otherwise, a manual registration needs to be performed at the gate. Once inside the terrain, the trucker parks at a specific location and checks in at the office. If the trucker is part of the E-Link program, he/she will receive priority on the queue. Otherwise, a First-In-First-Served (FIFS) queuing management is applied. When the clerk is available, the documentation is checked and if everything is in order, the dock allocation information will be provided. The trucker gets back on the vehicle and drives to the assigned dock. Here, he/she will have to wait if the dock is still not available and/or the warehouse employees are not ready. Once the loading process begins, the trucker waits until it is completed, performs a check against documentation and finally checks out of the terrain. From here on transportation is performed based on the previously defined route. Next destination could be: 2nd line warehouses, off-site facilities, final customers or to another airport under the Road Feeder Network (RFN) configuration.

The air cargo supply chain can be split in: Airside, Handling and Landside processes. According to Nsakanda et al. (2004) there are five categories of data that are required in order to describe these processes.
Figure 4.8: Import process ([Kallen, 2015], [Pieters, 2014], [Rouppe van der Voort, 2015] and [de Wit, 2014]). Modified by author.
These are: "(a) Shipment attributes, (b) shipment arrival or pick-up pattern distribution, (c) shipment processing time, (d) shipment routing data, and (e) other." In the next sub-sections, the processes and its actors will be described and data aligned to Nsakanda et al. (2004) presented as much as possible considering data availability limitations.

4.5.1. Airside process
Amsterdam Airport Schiphol has 5 runways with a total of 207 stands, 97 connected and 110 disconnected. As stated in Section 4.1 AAS is one of the most important airports in Europe. It ranks as 4th on a European level in terms of aircraft movements. Out of the 451000 movements registered in 2015, a 94% consisted of scheduled ones and only a 6% unscheduled. When differentiating between passenger aircraft and full freighters, it is clear that freighters represent a very small traffic for Schiphol, with barely a 4% of the movements (Schiphol Group, 2016e). It is worth noting that amongst full freighter there are cargo airlines like Cargolux but also integrators who own their own aircrafts (Pieters, 2014).

As the 3rd airport in terms of Cargo, in 2015 Schiphol handled 1.621 million tons of cargo, out of which 60% were transported on full freighters while the remaining 40% in passenger aircrafts as belly cargo. The trend from 2010 to 2015 showed an increase of 4% on average, reaching 1 million tons in 2014. However, the industry perception is that this year’s decrease of 3.5% will continue in the coming years (Schiphol Group, 2016e). Based on research carried out by de Wit (2014) and Lubbe (2015), on average a full freighter will carry 55 tons while on a passenger’s belly only 1.7 tons are transported.

**Airlines cargo market**
As already stated previously, cargo can be transported on passenger aircrafts or on full freighters. According to Schiphol Group (2016d), and as it can be seen on Figure 4.9, KLM has been steadily decreasing its cargo share, going from 44% to a 36% in the first period of 2016\(^2\). Their SkyTeam partners represent consistently a 15% of the cargo across the assessed period. In contrast, cargo airlines have increased their share by 2%. In addition to this, Schiphol has borne witness to the increased market share of Middle East Carriers (i.e. Qatar Airways, Emirates, Etihad Airways), increasing a 4% since 2013. Asian carriers like Singapore and Air China also contribute to the cargo industry. This reflects the industry shift towards Asian and Middle Eastern carriers. It is worth mentioning that DHL has seen its volume increase approximately twofold since 2013, to a 1.3% in 2015.

![Figure 4.9: Airline share based on carried freight (Schiphol Group, 2016d)](image)

**Arrivals and Departures**
In terms of arrivals and departures, there are two factors to consider: The arrival and departure pattern and punctuality. Different authors like de Wit (2014), Lubbe (2015) and Ankersmit (2013) have identified specific arrival and departure patterns. Since the scope of this research is that of import goods, only the arrival pattern will be discussed. There are different segmentation of peak times depending on the consulted author: Ankersmit (2013) identifies morning, day and evening while de Wit (2014) and Lubbe (2015) include an early morning one. There are slight inconsistencies among authors in their identified patterns, however, a day peak of approximately \(\frac{2}{3}\) of the arrivals (63% - 70%) is confirmed. The difference between full freighter and passenger aircrafts becomes clear during the evening and early morning periods. Before 6:00 passenger flights constitute less than 5% of the arrival, whereas for a freighter, it is close to 20%. After 18:00 the number of full freighter arrivals decreases by almost \(\frac{1}{3}\) contrary to passenger flights which decrease by less than 5%.

\(^2\)Data has been normalized in order to include January to April 2016.
4.5. Process analysis at AAS

The reason for this lies on the noise zones and regimes valid at Schiphol. In partnership with the Alders Platform (now the Schiphol Community Council) flight totals and developments are agreed on (Schiphol Group, 2015c). As Frenk Wubben and Busink (2004) explains, during the night time regime (23:00 - 6:00, extended voluntarily to 7:00), special landing procedures, take-off routes and runway combinations are required.

When it comes to the variability of arrivals and departures, the punctuality indicator can be used to describe the situation: 76.8% of departing and 83.7% of arriving flights are on time (Schiphol Group, 2016e). This indicator has no differentiation for passenger and full freighter aircrafts. However, as Pieters (2014) states, passenger aircrafts have higher punctuality than full freighters. The reason for this lies in the fact that punctuality is a key service component for passengers who could miss connections for instance, whereas cargo transport is more flexible or willing to wait for a Full Truck Load that is arriving late. As Zhang and Zhang (2002) point out, passengers prefer non-stop flights and reduced waiting times if transfers are required. Cargo, however, is indifferent to travel route, flight synchronization and airport terminal services. This argument is supported by Lubbe (2015) and de Wit (2014), who performed a data analysis of the arrival and departure patterns, as well as on the associated delays. As Figure 4.10 shows, passenger aircrafts have a higher tendency to be either on time or up to 30 minutes early. Full freighters, however, are on time only 10% of the time and show a behavior or being too early or more than 30 minutes late. As an example, more than 10% arrive between 2 and 4 hours late.

![Figure 4.10: Realized arrival and departure delays for passenger and full freighters (Lubbe, 2015) and (de Wit, 2014)](image)

The handled cargo is distributed almost equally between in- and outbound flows. 824,000 tonnes (51%) were inbound, while 792,000 tonnes (49%) outbound (Schiphol Group, 2016e). It can be expected then, that with growing volumes, these ratios are mostly kept.

**Process times**

The actual duration of cargo unloading of an aircraft cannot be fully separated from the rest of ground handling activities. For a short-haul flight, these activities include full off-loading, loading of baggage and cargo and catering and cabin cleaning procedures. There are additional activities to be performed like comprehensive technical tests and cabin services. According to a study conducted at London Gatwick Airport, this accounts for 25% of the delays (Wu and Caves, 2000). In the case of full freighters, though, the focus is solely on the cargo operations, and as previously mentioned, the time pressure is not as high as with passenger aircrafts. It the case of Schiphol, the data analysis presented on Figure 4.11 shows that approximately 2/3 of the aircrafts turn around in 2 to 4 hours. The small peak shown in the 18-19 hours category is assigned to integrators like DHL and FedEx who fly their own aircrafts (Lubbe, 2015).

Since turnaround times include other service activities, as mentioned by Wu and Caves (2000), it is difficult to separate the actual cargo handling component. van Blokland et al. (2008) support the fact that cabin activities define the critical route for the turnaround time. In the study performed by the authors, two aircrafts were assessed: Boeing 737-800 and Boeing 747-400 Combi. A possible reduction of 10% turnaround time is linked to the “Unloading/loading baggage and freight” task of the 737-800, while for the Combi cargo handling is not even on the critical path. Due to the ongoing efforts performed by airlines to increase their aircraft utilization, it can be assumed that this time will be reduced in the future.

---

3Within 10 minutes of scheduled time
4.5.2. Handling process

Handling processes can be split into import, export and transit flow. It directly affects the turnaround time of an aircraft and is thus a key indicator in achieving a high fleet utilization, a clear goal for all airlines. Wu and Caves (2004) defines turnaround as “the procedure to provide required services to an aircraft in order to carry out a following flight to another destination airport”. These services vary depending on the type of airline (e.g. low cost or full service) and can be catering services, aircraft fueling services and cargo and baggage handling. Turnaround operations are complicated and difficult to manage due to the amount of sequential and parallel workflows that take place during the turnaround time. The specific workflow in the scope of this research is that of the cargo handling.

Based on research from de Wit (2014) and Lubbe (2015), in addition to an interview conducted by them to Jos van der Zalm, a representative from Menzies, the cargo handling process at Schiphol can be described. Each cargo handler will unload the aircraft based on the respective contract. It will then be transported to the handler’s facility using dollies or transporters. This facility is normally divided in an import and export area. The first one is used for receiving, processing and releasing inbound freights, while the second one is used for outbound ones. For inbound freights the flow of goods goes from airside to landside and for outbounds, vice versa (Nsakanda et al., 2004). For import processes, M-ULD (mixed-ULD) are broken down and build up on skids, in order to proceed with the following transportation (i.e. landside or RFN). For exports, these need to be build up. For both cases, dedicated storage areas are present in order to provide buffer positions for transportation, either at landside or airside. These are organized based on destination. The performed controls at the facility will depend on the type of cargo and on whether or not Customs needs to perform an inspection. If it is loose cargo, then Customs will check directly at the 1st line warehouse. ULDs are required to be inspected at the Custom's airside facility (de Wit, 2014). There is also a Customs Joint Inspection Center, which cargo handlers can use for remote scanning (Schiphol Group, 2015d). Throughout all stages of the process, cargo is tracked through different information systems by means of scanners, card readers, wired scanners, etc. (Nsakanda et al., 2004).

The handling process continues when the cargo is to be picked up by the trucking company. In this stage of the process, the handling company verifies the presented information and assigns a docking door. In some instances, these are assigned based on the shortest distance within the warehouse, while in other cases, these are already pre-defined based on the type of cargo. Cargo handling employees pick up the cargo and load it in the truck. Together with the trucker an inspection of damages is performed and papers signed. After this point, the cargo is loaded in the truck.

Handler’s facilities

The specific location of where the handlers are located was explained in Figure 4.3. However, it is also important to know their respective area, capacity and amount of landside docks. This information can be obtained from the research conducted by de Wit (2014) and Lubbe (2015), in combination with information provided by Schiphol Group (2016d). Table 4.2 shows the estimated capacity per handler. This has been calculated based on the industry rule of thumb of 10 t/m² annual handling capacity. During a study conducted by Districon (2012) this theoretical assumption was verified. It is worth noting, though, that the maximum realized
productivity at Schiphol in a year was of 8 t/m² on average. When combined with the handled tons during 2015, the updated indicator for productivity can be calculated. It is clear on Table 4.2 that certain handlers (i.e. Menzies, Swissport) have a productivity above the Schiphol average. However, KLM, Dnata and the rest show a lower productivity, which negatively affects the airport productivity indicator. Even though the study by Districon (2012) states an average of 8 t/m², the productivity at Schiphol barely reached 7 t/m² in 2015. It is also important to understand how this indicator has progressed in the analyzed period. Figure 4.12 shows the average stated by Districon (2012) against the actual annual averages for 2013 through 2015. When contrasting it with the productivity average provided by Districon (2012), it is noticeable that some handlers have improved considerably like Menzies and Swissport. Others like KLM and WFS have remained constant, while Dnata and Skylink show a decrease.

The productivity indicator is not a direct measure of how well a cargo handler performs its activities, but how efficient the use of the area leased by Schiphol is. This is related to the existing contracts with airlines and their cargo and the leased area. The fact that contracts are signed for longer periods of time reduces the flexibility of the handler to adapt to a changing environment. Because of this, there are handlers who might have lost contracts to their competitors but cannot reduce their leased area, leaving them with a low productivity indicator. On the contrary, there are handlers that have implemented FTs in order to transship between 1st and 2nd line facilities. Dnata, KLM, Menzies and Swissport own and operate FTs in their 1st line warehouses. Dnata has 5 FTs, of which 3 are dedicated to exports and 2 to imports. In the case of Menzies, the 3 FTs are split among a flower import dedicated track and 2 bi-directional tracks. Swissport operates one FT for imports and KLM complements their FT with a pallet container handling system (PCHS). In addition to this, there are other collaborative FT like that of DB Schenker at the Skylink warehouse. Menzies also provides a dedicated flower track for Kühne+Nagel. In this case, Kühne+Nagel physically operates the FT (Kallen, 2015).

In the case of DHL, it is necessary to clarify that the low productivity is due to a ramp up of the volume. The company has been increasing their presence at Schiphol and even though the volume in 2014 was only 7500 tons, in 2015, it had been tripled to more than 21 000 tons. The trend for 2016 is also positive, which further confirms the increase in market share of integrators.

Table 4.2: Cargo handlers facilities and productivity. (Districon, 2012), (de Wit, 2014), (Schiphol Group, 2016c) and (Schiphol Group, 2016a)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
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</thead>
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<tr>
<td>1-3</td>
<td>KLM</td>
<td>69800</td>
<td>34%</td>
<td>46</td>
<td>522284</td>
<td>32%</td>
<td>7.48</td>
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<tr>
<td>8, 9</td>
<td>Menzies</td>
<td>40200</td>
<td>20%</td>
<td>57</td>
<td>547884</td>
<td>34%</td>
<td>13.63</td>
</tr>
<tr>
<td>5, 6</td>
<td>Dnata</td>
<td>45600</td>
<td>22%</td>
<td>86</td>
<td>324158</td>
<td>20%</td>
<td>7.11</td>
</tr>
<tr>
<td>9</td>
<td>WFS</td>
<td>10500</td>
<td>5%</td>
<td>17</td>
<td>41343</td>
<td>3%</td>
<td>3.94</td>
</tr>
<tr>
<td>9</td>
<td>Skylink</td>
<td>9100</td>
<td>4%</td>
<td>14</td>
<td>10105</td>
<td>1%</td>
<td>1.11</td>
</tr>
<tr>
<td>10</td>
<td>DHL</td>
<td>10000</td>
<td>5%</td>
<td>14</td>
<td>21097</td>
<td>1%</td>
<td>NA</td>
</tr>
<tr>
<td>11</td>
<td>Swissport</td>
<td>18750</td>
<td>9%</td>
<td>26</td>
<td>153991</td>
<td>10%</td>
<td>8.21</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>203950</td>
<td></td>
<td>260</td>
<td>1615862</td>
<td></td>
<td>6.9</td>
</tr>
</tbody>
</table>

Cargo handling market

The market share for cargo handlers has changed considerably in the last 3 years. Furthermore, the data obtained from 2016 supports the existing trend. As it can be seen in Figure 4.13, KLM has decreased its share by 2-3% from 2013 to 2016. Similar to it, Dnata suffered a reduction of 6% while on the contrary, Menzies has increased approximately 3%. Swissport has been one of the handlers to grow more (+4%). The reason for these changes is directly related to airline preferences, so it is expected that shifts in the airline industry are reflected in the cargo handling business. As expected, the most important changes reflect the increasing importance of the Middle East Carriers. Etihad Airways moved their volume of around 52 000 tons from Dnata to Menzies in 2014. In that same year, both Qatar Airways and Saudi Arabian moved to Swissport, increasing the volume handled by 2015 in more than 110 000 tons.

In the assessed period (2013-2016), the share of full freighters vs. passenger aircrafts has remained constant, with freighters carrying 60% of the cargo. But this division is not consistent along handlers. Data by

\[ \text{Physically operated by Skylink but DB Schenker is legally responsible} \]
Schiphol Group (2016d) shows that for Dnata, Menzies, and Swissport full freighter cargo represented around 90% of their volume in 2015. Contrastingly, WFS only handled a 34% of cargo from freighters and KLM practically none. An additional component of the market in which cargo handlers compete is the type of aircraft handled and its load. According to data provided by Schiphol Group (2016d), 60% of cargo transported in full freighters is split among the following aircrafts: 26% B744, 22% B77L and 5% both for MD11 and B748. In the case of passengers aircrafts, a 14% is carried on B744, a 6% both on B772 and B77W and approximately a 5% on both A332 and A333.

The operating reality of each handler can be assessed through the movements and the associated handled cargo. Each air transport movement indicates the handling of an aircraft when contrasted to the number of tons handled, it gives an evidence of the workload present at each cargo handler. However, it is necessary to understand as well the share of movements which have no freight associated. For full freighters, the percentage is historically around 5% whereas in the case of passenger aircrafts that increases to 30% of the movements. It is for this reason that the share of movements with no associated freight will be analyzed only for passenger aircrafts. Data provided by the Traffic Analysis and Forecasting department at Schiphol is used for an analysis of this indicator. The information for full freighters can be seen in Figure 4.14 while Figure 4.15 shows that of passenger aircrafts.

Figure 4.14 shows that there are considerable variations between handlers. Dnata handles 65 tons per movement, similarly to Menzies. Skylink handles around 40, whereas WFS has been steadily decreasing from 36 to 26. KLM, as expected, barely handles any full freighters, and for that matter has reduced the movements of these from 15 in 2013 to 7 in 2015. The data regarding DHL needs to be treated with care since it only started the ramp up of their operations at Schiphol recently. In 2014 it had 14 movements, while in 2015 it reached 24. The total amount of movements by DHL since 2013 represents basically a 0% of the movements at Schiphol.
4.5. Process analysis at AAS

A striking different scenario is seen on Figure 4.15. In this case, the highest tonnage (1.8 tons) per movement is achieved by KLM, whereas other handlers are consistently below 1 ton. In general, all handlers show a trend for increased tonnage handling per movement, especially WFS. In addition to this, the right axis shows the share of movements with no associated freight (i.e. zero tons). The noticeable differences are aligned to the company’s customers, which has already been explained previously. In such a way, KLM, who handles essentially only passenger aircrafts, fails to assign freight to 16% of their movements. In the case of the handlers with a strong full freighter business, the share of passenger aircrafts with cargo is less than half. This result is to be expected since airlines like Etihad Airways, which flies full freighters, will rather optimize the loading of those aircrafts rather than that of a passenger one.

![Figure 4.14: Freight tonnage per movement for full freighters. (Schiphol Group, 2016d)](image)

![Figure 4.15: Freight tonnage per movement and share of movements with no freight allocated for passenger aircrafts. (Schiphol Group, 2016d)](image)

**Process times**

Once the cargo arrives at the handler’s facility, there is the need to perform build up or break down activities. Depending on the type of cargo (i.e. mixed pallet, container, special cargo) the build-up process can take from 20 minutes to 1 hour while the break down between 10 and 25 minutes (de Wit, 2014).

The duration of the cargo at the handler’s facility is what is referred to as residence time. This varies per handler of course but an overview of these times can be seen on Figure 4.16. From it, it can be concluded that approximately 60% of the shipments are in the 8-18 hours range, followed by a 23% below 4 hours. This validates the fact that there is more "urgent" cargo, which is picked up in less than 4 hours versus cargo that can wait for almost 2 days. The occurrence of residency times above 18 hours is higher on Monday as expected due to the weekend.
4. Distribution Process Analysis

4.5.3. Landside process

The landside process starts in the moment in which the cargo is loaded in the truck and cleared for further transportation. As it was mentioned previously, this transport can be to a 2nd line facility, to a freight forwarder’s warehouse outside of the airport or to another airport under the RFN configuration. The available transport options are presented on Figure 4.17 by Ankersmit (2013). As the author states there are four clear routes departing from handler: i) Direct transport to the consignee, ii) Indirect transport via a 2nd line freight forwarder, iii) Indirect transport via the external facility of a freight forwarder and iv) RFN. Based on research and interviews conducted by van Doorne (2013) to KLM Cargo and Aviapartner around 50% of the flows are national shipments. The rest are shipped under the RFN configuration. These services are generally offered by different trucking companies since they constitute such opposing business models. In the case of RFN transport there is a truck schedule and since it is a long haul, trucks loads are maximized. On the contrary, for national transport, companies usually offer a 24/7 service between 1st and 2nd line facilities, while optimizing their load in order to reduce waiting times and visits.

Even though the trucking companies will mostly have a contract with the airline, they could also be directly hired by the freight forwarder. Because of this, their cargo might be dedicated for one consignee, for one freight forwarder or combined for several freight forwarders and airlines (Ankersmit, 2013). Based on this and the mentioned possible routes, trucks are capable of optimizing their load. Experts agree that the standard trucks (18.75 meters long) have a FTL of 9-10 tons. However, the average load of trucks connecting 1st and 2nd line facilities is of 4 tonnes only according to an interview conducted to Jan de Rijk by de Wit (2014) and Lubbe (2015). Based on data provided by CargoNaut and analyzed by these authors, an average of 3.88 tonnes is confirmed.

5Dnata acquired Aviapartner in July 2015
**Trucking market**

Even though Schiphol has more than 190 trucking companies visiting its premises, there is a small number of companies that manage the majority of the freight. Based on data analyzed by Pieters (2014), 8 companies represent 50% of the visits. The rest is performed by more than 100 companies, with none of them representing more than 3% of the visits. Some of these big companies like Jan de Rijk, Bos Logistics, and Kühne Nagel have defined schedules for pick-up and delivery of freight at the handlers and some even have direct contact with the handlers. Pieters (2014) considers likely, based on the results, that these 8 biggest companies do not only represent half of all the visits but also of the carried freight. The percentage might even be larger since for the data analysis no self-employed drivers were considered, who are often hired by these companies. As it was mentioned previously, trucking companies have a direct contract with the airline, which is why shifts in visits are correlated to changes of cargo handlers by the airlines.

**Process times**

As it was discussed on Section 4.5 and more clearly depicted in Figure 4.8, there are several queues that arise on this part of the process. As stated by Ritsema (2016), one of the main issues towards improved operations at Schiphol is precisely truck waiting times and the numerous visits performed by trucks in their distribution routes. This triggered research conducted directly for Schiphol Cargo by Rouppe van der Voort (2015) and Pieters (2014), whereas other organizations like ACN did so through the work of Ankersmit (2013). The key findings of their research will be detailed in this section, in order to set up a baseline for distribution proposals.

In order to understand the bottlenecks of the landside process, it is useful to understand the configuration of the handler’s terrain. A basic layout is depicted in Figure 4.18. As it can be seen, there is an initial registration at the gate. Once inside, truck drivers have defined parking spots so that they can perform the check in process at the documentation office. Once a dock is assigned, and if it is available, they will park at the assigned dock, wait for the truck to be loaded and carry on with the defined transportation route. The **residence time** is the critical indicator for the performance of this process. This can be split into the **registration time** to gain access to the terrain and the **lead time or turnaround time** at the terrain. Factors identified by Rouppe van der Voort (2015) affecting the registration and the lead time are: System (ACN Card, E-Link, paper), arrival moment (i.e. day and time), arrival pattern, occupancy at the handler, users per system, the quantity of cargo, handler and import or export flow. Differences in time between import and export trucks were proven to be not statistically significant by Rouppe van der Voort (2015), which is why it will not be mentioned further in this report.

![Figure 4.18: Overview terrain 1st line handler. (Rouppe van der Voort, 2015)](image)

The registration time changes considerably between handlers since some of them have independent check-in gates and others combined. Handlers like KLM, Dnata, DHL, and Swissport have their own check in gate, whereas Menzies, WFS and Skylink have a combined one (Pieters, 2014). This creates different arrival patterns and service rates, causing differences in queues as well. An additional difficulty is the fact that there is no recorded data for registration times. An initial estimate was performed by Rouppe van der Voort (2015) by registering the times of 122 truck visits. A 75% of these accessed the terrain with an ACN Card, whereas
the rest did so through a paper registration. The time for a paper registration has an average of 2.43 minutes, which can be reduced by using an ACN card to only 0.20 minutes.

In terms of the lead time or residence times, this data can be gathered through SmartLOXS, the organization that logs the arrival and departure times at each gate. An analysis of data at three handlers over a two week period was conducted in 2011 by the Schiphol Cargo Department, updated in 2013 by Pieters (2014) and in 2015 by Rouppe van der Voort (2015). Results are similar, which leads to the following conclusions per factor:

- **Day of arrival:** The differences among individual days are not statistically relevant. However, when days are grouped into weekdays and weekend days, there is a clear distinction. 80% of the visits occur between Monday and Friday, whereas both Saturday and Sunday have a 10% of visits each. There is a small difference between the beginning of the week and the end (17%-18% vs. 15%). This small peak corresponds to trucks delivering exports before the weekend and picking up imports that arrived during it.

- **Time of arrival:** As Figure 4.19 shows there is a clear pattern in both data sets. Grouping can be done in order to obtain statistically different hour ranges (Rouppe van der Voort, 2015). 75% of the trucks arrive between 5 and 20 o’clock, 10% before 5 o’clock and 15% later than 20 o’clock. This pattern holds for the three assessed cargo handlers. According to an interview conducted by trucking company J. van de Put by de Wit (2014), this is expected since most trucking companies work on a Monday to Friday schedule due to increased wages on weekends (i.e. 150% on Saturdays and 200% on Sundays) and restricted night hours.

- **Arrival interval:** Based on the same statistical analysis it was concluded that only 15% of the trucks arrive within 45 seconds of each other. 42% arrive within 45 seconds and 4.5 minutes, while a 41% do so within 4.5 and 30 minutes. Only a 3% arrive with an interval superior to 30 minutes. In total, 98% of the trucks arrive with an interval smaller than 30 minutes (Rouppe van der Voort, 2015).

- **Registration Time:** Initial estimate shows that a paper registration has an average of 2.43 minutes, which can be reduced by using an ACN card to only 0.20 minutes.

- **Turnaround Time:** Based on a sample of 2822 visits, Pieters (2014) calculates an average time of 66 minutes. Contrasting this to Rouppe van der Voort (2015), who defines the time at 62 minutes, it can be concluded that the estimations are adequate. This average is mostly constant throughout day hours, and even slightly lower. However, it is largely exceeded during night hours (i.e. 23 to 5 o’clock). Even though visits are the lowest during this period, turnaround time increases to more than 80 minutes and up to 100. This influences the early hours of the day as well since there a queue builds up. This inversely proportional relationship of visits and turnaround time is caused by the lower capacity of handlers during these hours. Higher wages during night shifts drives handlers to limit their staff and thus their capacity. There is even a peak identified between 22 and 23 o’clock due to the change of shift.
An increase in turnaround times is also identified on the weekend (mostly on Saturday). According to Pieters (2014) this is due to the peak delivery on Friday evening and lower capacity on the weekends. Mondays morning also suffer from an increased turnaround times, directly related to the mentioned import pick up peaks on Monday morning.

- **Residence Time**: When combining the results obtained from the registration and turnaround times, it can be stated that the residence time is between 61 and 68 minutes. The residence time, specifically for paper registration is at almost 100 minutes (Pieters, 2014) (Rouppe van der Voort, 2015).

- **Number of visits**: A limitation of the data is the fact that no differentiation between handlers with a shared gate can be performed. For this reason, both Pieters (2014) and Rouppe van der Voort (2015) exclude this factor from their research. de Wit (2014) and Lubbe (2015) try to approximate it by deriving the number of visits from travel times between handler’s gates. The data contains truck turnaround times at KLM, Dnata and Menzies. The data does not include Swissport or handlers inside a shared terrain. Based on this analysis and a correction factor, the authors define an 84% of the truck visits performing one visit, a 13% two visits and a 3% three visits.

- **System**: The last data analysis performed in 2015 showed the following system adoption: ACN Card 93.5%, E-Link 3.6% and Paper 2.9%. This represents an increase from the 72% average adoption of the ACN card stated by Pieters (2014) in 2013. In the same way, E-Link now has an adoption of 35% (Schiphol Group, 2015a).

Even though these factors pose a comprehensive overview of the landside process, it is important to understand that they do not explain the totality of truck residence times. Critical additional factors to consider which are not present in the data are: quantity of cargo to be transferred, process time per truck, occupancy at each handler and the real number of visits. In addition to this, there are unquantifiable factors like the motivation of the employees, their training, cultural differences when interacting with East-European truck drivers and the lack of timely information for tactical decision making.

### 4.6. KPIs definition

Based on the process analysis carried out in the previous section, the KPIs that evaluate the performance of the FT can be presented. These indicators are based on the initial understanding of the process and the literature as proposed by Rezaei et al. (2016) and Feng et al. (2015), among others. This list might be expanded or elaborated on once the design alternatives are clear.

A differentiation between criteria for the airside distribution, FT and landside distribution can be made, as it can be seen on Table 4.3. To conclude this chapter the relevant research sub-questions are presented and answered. This structure will be kept along the report, serving as a concluding summary and as a resource to the reader.

#### Table 4.3: Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
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<tbody>
<tr>
<td><strong>Landside</strong></td>
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<tr>
<td>Truck Load Factor (TLF)</td>
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</tr>
<tr>
<td>Turnaround time</td>
<td>[min/truck]</td>
</tr>
<tr>
<td>Waiting time</td>
<td>[min/truck]</td>
</tr>
<tr>
<td>Cost of transport - truckers</td>
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<td><strong>FT</strong></td>
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<td>Throughput</td>
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</tr>
<tr>
<td>Lead Time</td>
<td>[hours/BUP]</td>
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<tr>
<td><strong>Airside</strong></td>
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<tr>
<td>Transport time from aircraft to fast track</td>
<td>[min]</td>
</tr>
<tr>
<td>Cost of transport - cargo handlers</td>
<td>[€]</td>
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</tbody>
</table>

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*WFS and Freshport share a gate with Dnata; WFS and Skylink with Menzies.*
Research Sub-question 1

What are the characteristics of the current distribution process?

In 2015, Schiphol handled 824,000 tonnes of import cargo, out of which 20-35% is suitable for a FT. 294,000 tonnes (i.e. 94,000 BUPs) are transshipped annually. The import process can be split into:

**Airsde:**
- **Capacity:** Dictated by 5 runways, 97 connected and 110 disconnected stands.
- **Cargo Composition:** Freighters carry 60% of the cargo while representing only 3.6% of the movements. This is explained by their average load (i.e. 55 vs. 1.7 tonnes for belly freight).
- **Arrival and departure pattern:** 2/3 of the flights arrive during the day, with 20% of the freighters doing so before 6 o’clock. In general, 84% arrive on time, although there are differences based on type. 2/3 turn around in 2-4 hours.
- **Market:** Industry shift towards Asian and Middle East Carriers, changing the handling market.

**Handling:**
- **Process:** Unload/load aircrafts, break down/build up and cargo storage until pick up. Some offer express handling (i.e. pick up under 3 hours) and 4 of them have FTs in their 1st line.
- **Efficiency:** The efficiency at Schiphol is at 8t/m² below the standard of 10. There are mixed results among handlers, which has to do with their customers and type of aircraft handled. For Dnata, Menzies and Swissport 90% of their volume consists of full freighters, reaching an average of 65 tonnes per movement. Handlers with a stronger passenger business, like KLM, move around 1.8 tonnes per movement. All handlers show a trend for increased tonnage handling.
- **Process times:** Throughput time is split among process time (i.e. break down (10-25 minutes) and build up (20-60 minutes)) and storage time. 60% of the shipments are stored 8-18 hours and a 23% below 4 hours.

**Landside:**
- **Process:** Consists of cargo pick-up and distribution, which can be split in: i) Direct to the consignee, ii) Indirect via a 2nd line forwarder, iii) Indirect via the external facility of a forwarder and iv) RFN.
- **Cargo Composition:** The loading depends directly on the route: 50% of the shipments are RFN, in which case the truck load is optimized (FTL is 9-10 vs. LTL of 4 tonnes). For national cargo, waiting times and visits is critical, and it is impacted by the arrival pattern and process times: 4/5 of the visits occur during the week and day hours with a slight peak on Mondays due to weekend imports.
- **Arrival and departure pattern:** The inter-arrival time is highly variable (i.e.a 40% arrives either in a 0.75-4.5 minutes range or between 4.5-30 minutes)
- **Process times:** Turnaround time is around 60 minutes, which is largely exceeded during night hours, weekends and Monday mornings due to lower capacity of the handlers.
- **Systems:** The process relies on the use of certain systems (ACN Card, Elink) and time slot assignment, however allocation is still performed on a FIFS base.
- **Market:** It is a concentrated market, with 8 companies representing 50% of the visits. The rest is performed by 100+ companies.
What are the requirements in terms of input and output of the FT?

**Input:** The FT should be able to cope with peak handling of 13 to 23 tonnes per movement and it needs to do so while ensuring no bottlenecks are present during the reception of cargo and subsequent transshipment. The FT needs to ensure unloading for multiple cargo handlers is possible and the airside dock allocation process needs to be seamless for them (i.e. clear rules on priority treatment). Inspections by customs need to be supported before entering the FT or at the facility itself.

**Output:** The FT should allow cargo to be loaded at the designated dock in a JIT way (i.e. minimizing storage time). The allocation of the docks should be performed considering: route, type of distribution (e.g. milkrun, destination based, others), priority and arrival pattern. Turnaround times should be reduced and capacity constrained situations (i.e. night shifts) considered for slot assignment. This should all be supported by a system that makes use of the existing initiatives (i.e. ACN Card, Elink) and does not rely on warehouse personnel for tactical decisions as dock allocation, priority treatments and performance tracking.
Fast Track Design Revision

In this chapter, a revision of the FT design will be done. In order to do so, the concept of cross-docking and the corresponding truck scheduling and planning from Chapter 3 will be referenced and with these, the associated variables for the proposed design defined in Sections 5.1.1 and 5.1.2. The Vehicle Routing Problem (VRP) variants which are applicable to the case under study are also detailed. Based on the above, the critical design variables are defined and the FT evaluated. It is of key importance to assess the FT under these considerations since one of the assumptions by Kallen (2015) was precisely that of seamless input and output flows. A conclusion of the FT implementation at Schiphol based on these is then presented.

5.1. Design variables from literature

5.1.1. Cross-Docking

As it was stated in Section 3.1: Cross Docking and Section 3.2: Truck Scheduling, the characteristics of a cross dock are defined by any of the following three main components:

- **Physical**: Shape, number of dock doors and internal transportation.
- **Operational**: Service mode and dock holding pattern.
- **Flow**: Arrival and departure pattern, product interchangeability and temporary storage.

5.1.2. Distribution

At the moment, and as it was assessed in the previous chapter, Schiphol’s airside operations are defined by a point-to-point nature carried by the cargo handlers. On the landside, the situation is harder to define. Even though trucking companies try to create and manage corridors, each freight forwarder (or customer) optimizes their own chain solely (Pieters, 2016). In an air industry like the one present at Schiphol, with more than 100 freight forwarders and 200 trucking companies, optimizing individually and not as a system, creates considerable inefficiencies.

The possibility of applying a Vehicle Routing Problem (VRP) to these distributions was considered and based on the literature review and the assessed VRP variants (see Table 3.1), evaluated. Some of these variants are not applicable to the case under study, are out of the scope or simply not convenient. The motivation for the performed selection is based on the understanding of the process derived from Chapter 4 and interviews conducted to experts in the industry (see Appendix A). Considering this, a short explanation of why variants were selected or not is provided:

**Applicable**

- **CVRP**: The most common VRP variant resembles the current landside distribution the best: A system in which the main constrain is the truck capacity.
- **SVRP**: Static and stochastic problems have a certain randomness in their input variables (i.e. customers, demand, etc.), which is why even though the routes are defined a-priori, certain smaller changes are made during the execution of it (Pillac et al., 2013).
• **VRPTW:** Adding time windows is also representative of the reality since both trucking companies and handlers have defined service times. Minimizing waiting time as part of the objective could also prove to be beneficial.

**Non-Applicable**

• **MDVRP:** The only depot available is the FT and the destination. This variant could be applicable to a milkrun with multiple 1st line handlers but not on the present scope.

• **PVRP:** Routes are constructed for a specific period (e.g. 1 week) and during it, customers are visited a pre-set number of times (Francis et al., 2006). In this case, BUPs are transported on a JIT way, which means that cargo will not wait 1 or 2 days for a route. Since most customers are served on a daily basis this variant is not applicable.

• **SDVRP:** This variant minimizes the number of vehicles based on the demand and the capacity. So, solutions with a minimum total cost of the routes may be overlooked for a solution that uses less vehicles (Archetti and Speranza, 2012). For air cargo, total cost and time are more important than vehicle quantity, which is why this variant is not applicable.

• **VRPPD:** This variant could be used if exports were also included in the FT; as it also includes the requirement of pick up. However, since exports are out of the scope this variant is not considered.

• **DVRP:** In the case of air cargo it is expected that all the information is contained in the AWB, which is why having information revealed dynamically during the route execution is not likely (Pillac et al., 2013).

• **OVRP:** Vehicles are allowed to "depart" after servicing the last customer on a route. Airplanes for instance have open delivery routes among airports (Li et al., 2007). However, trucks will usually return to their company's facility or to another warehouse .

• **VRPSF:** Satellite facilities to replenish do not exist in this type of distribution but usually only on the fuel industry.

• **VRPB:** There are no return goods going from the freight forwarders back to the FT.

This analysis on which types of VRP are applicable to the air cargo logistic chain can serve as reference for future studies. As it was mentioned before, due to lack of data and the existing limitations, a landside study is not feasible (Pieters, 2016). For further information on the truck scheduling process and the existing challenges see Appendix A.5.

### 5.2. Critical design variables

Based on the literature review presented and the defined scope, the critical variables are presented. Initially, these will be identified, described and then evaluated for the FT design proposed by Kallen (2015).

#### 5.2.1. Identification of critical design variables

Combining the variables identified through the literature study of cross dock systems (Section 3.1), truck scheduling and planning (Section 3.2) and distribution (Section 3.3), the critical variables can be stated.

Figure 5.1 presents the scheme of the airside, handling and landside system. The variables in green represent the ones which will be part of the proposed alternatives, whereas the black ones have either been defined as not applicable or are out of the scope. The motivation for this lies on the process analysis performed in Chapter 3 and the conducted interviews with industry experts (see Appendix A). In addition to the variables, the specific criteria is also defined.

- **Arrival pattern:** Air cargo operations should not be stopped by the operating hours of the FT, which is why, for airside, the arrival is non-restricted.

- **Pre-emption at arrival:** For unloading of dollies and transporters this strategy is not preferable since, just like with the arrival pattern, it would turn the FT in the bottleneck of the process. Each arriving transport unit is to be fully unloaded before processing the next one. Priorities will be assigned in the dock allocation.
5.2. Critical design variables

- **Service Mode:** There is no interchangeability between airside and landside docks since there are customs requirements associated with these flows. All air cargo should enter through the airside docks and leave through the landside ones. Once it does so, it has already complied with governmental regulations.

- **Airside and landside docks:** Critical variable to be assessed during the modeling and evaluation of this research. It directly impacts the truck scheduling and planning, making it one of the most important critical variables. The amount of docks will depend on the desired dock utilization, truck waiting time and expected volumes, among others.

- **Temporary storage:** The options are whether there is temporary storage available or not. There are no detailed calculations as to what the required area or storage design should be since that is out of the scope.

- **Shape:** Out of scope. The chosen shape is that of an I based on the design by Kallen (2015) and supported by authors like Bartholdi and Gue (2004).

- **Internal transportation:** Out of the scope. Kallen (2015) proposed several handling methods in her thesis, and based on the desired goal of either performance or cost reduction, a manual handling or an ETV should be considered.

- **Product interchangeability:** Not applicable for this research since all cargo that enters the FT already has an assigned destination and customer. This variable will no longer be considered.

- **Pre-emption at departure:** For landside, pre-emption can be applied or not since trucks can wait at designated areas when necessary and priority can be given in case of urgent shipments with no allocated dock. However, after consulting with experts, pre-emption is deemed not applicable in a real life scenario since trucking companies would not endorse such a policy.

- **Departure pattern:** Trucks can have a non-restricted pattern or a restricted one, in which case they are only allowed to stay a pre-defined amount of time at the dock. The departure pattern defines if a the system behaves in a push or a pull way. A restricted one will behave as a pull system, whereas a non-restricted one like a push one.

- **Distribution:** The distribution both at airside and landside is critical in order to ensure a continuous flow at the FT. It is for this reason that at airside two different configurations will be assessed (i.e. Milkrun by a 3rd party or current configuration with multiple handlers). In the case of landside, the distribution will not be considered as mentioned in this document’s scope definition (Section 2.4.1).

5.2.2. Assessment of the FT’s critical design variables and requirements

The detailed explanation of the FT concept and design, as devised by Kallen (2015) can be consulted in Section 2.2.4. In this section, however, a closer look will be taken on the variables used, as well as the applicable requirements and some of the model assumptions, which might conflict with the an improved flow through the FT towards the destination (i.e. including the distribution).
In her work, Kallen (2015) states as the most important variables: Storage, Number of dock doors and Number of storage positions. However, these are only the critical variables from a set of wide alternatives that include area, equipment and configuration variables. As Table 5.1 shows, for the most part, the variables assessed in the design of the FT by Kallen (2015) are not reviewed. However, the ones with the green check marks can be categorized as interface variables, which is why they will be considered for this research by the author (K. Schuppener). It is important to mention that storage will be only considered as existent or non-existent. The amount of storage positions is not under review.

Table 5.1: Design variables by Kallen (2015) and interface variables considered on this research.

<table>
<thead>
<tr>
<th>General Variables</th>
<th>Equipment Variables</th>
<th>Configuration Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Terminals</td>
<td>Storage System</td>
<td>Rollerbed Lanes Import [#]</td>
</tr>
<tr>
<td>Terminal Shape</td>
<td>Storage Equipment</td>
<td>Rollerbed Lanes Export [#]</td>
</tr>
<tr>
<td>Terminal Levels</td>
<td>Main Transport Mean</td>
<td>Storage Capacity [Yes/No]</td>
</tr>
<tr>
<td>Transshipment Direction</td>
<td>Truck Docks</td>
<td>Cooled Storage Capacity [#]</td>
</tr>
<tr>
<td>Customs Control Function</td>
<td>Scale &amp; Scanner (export)</td>
<td>Workstation [#]</td>
</tr>
<tr>
<td>Rebuilding Function</td>
<td>Inspection Equipment</td>
<td>Airside Import Docks [#]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Airside Export Docks [#]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Import Truck Docks [#]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Export Truck Docks [#]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storage Equipment [#]</td>
</tr>
</tbody>
</table>

The design by Kallen (2015) is also delimited by her set of process, performance, area and equipment requirements. Not all of these are relevant for this research, which is why only the applicable ones, either to be kept or challenged are mentioned. This is seen in Table 5.2. Here, the relevant requirements are shown and the status of these is explained through check marks. As it can be seen, green check marks mean that the requirements are kept and used as such in the following chapters. Yellow exclamation marks though, mean that these requirements need to be revised, either in terms of their value (e.g. import capacity, amount of truck buffer positions) or in terms of their intention (e.g. customs check before FT or storage existence).

Table 5.2: Relevant requirements by Kallen (2015) with the respective status.

<table>
<thead>
<tr>
<th>Component</th>
<th>Requirement</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>&lt; 65000 m² so that the minimum throughput is 650 000 t/year</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Large enough for 2 truck buffer positions/dock and trucking</td>
<td>✓</td>
</tr>
<tr>
<td>Depth</td>
<td>&lt; 365 or 320 m (depends on location)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>&lt; 40 m</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Needs to consider the facility, air and landside terrain</td>
<td>✓</td>
</tr>
<tr>
<td>Equipment</td>
<td>(Un)loading docks at air and landside</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Sufficient cooled and non-cooled storage positions in order to prevent bottlenecks.</td>
<td>✓</td>
</tr>
<tr>
<td>Process</td>
<td>Only import BUPs may enter the FT</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>All commodity categories except live animals</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Import BUPs split from ULDs before FT at airside</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>BUPs transported with a dolly or transporter (depends on distance)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>BUPs are to enter FT via an airside dock and leave via a landside one</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Import BUPs must be able to be checked by customs before entering</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>FT should offer at least transshipment and storage buffer function</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Import cargo trucks should depart when it is fully loaded or when a departure signal is provided</td>
<td>✓</td>
</tr>
<tr>
<td>Performance</td>
<td>Transshipment time &lt; 3 hours</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Minimum required import capacity = 450 000 t</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Minimum required import capacity = 147 500 BUPs</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Productivity ≥ 10t/m²/year</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Storage capacity should cope with peak throughput</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Resources should be used efficiently, Utilization between 30% - 50%</td>
<td>✓</td>
</tr>
</tbody>
</table>

In addition to this, it is relevant to understand some of the assumptions or values that Kallen (2015) considered, since they do not only impact the evaluation of the FT design alternatives but also, as a consequence, the input used for the present research. These are:
Landside:
The truck notice time is 2.5 hours. Once the truck arrives, it can dock at any of the 5 present doors. These are allocated in a FIFO way with priority for perishables. If a dock is not assigned, the truck can wait in any of the truck buffer positions. There are 2 positions per dock door, for a total of 10. It takes 5 minutes for a truck to switch at the dock and each truck is loaded with 4 to 5 BUPs. The loading time per BUP is of 3 minutes, so total loading time would be 12 to 15 minutes per truck. Since a milkrun is assumed, any BUP can be loaded in any truck, making the cargo basically interchangeable.

Handling:
The FT has an average throughput time of 1 hour with 2.5 hours or less guaranteed. The BUPs go through on the conveyor belt system based on the utilization of it and the number of pallets waiting. So, pallet push back occurs when the utilization rate is below 60% (70% for perishables) and the number of pallets waiting for conveyor B and C is less than 1. Otherwise, the pallet will be directed to the storage buffer position.

5.3. Issues for a FT at Amsterdam Airport Schiphol

After the performed assessment, it can be concluded that the design of a FT or cross dock facility entails much more than just the internal operations. According to Yu (2002), even if all the physical elements are in place, formal programs (i.e. physical equipment and logistics control) are required to ensure proper functioning of the internal and external functions.

The key issues found in order to implement a FT at AAS is the assumption of "seamless" flow from airside to landside. The design by Kallen (2015) has optimized the internal flow of the FT, however, the assumption of a fully functioning milkrun is not realistic. By having a landside distribution that is likely to turn into a bottleneck and an airside distribution, in which processes are not defined in terms of the actors, the current design runs the risk of turning into a short-term storage facility instead of a proper cross dock.

It is thus essential for this research to look at the mentioned distributions, while considering the variables defined in Section 5.2 (Critical design variables). Some of the key implementation success factors, as stated by Schaffer (1998) are partnering with other members of the distribution chain, operational management and communication and control within the cross docking operations. These are precisely the factors that this research aims at solving.
### Research Sub-question 3

**Which distribution and cross docking design variables have a critical influence on the functioning of the FT?**

- **Arrival and departure pattern:** Defines the way in which the dollies/transporter and trucks are handled. It can be restricted or non-restricted, in which case they are only allowed to stay a pre-defined amount of time at the dock. A restricted pattern turns the system into a pull one, whereas a non-restricted one, into a push one.  
  **Airside:** Non-restricted, **Landside:** Non-restricted/Restricted

- **Pre-emption:** Defines whether or not an unit (i.e. incoming or outgoing vehicle) needs to be fully processed before servicing the next one. Units whose loading/unloading is stopped wait until the process can be resumed.  
  **Airside:** No, **Landside:** Yes / No

- **Service Mode:** There is no interchangeability between airside and landside docks since there are customs requirements associated with these flows.  
  **Exclusive**

- **Airside and landside docks:** Critical variable to be assessed during the modeling and evaluation of this research. It directly impacts the truck scheduling and planning, making it one of the most important variables. The amount of docks will depend on the desired dock utilization, truck waiting time and expected volumes, among others.  
  **Airside docks, Landside docks**

- **Temporary storage:** No detailed calculations on the required area but on whether or not the distribution can cope with the process variability without a storage buffer.  
  **Temporary storage:** Yes / No

- **Shape:** The chosen shape is that of an I.  
  **Out of scope.**

- **Internal transportation:** Throughput capacity of the system will be assessed based on the design by Kallen (2015) and literature.  
  **Out of the scope.**

- **Distribution:** The distribution both at airside and landside is critical in order to ensure a continuous flow at the FT, however landside distribution is out of scope.  
  **Single or multiple handler configuration**
Design of FT and Distribution Alternatives

In this chapter the design alternatives for the FT, the distribution and the combination of both is presented. Alternatives will be introduced, categorized and eliminated according to the reality present at Schiphol. The first section, Section 6.1 provides a revision of the FT conceptual design. Following this, Section 6.2 goes over the possible design alternatives and defines the final ones. Finally, Section 6.3 determines and illustrates the respective process designs.

6.1. Revised FT conceptual design

As it was mentioned in Chapter 4, the critical variables under analysis for the design of a FT are: The arrival and departure pattern, pre-emption, service mode, number of airside and landside docks and temporary storage. As it was concluded, some of these cannot be changed and have only one possible value. For instance, the arrival pattern needs to be non-restricted and pre-emption is not allowed due to the nature of operations. The same applies to the service mode, which needs to be exclusive, in order to comply with customs regulation. This means that only the remaining variables (i.e. **Temporary storage and departure pattern**) can be altered in order to obtain several FT designs. Table 6.1 shows the variables in a matrix, from which 8 designs can be identified.

It is expected that some of these alternatives are not applicable, which is why an additional column including the respective feasibility is included. From the presented 8 designs, 4 are not feasible (i.e. #1, #3, #6 and #8). The commonality between these designs is the fact that they allow pre-emption. Due to the nature of the arrival pattern at landside and the current practises of the industry, it is not likely that a strategy where pre-emption exists could be successful. It is true that for certain outlier cases (e.g. expedite shipment with medicines) pre-emption could be performed. Nonetheless, these remain outlier cases which are not representative of the functioning of the system. Because of this, designs with pre-emption are considered unfeasible. It is worth re-visiting in the future though since it provides the flexibility of stopping an existing loading and giving priority to an arriving truck. From this point on, these designs will no longer be mentioned.

<table>
<thead>
<tr>
<th>FT Design</th>
<th>Temporary Storage</th>
<th>Pre-emption</th>
<th>Departure pattern</th>
<th>Feasible?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Non-Restricted</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>No</td>
<td>Restricted</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Restricted</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>Non-Restricted</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td>No</td>
<td>Restricted</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>No</td>
<td>Yes</td>
<td>Non-Restricted</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>No</td>
<td>No</td>
<td>Non-Restricted</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td>Yes</td>
<td>Restricted</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 6.1: FT designs based on critical variables
6.2. Distribution and FT design alternatives

Figure 6.1 presents a scheme of the design alternatives and the respective variables to be modified. The combination of the variables constitutes the FT design alternatives mentioned in the previous section, excluding pre-emption. Coupled with the airside distribution configurations, a broader range of choices can be made based on the type of existing or desired FT. It is important to note that since in this case the FT is not built yet there is no optimal distribution but on the contrary, a range of non-optimal solutions based on each FT design.

![Figure 6.1: Scheme of variables and their respective values for the FT and the distribution](image)

Table 6.2 can be created. In this table the preselected FT designs are present, as well as the distribution variants (i.e. single and multiple cargo handler). When looking at each FT design individually, it becomes clear that there are certain variable configurations that when combined, achieve a higher flexibility. Consequently, the designs can be ranked from flexible to strict, which matches the existing order of the designs. In terms of flexibility, the most critical variable is the existence of temporary storage or not. As mentioned in previous sections, a storage area serves as a buffer to smooth out the variability associated with the distribution processes and internal performance.

The second most important is the departure pattern, which defines if trucks can wait for a shipment to be completed or not at the dock door. So, as an example, in a non-restricted departure pattern, a truck would wait for a BUP that is still at the JIC being checked. This however, would not work in a real-life scenario due to the area constraints at Schiphol South-East, a small number of dock doors is desired at the FT. It is thus illogical to expect a system configuration in which the truck seizes the dock door for an extended period of time, waiting for a BUP to arrive. Based on this, the concept of Push/Pull explained in Section 3.4 is applied in a more straightforward way and specifically, on the ability of the FT to perform an actual truck scheduling and allocation. In this way, a FT with a non-restricted departure pattern will behave in a Push way, creating truck shipments based on destination groups and optimizing thus the truck load. On the contrary, a Pull system will respect the original shipments of the RFN network, which means that even if a truck is departing with a LTL, the system will not include extra BUPs with the same destination. Currently, cargo handlers have mostly no say in the truck allocation since contracts are made directly between airlines and truck companies or between freight forwarders and truck companies. And yet, it is clear that achieving a higher collaboration would improve the efficiency of the system as a whole. Based on this, the non-restricted departure pattern will be considered as a Push configuration and the restricted one as a Pull one.

Table 6.2: Matrix of FT design and distribution alternatives.

<table>
<thead>
<tr>
<th>FT Design</th>
<th>Temporary Storage</th>
<th>Departure pattern</th>
<th>System Configuration</th>
<th>Single Handler</th>
<th>Multiple Handlers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Yes</td>
<td>Restricted</td>
<td>Push</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td>Non-Restricted</td>
<td>Pull</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>No</td>
<td>Restricted</td>
<td>Pull</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>No</td>
<td>Non-Restricted</td>
<td>Push</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As Table 6.2 shows, some FT designs are more compatible to certain airside handler configuration than
others. So, for instance, #2 is the most flexible having storage and a push configuration. It would thus be more capable of dealing with the increasing complexity of having to receive cargo from multiple handlers. A stricter FT design like #7 would probably not suffice in coping with the associated variability of multiple handlers. Design #7 constitutes the most strict option: No storage, no pre-emption and restricted departures (i.e. pull configuration). Because of it, this FT design is the least suitable to deal with a variable environment and is considered the most applicable to the single handler configuration. This assessment of delivered flexibility leads to the hypothesis of best distribution per FT design. However, it is necessary to understand how a distribution affects a single FT design and vice versa. Accordingly, the most likely FT design is selected (i.e. Design #2). As Table 6.2 shows, there are two steps in the modelling and testing of these design alternatives. In step 1) Design #2 is tested along both handler configurations (i.e. Single and multiple handlers). Based on the results, the best distribution is selected. Next, in step 2) it is tested along all FT designs. Different demand scenarios will be considered as well.

6.3. FT and Distribution process design

In this section the processes for each area will be described according to the proposed design alternatives. The process under analysis starts with the blockage of the aircraft at the assigned ramp and finishes with the unloading of the cargo at the destination (i.e. 2nd line facility for AMS cargo or final destination for RFN cargo).

As it was described, the overall process can be split into airside, handling and landside. In this case, the handling is to be performed not at an ordinary 1st line facility but at a FT. Figure 6.2 shows the scope of this research, which focuses primarily on the airside and landside processes, while considering the interface variables with the FT as well. The design of the FT terminal itself is not considered as previously stated.

In the next subsections, the process design for each of these components (i.e. airside, FT and landside) will be explained and the respective processes mappings presented.

6.3.1. Airside process design

The conceptual opportunities for the airside process are limited due to the strict regulations in place. As it was seen in Section 5.2, some of the critical design variables are fixed due to the existing procedures. Because of this, the only options that are available for varying the airside process are: Location of customs checks, moment of split of the cargo (i.e. BUPs/ULDs and cargo requiring customs checks) and handler configuration.

**Location of customs checks**

One of the strong points of AAS is precisely the synergy between customs and the industry, achieving streamlined processes. It is for this reason that several options are offered by customs in terms of the execution of checks. A cargo handler can either directly take the cargo to the Joint Inspection Center (JIC), have a scanner at its own facility or, depending on the cargo, have it scanned with a mobile unit at airside.

Based on interviews with Gerard Kervezee from Dnata (appendix A.4) and Hendriena Ritsema from Schiphol Cargo, it becomes clear that the best option is to take the cargo directly for scanning at the JIC. This is easily understood by revising the purpose of a FT. By having customs checks and clearance performed at the FT, the goal of a facility solely focused on transshipment is strayed. As a consequence, **the design considers the location of the customs check to be at the JIC**.

**Cargo split - BUPs and Customs**

As cargo is unloaded, the handler scans the incoming cargo in order to verify what its next destination is.
This might be the Joint Inspection Center if a customs check is required or the 1st line facility of the freight forwarder for BUPs, as is the case with DHL or Panalpina for instance. Based on this, and corroborated by Gerard Kervezee (see appendix A.4), the BUPs are split from the ULD at the ramp. This reduces unnecessary handling and transport times, enabling a process with less non-value added activities. It is for this reason, that an airside process in which the split of BUPs and ULDs occurs at the ramp is selected for the design.

In order to fully understand the impact of splitting up the cargo at the ramp or at the handler's facility, process maps have been created. The following process maps intend on clarifying the activities and players, as well as the extra activities in the case of performing the split at the handler's facility. Figure 6.3 shows Variation #1, in which case the split is performed at the ramp. As it is clear from the figure, the cargo handler transports the BUPs either directly to customs or to the FT. In contrast, Figure 6.4 shows the additional handling performed when the cargo is taken immediately to the handler's facility and only then split. There is an additional transport and unloading, as well as the coordination required in order to deliver or pick up the cargo that needs to go to the FT. It is clear from this comparison, that the airside process design that offers the best results is #1.

**Airside Process Variation 1: Multiple handlers – Split at ramp**

In order to fully understand the impact of splitting up the cargo at the ramp or at the handler's facility, process maps have been created. The following process maps intend on clarifying the activities and players, as well as the extra activities in the case of performing the split at the handler's facility. Figure 6.3 shows Variation #1, in which case the split is performed at the ramp. As it is clear from the figure, the cargo handler transports the BUPs either directly to customs or to the FT. In contrast, Figure 6.4 shows the additional handling performed when the cargo is taken immediately to the handler's facility and only then split. There is an additional transport and unloading, as well as the coordination required in order to deliver or pick up the cargo that needs to go to the FT. It is clear from this comparison, that the airside process design that offers the best results is #1.

**Airside Process Variation 2: Multiple handlers – Split at 1st line facility**

Another variable that can be changed is who performs the handling and transportation of the BUPs at airside. After settling upon Airside Process Design Variation #1, there is already a defined process in terms of splitting of the cargo and the way in which customs checks are performed. That process however, includes only one handler at airside. However, a 1st line facility, like the proposed FT, that receives BUPs from all 7 cargo handlers active at Schiphol could benefit from having an organized pick up and drop off distribution. Hence, in the first case, each cargo handler drops the respective BUPs at the FT (as seen in Figure 6.3). In the second
case, there is a collaboration among parties and one neutral 3rd party becomes responsible for picking up the cargo at each specific cargo handler’s location and unloading it at the FT. The first two variations have only one airside handler, whereas the third one, has two (i.e. the cargo handler and the neutral party.) This third variation of the airside process is depicted in Figure 6.5.

As it can be seen on this figure, the ground handler performs airside process variation #1 as he would under normal circumstances, with the exception that he does not deliver the BUPs at the FT. Instead, he transports it to his own facility where they are left waiting to be picked up by the neutral 3rd party. This party, needs to consolidate requests from all cargo handlers and create a route that will minimize costs and time. Once the route has been created, it is executed and BUPs are picked up at each determined location.

Even though this process has additional activities and might seem more inefficient than variation #1, the complexity of the FT operations at airside might be reduced by introducing one new party that engages all cargo handlers and through which all requests are placed. Whether or not this proposed design is beneficial or not will be assessed through the simulation of this model.

6.3.2. FT process design
As has already been mentioned the FT design itself is out of the scope of this research. However, there are key functionalities of it that need to be incorporated in order to test out the interface variables. It is because of this reciprocal relationship between FT and landside that the different process designs will be shown in Figure 6.6.

6.3.3. Landside process design
The landside process in Figure 6.6 shows the general process with the decision making points with the critical variables defined in Section 5.2. It begins with the unloading of the BUPs from airside to the FT. The type of departure pattern is critical since it defines the Pull/Push nature of the system. So, if the system has a restricted departure pattern, shipments need to be consolidated before truck loading (i.e. Pull). In that case, the relevance of the second variable existence of storage determines the actions to take. If there is indeed storage, the BUPs are kept there until shipment completion and truck arrival. Otherwise they are grouped based on destination and truck type. However, if the departure pattern is not restricted storage is not necessarily required. In that case, if a dock is available, the BUPs are taken directly to the dock door area for the respective truck loading.

In parallel the truck company has already received the notice and performs a route planning based on it. Once it has arranged the necessary resources (i.e. truck and driver), the truck goes to the FT. As it can be seen in Figure 6.6 the truck performs an empty movement to the FT terrain. After arrival at the FT terrain, and if there is an available dock, the BUPs can start being loaded. However, in the eventuality that there were no free dock doors, the truck would have to wait.
6. Design of FT and Distribution Alternatives

Figure 6.6: FT Handling and Landside process

Research Sub-question 4

What are the theoretically viable alternatives to design a distribution process that facilitates higher throughput?

The theoretically feasible FT designs were chosen, for a total of 4. In these designs, alternatives are built through the variation of the 2 critical design variables (i.e. temporary storage existence and departure pattern). Completing the matrix, there are 2 variations of the airside handler configuration as it can be seen on this figure.

Due to time constraints not all 8 models can be tested, which is why the most likely FT design is selected. This design is #2, which has storage present, no pre-emption and a restricted departure pattern or Pull configuration. This will be modelled against both handler configurations (single and multiple handler for 3 different demand scenarios). In the single handler distribution, a 3rd party picks up the BUPs at the cargo handler’s airside and drops them off at the FT. In the multiple handler configuration, all cargo handlers deliver the BUPs at the FT. The best performing distribution will then be chosen for testing all remaining FT designs. This will define the required actor configuration. From this point on, all designs will be referred by new nomenclature (i.e. A, B, C and D).

Figure 6.7: Matrix of FT design and distribution alternatives.
The objective of evaluating the performance of the different FT designs can be accomplished through the use of a verified and validated simulation model. Simulation is used often as an imitation of the operation of a real-world process or system over time and it is an indispensable tool for decision making and problem solving (Schriber and Brunner, 2000). There are several types of simulation models, however, this research uses discrete event simulation. According to Banks (1998) it can be defined as “one in which the state variables change only at those discrete points in time at which events occur.”

In this chapter, the discrete event simulation is explained and detailed in its variables, scenarios and results. This chapter is split in the following way: In the first section, the model is conceptualized, the scope, assumptions, the specific fixed parameters and the input and output data explained. Following this, Section 7.3 presents the verification and Section 7.4, the validation of the model. After proceeding with the experimental plan (Section 7.5), Section 7.6 presents and provides the discussion of the model results.

7.1. Model conceptualization

In order to conceptualize the model it is important to scope it precisely, have a clear understanding of what input and output variables are present and which assumptions are in place. It is based on this that the process description or meta-model is created and finally, the required model data presented. This section aims at presenting these factors in order to achieve a better understanding of the simulated model.

7.1.1. Model scope

The processes taken into account have been explained in Section 6.3 FT and Distribution Process Design. As it was stated, the scope of the import process under review can be seen in the following figure. It is clear that the process starts with the parked aircrafts at airside and finishes with the trucks leaving the FT terrain. It is important to clarify that the FT internal functioning is not within the scope; only whether or not storage is required, the associated Push/Pull configuration and the number of dock doors is considered.

Figure 7.1: Scope of the Simulation Model
The model will use the following configuration variables in order to obtain the Key Performance Indicators (KPIs). As such, the first ones will be used in the experimentation in order to create the different designs while the KPIs serve as a measure of the success in meeting the requirements of the design. The variables are stated in Table 7.1 and include two types (i.e. physical and logistic). The physical variables include the number of dock doors and the storage size of the station, whereas the logistic ones are linked to the main distribution processes under analysis.

Regarding the Key Performance Indicators (KPIs), it is important to reference Table 4.3 in Section 4.6. Originally, it was stated that in addition to the KPIs presented below, the cost of transport for truckers and handlers would be incorporated. This however, is no longer the case. After conducting interviews and discussing the matter with experts it becomes clear that the cost structure of these parties is not only confidential but also quite different among them. So, for instance a handler like KLM will not have the same costs as Dnata. In addition to this, the Truck Reduction indicator is included for the reason that the model configuration (i.e. Push or Pull) influences the truck load and therefore, the amount of trucks actually confirmed for a FT pickup. It is also necessary to clarify that the system for the truck turnaround time indicator is defined as the moment in which it reaches the Gate In at the terrain and leaves through the Gate Out process. Statistics are collected on these KPIs for all runs for further analysis. The model parameters by Kallen (2015) that are applicable to this research will be referenced to understand if the results of this model are within the expected ranges: Throughput Time (1, 1.5, 2.5 [hour] triangular distribution) and Truck Notice Time (1, 2.5 [hour] uniform distribution). The final KPIs are described in Table 7.2:

Table 7.1: Configuration Variables

<table>
<thead>
<tr>
<th>Type</th>
<th>Variable</th>
<th>Unit</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Airside Dock Doors</td>
<td>#</td>
<td>Number of dock doors for unloading at airside</td>
</tr>
<tr>
<td>Physical</td>
<td>Landside Dock Doors</td>
<td>#</td>
<td>Number of dock doors for loading at landside</td>
</tr>
<tr>
<td>Physical</td>
<td>Storage Size</td>
<td>[BUP]</td>
<td>Capacity of the storage area in the FT</td>
</tr>
<tr>
<td>Logistic</td>
<td>Handler Configuration</td>
<td>-</td>
<td>Single 3rd party handler or multiple handlers</td>
</tr>
<tr>
<td>Logistic</td>
<td>Storage Utilization</td>
<td>[0-1]</td>
<td>Utilization after which the system changes from Pull to Push</td>
</tr>
<tr>
<td>Logistic</td>
<td>Truck Notice Time</td>
<td>[hour]</td>
<td>Time after truck request in which the truck is available</td>
</tr>
</tbody>
</table>

Table 7.2: KPIs definition

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Unit</th>
<th>Obj.</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airside</td>
<td>Airside Lead Time</td>
<td>[hour]</td>
<td>↓</td>
</tr>
<tr>
<td>FT</td>
<td>Throughput</td>
<td>[BUPS/hour]</td>
<td>↑</td>
</tr>
<tr>
<td></td>
<td>Lead Time</td>
<td>[hour]</td>
<td>↓</td>
</tr>
<tr>
<td>Landside</td>
<td>Truck Load Factor</td>
<td>[percent]</td>
<td>↑</td>
</tr>
<tr>
<td></td>
<td>Truck Reduction</td>
<td>[percent]</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Turnaround time</td>
<td>[hour]</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Waiting time</td>
<td>[hour]</td>
<td>↓</td>
</tr>
</tbody>
</table>

7.1.2. Model assumptions

In order to simplify the system to model, assumptions are necessary. However, these need to be treated with care since making the wrong assumptions can render not only a false result but also an incorrect understanding of how the real system works. It is for this reason that assumptions are checked during the validation phase of the experimentation. The assumptions made in the current research are:

1. **BUPs per aircraft**: Based on the data provided by Schiphol Group (2016d), an average number of BUPs per type of aircraft is calculated. The results show that for a freighter the average is of 6.07 BUPs while a passenger aircraft carries 0.48 BUPs. However, these numbers are not practical for the implementation of the model, since 1/2 a BUP is simply not possible. Rounding up to 1 full BUP on all aircrafts would inflate the demand, which is why it is assumed that each freighter carries 4 or 5 (instead of the 6 BUPs from the calculation) and each passenger aircraft 0 or 1 BUP. These have a triangular random distribution.
2. **Fixed parameters:** The model fixed parameters assumptions are primarily derived from the work of Kallen (2015), specifically the share and duration of customs share. The distribution for the TNT is also based on it but tested as part of the verification tests. The duration for unloading of a passenger aircraft is based on the interview with Kervezee (2016) and modified based on the fact that this duration applies for the complete cargo unloading of an aircraft. In this research, the duration should consider only one BUP and not the complete loading, which is why the duration is reduced to (10, 15, 20) minutes with a random triangular distribution.

3. **Moving units:** All moving units (i.e. dollies, trucks and BUPs) can bypass each other on roads and conveyor belts, when applicable. However, all dollies and trucks will travel at the designated speed constant, so overtaking should occur only due to external requests.

4. **Additional resources:** Due to the nature of this research, it is out of the scope to define certain resources like headcount, equipment and tools. It is assumed that all necessary resources are present and available during the operation.

5. **No downtimes:** Since the specifics of the equipment are not being considered, failure events regarding dock doors, conveyor belts or other storage equipment are not present in this model.

6. **Storage Retrieval:** The retrieval of the BUP units is done independently of where they are located in the station. There is no additional time for units further away from the storage station exit.

7. **24x7 Operation:** There is no work schedule included in the model, however, the arrival of BUPs is based on real data. This means that there are close to none aircrafts arriving in the middle of the night or early morning. The operation needs to support all arriving cargo, which is why cargo handlers run 24x7 operations as well. Trucking companies are also assumed to be available for pickup upon request.

8. **Single Handler Configuration Pickup Point:** The volume share of each cargo handler is reviewed and the number of cargo handlers reduced based on their proximity and their volume. Consequently, all volume going to WFS (1%) is directed to Dnata and all volume destined to Skylink (1%) and DHL (1%) is added to the volume of Swissport.

9. **Single Handler Configuration Milkrun:** In the case of a single handler a milkrun is proposed due to the fact that the arrivals are too frequent and the quantity too variable (e.g. a freighter with 4 or 5 BUPs or passenger aircraft with 1 BUP). The proposed milkrun routes can be seen in Figure 7.2. It is assumed that the handler performs both routes simultaneously with the existing dolly capacity and he is able to re-direct the resources as necessary.
### 7.1.3. Model input

There are two main types of input data that will be used in this simulation. The first are the model constants or fixed parameters, which are obtained through literature review, interviews, and measurements. The second is the input data, which is obtained directly from Schiphol Group (2016d) and provides the detail of the airside arrival pattern and associated freight. On the landside, the data set has been provided by SmartLox for previous research. Since the research has been performed in recent years and no considerable changes have been implemented at landside or have occurred in the trucking market, the data set is deemed to still be applicable.

#### Fixed parameters

Input data is particularly important for the description of the airside operations as fixed parameters like distances between locations, share of ramp arrivals, volume share by cargo handler and customs activities are described through these. In order to simulate the design alternatives, certain parameters are defined and this fixed value used. These are derived from interviews, measurements, and literature, as it can be seen on Table 7.3. As explained in Section 7.1 there are two airside handler configurations under analysis (i.e. multiple and single). In the case of multiple handlers, they all individually bring the BUPs to the FT while if a 3rd party handler is used, it needs to pick up all the BUPs at the individual handler’s locations. Because of this, it is key to know which distances exist and how the volume is distributed amongst cargo handlers. Table 7.4 shows the volume shares while Table 7.5 the respective distances.

In addition to this, the destinations are segregated into 8 different groups. Four of these correspond to Amsterdam area destinations and have been created based on the proximity of the top freight forwarders (Nieuwsblad Transport, 2015). As it can be seen on Figure 7.3, the 8 freight forwarders considered for this research are split into 3 main routes that will be served by a milkrun. The fourth route is composed of the remaining freight forwarders. The remaining routes are based on the Road Feeder Network (RFN) destination frequency research by van Doorne (2013). The arriving aircrafts will be loaded with BUPs in the corresponding shares shown in Table 7.6.

#### Input

As model input, data provided by Schiphol Group (2016d) is used in order to derive the airside arrival pattern from real data. In order to do so, arrivals of passenger aircrafts and freighters were differentiated. Based on expert criteria the month of April was selected as a representative month. April is a month in which no holiday related peaks are present (i.e. Valentine’s Day, Mother’s Day in Russia, etc.) and data is also not impacted by

#### Table 7.3: Model Fixed Parameters

<table>
<thead>
<tr>
<th>Model constant</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airsie</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unloading time Freighter</td>
<td>45, 60, 90 [min] Triangular</td>
<td>(Kervezee, 2016)</td>
</tr>
<tr>
<td>Unloading time Belly Freight</td>
<td>10, 15, 20 [min] Triangular</td>
<td>(Kervezee, 2016) / Assumption</td>
</tr>
<tr>
<td>Dolly/Transporter speed</td>
<td>15 [km/h]</td>
<td>(Schiphol Group, 2015d)</td>
</tr>
<tr>
<td>Customs scan required</td>
<td>10%</td>
<td>(Zonneveld, 2015)</td>
</tr>
<tr>
<td>Customs scan duration</td>
<td>10 [min]</td>
<td>(Zonneveld, 2015)</td>
</tr>
<tr>
<td>Detailed customs check</td>
<td>10%</td>
<td>(Zonneveld, 2015)</td>
</tr>
<tr>
<td>Detailed customs duration</td>
<td>0.5, 1, 1.5 [hour] Triangular</td>
<td>(Zonneveld, 2015)</td>
</tr>
<tr>
<td>Unloading time at FT</td>
<td>1 BUP/ 3[min]</td>
<td>(Kervezee, 2016)</td>
</tr>
<tr>
<td>Dolly switch time</td>
<td>3 [min]</td>
<td>(Kervezee, 2016)</td>
</tr>
<tr>
<td>Truck Destination Share</td>
<td>50% RFN</td>
<td>(Van Doorne, 2013)</td>
</tr>
<tr>
<td></td>
<td>50% AMS</td>
<td></td>
</tr>
<tr>
<td><strong>Landside</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Delay AMS</td>
<td>10, 20 [min] Uniform</td>
<td>(Pieters, 2016)</td>
</tr>
<tr>
<td>Truck Delay RFN</td>
<td>30, 60 [min] Uniform</td>
<td>(Pieters, 2016)</td>
</tr>
<tr>
<td>Out of countour BUPs</td>
<td>4%</td>
<td>(Kervezee, 2016)</td>
</tr>
<tr>
<td>BUP countour fixing</td>
<td>45 [min]</td>
<td>(Kervezee, 2016)</td>
</tr>
<tr>
<td>Loading of BUP in truck</td>
<td>1 BUP/ 3[min]</td>
<td>(Kervezee, 2016)</td>
</tr>
<tr>
<td>Max BUPs per truck</td>
<td>5 [BUP]</td>
<td>(Kervezee, Wouterse, 2015)</td>
</tr>
<tr>
<td>Truck switch time at Dock</td>
<td>5 [min]</td>
<td>(Kallen, 2015)</td>
</tr>
<tr>
<td>Time at Gate In/Gate Out</td>
<td>0.5, 2.5 [min] uniform</td>
<td>(Rouppe van der Voort, 2015)</td>
</tr>
</tbody>
</table>

---
Table 7.4: Volume arrival per ramp and cargo handler. (Schiphol Group, 2016d), (Schiphol Group, 2016a)

<table>
<thead>
<tr>
<th>Handler</th>
<th>Share</th>
<th>KLM</th>
<th>Menzies</th>
<th>Dnata</th>
<th>Swissport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romeo</td>
<td>36%</td>
<td>11.52%</td>
<td>12.24%</td>
<td>7.56%</td>
<td>4.32%</td>
</tr>
<tr>
<td>Sierra</td>
<td>64%</td>
<td>20.48%</td>
<td>21.76%</td>
<td>13.44%</td>
<td>7.68%</td>
</tr>
<tr>
<td>D</td>
<td>9%</td>
<td>2.88%</td>
<td>3.06%</td>
<td>1.89%</td>
<td>1.08%</td>
</tr>
<tr>
<td>E</td>
<td>32%</td>
<td>10.24%</td>
<td>10.88%</td>
<td>6.72%</td>
<td>3.84%</td>
</tr>
<tr>
<td>F</td>
<td>38%</td>
<td>12.16%</td>
<td>12.92%</td>
<td>7.98%</td>
<td>4.56%</td>
</tr>
<tr>
<td>G</td>
<td>21%</td>
<td>6.72%</td>
<td>7.14%</td>
<td>4.41%</td>
<td>2.52%</td>
</tr>
</tbody>
</table>

Table 7.5: Distance between airside locations. Units in kilometers. (Google Maps)

<table>
<thead>
<tr>
<th></th>
<th>KLM</th>
<th>Menzies</th>
<th>Dnata</th>
<th>Swissport</th>
<th>FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romeo</td>
<td>1.35</td>
<td>1.60</td>
<td>0.15</td>
<td>2.00</td>
<td>1.50</td>
</tr>
<tr>
<td>Sierra</td>
<td>1.85</td>
<td>0.15</td>
<td>1.55</td>
<td>0.20</td>
<td>1.25</td>
</tr>
<tr>
<td>D</td>
<td>1.38</td>
<td>3.05</td>
<td>2.50</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>E</td>
<td>1.63</td>
<td>3.30</td>
<td>2.75</td>
<td>3.75</td>
<td>3.75</td>
</tr>
<tr>
<td>F</td>
<td>1.78</td>
<td>3.45</td>
<td>2.90</td>
<td>3.90</td>
<td>3.90</td>
</tr>
<tr>
<td>G</td>
<td>2.13</td>
<td>3.80</td>
<td>3.25</td>
<td>4.25</td>
<td>4.25</td>
</tr>
</tbody>
</table>

Figure 7.3: Amsterdam area routes and freight forwarders

Table 7.6: Destination Groups and Share

<table>
<thead>
<tr>
<th>BUPEntity</th>
<th>BUP Type</th>
<th>DestGroup</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUPAMS1</td>
<td>AMS</td>
<td>1</td>
<td>5.5%</td>
</tr>
<tr>
<td>BUPAMS2</td>
<td>AMS</td>
<td>2</td>
<td>13.5%</td>
</tr>
<tr>
<td>BUPAMS3</td>
<td>AMS</td>
<td>3</td>
<td>5.5%</td>
</tr>
<tr>
<td>BUPAMS4</td>
<td>AMS</td>
<td>4</td>
<td>25.0%</td>
</tr>
<tr>
<td>BUPRFN1</td>
<td>RFN</td>
<td>5</td>
<td>5.5%</td>
</tr>
<tr>
<td>BUPRFN2</td>
<td>RFN</td>
<td>6</td>
<td>5.5%</td>
</tr>
<tr>
<td>BUPRFN3</td>
<td>RFN</td>
<td>7</td>
<td>5.5%</td>
</tr>
<tr>
<td>BUPRFN4</td>
<td>RFN</td>
<td>8</td>
<td>33.5%</td>
</tr>
</tbody>
</table>
the rush of summer, which is the highest peak of the year. The week from **Monday 18th through Sunday 24th of April** is chosen and each day split into periods of 4 hours. There are thus 6 periods per day and by consequence, 42 periods in the whole week. These periods, for freighters and passenger aircrafts separately, are filled in the rate tables of the model (see Appendix B.3.1 for reference). Within each period the amount of arrivals will be distributed randomly, making it possible to have consecutive weeks with non-identical arrival patterns. Figure 7.4 shows the pattern for the specified week. In it, both arriving passenger and freighter flights are shown. In addition to it, an estimation of the number of BUPs for the freighter is presented. This is done based on 5 BUPs per flight and serves to illustrate the possible incoming BUP flows.

Figure 7.4: Arrival pattern for passenger and freighter aircrafts

### 7.1.4. Model output
The model is able to record entities states and their individual values at certain points in time or when reaching a certain instance in the operation flow. Because of the large quantity of data available, specific indicators are checked to verify and validate the behavior of the model. As stated in Table 7.2, there are KPIs on which the performance of the system will be assessed for the different FT designs. It is worth noting that these are not the only available indicators but the key ones. In addition to this other indicators are checked: Number of entities in the system, Total Time in System, Resource Utilization for the dock doors, Average Number of BUPs in the FT, Total Distance Travelled for the 3rd party handler and many more.

### 7.1.5. Meta-Model
The meta-model serves as a representation or description of the model to be simulated. It is a simplification that highlights the properties of the model, including the model's inputs and outputs. According to Verbraeck (2015c), the meta model also defines the concepts, relations, rules and constraints. As such, it is the most common way to represent modeling languages in a formal manner. As Figure 7.5 shows, there are four main components of the model, starting at the airside operations (i.e. 1. BUP Arrivals) and finishing with the Truck loading. Under each component, the critical alternative decisions or variables are presented. Figure 7.6 depicts the meta model in a lower level of detail, as it would be modelled.

Figure 7.5: Meta Model

#### 1. BUP Arrivals
On this first module aircraft entities are created based on the input data provided by Schiphol Group (2016d). Then, based on the destination shares as stated in Table 7.6, the BUP entities are created. The process of aircraft unloading is performed with distinct times per type of aircraft (i.e. freighter or passenger) and the
7.1. Model conceptualization

BUPs loaded in dollies. It is important to mention that at this point, trucks are pre-noticed of the existing shipment and it is from this moment on that the Truck Notice Time (TNT) starts. The BUPs that need to be inspected by Customs are loaded in separate dollies and transported to the JIC. If a more detailed inspection needs to be carried on a BUP, the dolly can take back the released BUP to the FT and then come back for the remaining one. The BUPs that did not have to go to Customs are transported directly to the FT from all different ramps.

It is specifically at the transport activity where the difference between single or multiple handler configuration comes up. In the case of multiple handlers, the transport duration depends on the ramp at which the aircraft arrived, which is treated as a constant (see Table 7.3). The BUPs are loaded and transported directly to the FT. In the case of a single handler, additional steps are included (see Figure 6.5 for the detailed process mapping). These include transportation to the airside handler’s facility, unloading, loading by the single handler, transportation to the FT and unloading.

In parallel, the trucks which have already been created are stored in a Roaming Node waiting for Shipment Confirmation. This follows real life practices since truck companies are notified of incoming shipments based on aircraft arrival time and then receive a shipment confirmation once it is ready for pick up.

2. FT Unloading

When dollies reach the FT, BUPs are unloaded making use of the airside dock doors. The number of these is a configuration variable under study since it limits the influx of BUPs to the FT. If capacity is not available, the dollies will queue and they will be processed in a FIFO manner.

3. FT Handling

It is in this module and the following one (i.e. 4. Truck Loading) where the majority of the intelligence of the design lies in. Hence, it is also were most of the decisions and system processes are present.

Once at the FT, a capacity check is performed. If there is capacity available at the FT, the BUPs are stored. Otherwise, the BUPs accumulate on the conveyor belt. This of course represents a blockage of the system,
since the conveyor belt stops and the FT can no longer receive any more BUPs from the unloading process.

When the BUPs enter the storage area it is based on the configuration of the system (i.e. Pull or Pull) that the batch grouping is decided upon. So, in the case of a Pull configuration, shipments are created based on Arrival Times for RFN and Destination Groups for AMS. Because of the fact that the distances between freight forwarders in the Amsterdam Area are relatively small, it makes sense to batch by destination group, independently of arrival time. That is not the case with all RFN shipments. Distances for RFN cargo are larger and destinations can have several hundred kilometers at least between them. Because of this, RFN BUPs are only batched by destination group and not by the original intended batch only when the system moves to a Push configuration.

It is also worth stating that an additional process has been added in order to prevent BUPs with storage times above 3 hours to remain in the FT. Once a BUP reaches the 3 hours, a search in the storage unit is performed in order to complete a shipment based on destination groups only.

Upon confirmation that the shipment is complete, a truck search is conducted in the Roaming Node. The match is simply done by destination type (i.e. RFN or AMS) and once a truck is found, an unique identifier is assigned to the truck and vice versa. In this way, the truck knows specifically which shipment it needs to pick up and the BUP shipment recognizes that specific truck as the assigned one. The shipment remains in storage until the truck docks.

4. Truck Loading
The final part of the process under analysis starts with the Gate In at the FT terrain. It is at this point that the assignment of a dock is performed. Once the truck docks, it announces its arrival to the assigned BUP shipment and waits for its loading. Consequently, the individual BUPs that conform the shipment transfer out of the storage station and are batched. They continue to the specific dock and are loaded in the truck. Following this, the truck proceeds to the Gate Out process and leaves the terrain.

7.2. Model implementation
The model conceptualization shown in Figure 7.6 is implemented in the Simio simulation software. Just like in the meta model it is split into 4 main modules: 1. BUP Arrivals, 2. FT Unloading, 3. FT Handling and 4. Truck loading. Due to the fact that there are internal processes on each module and critical decisions made as a product of it, the model is explained in detail in Section B.2.2 of the appendices. Particularly for the handler configuration, the difference between multiple and single handler can be seen in Figures B.1- B.2.

Figure 7.7: Model Layout

7.3. Verification
After having built the model it is vital to understand if it is correct against the specifications (Sargent, 2005) (Corman and Duinkerken, 2015). This section includes the description of the verification strategy in Section 7.3.1, followed by the verification checks (Section 7.3.2). Finally, the specific verification runs and results are presented in Section 7.3.3.
7.3. Verification

7.3.1. Verification strategy

There are two main components to a verification process and these are equally important. First the checks aid the researcher to understand if the model is functioning against requirements. These are extremely practical as they are used while building the model and verifying the stepwise implementation of the different mechanisms and processes in the model.

After this, and once the model is completed, the verification runs are performed. Optimally, runs should be performed on all existing variables, their combinations and for all KPIs. Having said that, it is clear that a model with the level of complexity like the one hereby presented, cannot be fully verified or validated. The proposed model has 6 configuration variables, which can be assessed individually or combined on all 7 KPIs. Because of this and considering the existing time restriction and scope of research, a full factorial analysis is not executed. Instead, key relationships are distinguished and the most important KPIs analysed. For most runs LT, TP, Truck Turnaround Time and Truck Load are evaluated. The verification strategy for the test runs can be seen in Table 7.7:

Table 7.7: Verification strategy for test runs

<table>
<thead>
<tr>
<th>Verification tests</th>
<th>Configuration Variable</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuity</td>
<td>Storage Utilization</td>
<td>LT, TP, Turnaround Time &amp; Truck Load</td>
</tr>
<tr>
<td></td>
<td>Truck Notice Time</td>
<td>LT, TP, Turnaround Time &amp; Truck Load</td>
</tr>
<tr>
<td>Degeneracy</td>
<td>Dock Doors, Station Size, TNT</td>
<td>All KPIs</td>
</tr>
<tr>
<td>Consistency</td>
<td>Dock Doors</td>
<td>Resource Utilization</td>
</tr>
</tbody>
</table>

7.3.2. Verification checks

In this section the way in which the model was verified is described and elaborated upon:

- **Model Correctness**: The de-bugging and checking of the model was performed not only once it was finished but on each individual process and sub-process. Most of these were built separately and then added once their correctness was verified. By following a modular design during the building, errors were contained to their specific "model", solved and then implemented in the final model.

- **Balance checks**: Performed with the help of the visual aids of Simio (i.e. labels and the Pivot Grid in the Results tab). All entities created match with those either still in the system or destroyed. Regarding the share of destination groups this is also verified and is indeed a statistical match to the ones provided as input.

- **Event tracing**: Throughout the building of the model, the trace capability of Simio was used, allowing the researcher to follow each step of each process with the respective entity and understand fully if the model's logic matches the conceptualized model.

- **Run time visualization**: Counters, status plots and pies are included in all servers and stations in order to understand the behaviour of the model during run time. In addition to this, the fact that the software used for the simulation is Simio, enhances the visualization by allowing the import and use of icons and 3D visualization.

- **Input Checks**: Based on the arrival rate for aircrafts and the associated number of BUPs per type of aircraft, it can be verified that the model creates the expected number of BUPs. Following from this, it is also cross-checked against the amount of created trucks. Since each time an aircraft lands a truck is requested, the verification results easily. Finally, all server type stations are checked in order to understand whether or not the "production rate" matches the given values.

- **Fault injection**: This check aims at ensuring that the threats to the dependability of the system are minimized. Threats can be categorized as faults or errors. In this case, errors have already been verified through multiple runs of the model and by applying the other above mentioned checks. Focusing specifically on the faults which are, according to Kooli and Di Natale (2014), "physical defect or imperfection that happens in the hardware, software or human component of the system." It can be the cause of specification or implementation mistakes, as well as external disturbances or misuses. Based on this, a review of the most likely fault was performed. As mentioned beforehand, the only inputs provided manually are the model constants (see Table 7.3) and the arrival rate tables (see Table B.2 for freighters.
and B.3 for passenger aircrafts in Appendix B.3.1). In order to test these, negative arrivals were included in the Rate Tables to verify if the model considered them or not. The model considered the arrivals as an absolute value, having thus no effect on the actual arrival pattern. No warning was presented to the modeller though. In addition to this, model constants were tested and as expected, if the value was completely unlikely (e.g. truck loading time of infinity), the system would basically stop processing units. When this occurs and with the help of the run visualization tools this is very clear to identify.

### 7.3.3. Verification runs

In this sub-section the model is verified through specific tests to corroborate that it behaves in the expected way when extreme cases or changing conditions occur. The verification is performed according to the strategy presented in Table 7.7 for the multiple cargo handler model configuration, as this is considered the most feasible. The specific tests were performed considering 10 airside and 5 landside docks whereas other variables are changed depending of the test. The results can be seen below:

**Continuity tests**

In this subsection the results of running the model with slightly different parameters is tested. Specifically, the storage utilization percentage and the TNT are changed gradually and the resulting lead time and throughput are analysed. Additionally, metrics regarding truck entities (i.e. Truck Load and Turnaround Time) are included.

**Storage Utilization**

Using a storage capacity of 50 as a fixed parameter, Figure 7.8 and Figure 7.9 show how the LT and TP change when the storage utilization is changed in 10% increments. As it was mentioned before, the storage utilization percentage defines the point at which the system moves from a Pull to a Push one. As it can be seen, the TP decreases slightly from the maximum of 42 to 39. This change however, is not as striking as the LT one, where there is an increase of almost 30% in the LT.

![Figure 7.8: Continuity Test- LT against Storage Utilization](image)

![Figure 7.9: Continuity Test- TP against Storage Utilization](image)

In the case of the truck metrics, it can be seen on Figure 7.11 that, as expected, the average truck load decreases from 5 in the case of a full Push system to 2 when the system works entirely as a Pull one. The turnaround time, seen in Figure 7.10 increases from 14 to 24 minutes. This result verifies the functioning of
the model since, as expected, a Pull strategy creates smaller shipment sizes and increases thus the amount of trucks arriving at the terrain. This in exchange, increases the turnaround time of the trucks.

**Truck Notice Time**
The TNT is changed from 0 to 3.5 hours in order to verify its impact on the model. As it can be seen in Figures 7.12 and 7.13, the Truck Notice Time has no detectable influence on the LT and TP. Specifically for the LT, in spite of the existing variations between the TNT values, a specific pattern is difficult to identify. Figure 7.14 supports this as there is no effect of the TNT on the turnaround times. The only KPI that shows a trend is truck load as it can be seen in Figure 7.15. Nonetheless, none of these are statistically significant as it can be concluded from the box plots. In reality, the differences do not even amount to a 5% improvement. It seems based on it, that either a value of 2 or 3 hours would be ideal. This is not a robust result though since it does not consider the influence the other variables might have on the Push or Pull strategy followed by the system.

![Figure 7.12: Continuity Test- LT against TNT](image1)

![Figure 7.13: Continuity Test- TP against TNT](image2)

![Figure 7.14: Continuity Test- Turnaround Time against TNT](image3)

![Figure 7.15: Continuity Test- Truck Load against TNT](image4)

**Degeneracy tests**
In these tests the response of the model to extreme cases is verified. Some of the performed tests included changing the following factors to zero or infinite: *airside or landside dock number to zero, station size, TNT and certain server process times*. The modified dock capacity results in either a blocked system (i.e. one where the BUPs cannot continue either to the FT conveyor or to the assigned truck) or a very low resource utilization. In the case of the station size, an infinite station can be implemented in the model, however, this does not reflect the reality, which is why it is not tested. A capacity approximating zero changes the system towards a push one. The TNT can be derived from the test performed in the continuity test. Basically, an extremely large TNT would prevent the FT from having a constant output flow and would eventually result in no more BUPs being unloaded from airside to the FT. Finally, increased server times directly affect the LT and the amount of stored units. Reduced times overburdens the system since the TNT is still present.

**Consistency tests**
The key resources in this model are the airside and landside docks, as well as the FT. Considering that in the validation section the relationship between the FT size and the storage utilization will be tested, in this section only the dock capacity is tested. A set of 5 scenarios is chosen, in which a combination of 2 airside and 1 landside docks is increased up to 10 at airside and 5 at landside. The results can be seen in Figure 7.16
and it shows that indeed the utilization decreases as the capacity is increased. The relationship is not solely linear though, and it can be seen that there are certain breaking points at which the utilization can no longer be decreased. Such is the case of increasing from 2 airside docks to 4. The reason behind this is the fact that with 4 airside docks the facility is barely capable of coping with existing demand. It is of vital importance to remember that these resources are not independent of each other. On the contrary, if the airside docks are not enough, landside docks will not have any cargo to load. Furthermore, if the landside docks are not enough to expedite the shipments, the FT might be filled too quickly and no more cargo could be received from airside. Figure 7.16 shows the expected behavior and it can be verified that the model portrays the use of these resources as it should.

Based on the performed checks and test runs it can be concluded that the model functions according to the model conceptualization and existing requirements. This means that the likelihood of the model leading to erroneous results has been reduced within the possibilities of the present research.

7.4. Validation

Validation aims to answer whether or not the model is able to respond to the real life questions and scenarios under study. It is the "substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model" Corman and Duinkerken (2015). Unfortunately, there is no standard way of validating a model and according to some experts there is no 100% proof validation. However, there are several validation methods that can be applied. In the lecture by Corman and Duinkerken (2015) input parameters and distribution are validated against historical data and expert knowledge. Model assumptions and processes can be validated through a structural validation and experimental results can also rely on historical data and real-world outcomes. Verbraeck (2015a) supports these methods and divides them in structural (i.e. testing of hypotheses on the model), replicative (i.e. comparing values against real system values) and lastly, expert analysis.

7.4.1. Validation strategy

In this case, it is impossible to perform any analysis based on historical data since the FT does not exist yet. However, it is possible to perform runs to validate the chosen values for the configuration and assess these against expert analysis and previous research. In this way, the chosen values are selected based on the desired performance of the system and do not pose a hindrance on the evaluation of the designs. As mentioned in Section 7.3.1, a full factorial is not possible due to the high amount of variables and KPIs. How this limits the results and what the associated concerns are will be discussed in Chapter 8. For this reason, only the most relevant interactions are selected. These were discussed with experts and constitute the critical configuration variables for the design alternatives. In addition to this, one interaction (i.e. storage size and storage utilization) is tested in order to better understand the functioning of the system. The chosen tests and variables can be seen in Table 7.8.
### Table 7.8: Validation strategy for runs

<table>
<thead>
<tr>
<th>Validation tests</th>
<th>Configuration Variable</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airside/Landside Dock Capacity</td>
<td>Dock Doors</td>
<td>LT, TP, Turnaround Time &amp; Truck Load</td>
</tr>
<tr>
<td>FT</td>
<td>Storage Size, Storage Utilization</td>
<td>LT, TP, Turnaround Time &amp; Truck Load</td>
</tr>
<tr>
<td>Dolly Capacity Single Handler</td>
<td>Number of dolly trains</td>
<td>LT, TP, Turnaround Time &amp; Truck Load</td>
</tr>
</tbody>
</table>

#### 7.4.2. Validation of landside and airside dock doors

As it was shown in Figure 7.16 during the verification phase there is an interdependency in the amount of dock doors at airside and landside. It was stated in the previous section that certain combinations are undesired (e.g. 2 airside and 1 landside dock) since they do not match the minimum required capacity. However, it remained unclear which of the "middle ground" combinations would impact positively the KPIs under analysis. It is for this reason that LT and TP are assessed under the different combinations. Figure 7.17 shows the LT and TP, where it is obvious that a combination below 6 airside docks is not desirable seeing that the LT increases above acceptable limits. The TP is also the lowest for those two combinations. Viable choices are hence above 6 airside and 3 landside docks. These combinations show a similar TP with differences smaller than a 1% but differences of approximately 30% in LT. It that case, an improvement on LT of 45 minutes would be a desired reduction. Considering the fact that the goal of this research project is to understand how the distribution processes can facilitate a seamless flow, it has been decided to make use of the dock door configuration that shows the best performing KPIs. That means, that for the rest of the analysis, a dock door configuration of 10 and 5 will be used.

**Figure 7.17: Dock door number - LT and TP**

#### 7.4.3. Validation of FT storage capacity and storage utilization

Another key dependency in the model is the storage capacity of the FT and the storage utilization above which the system moves to a Push strategy. In order to better understand this, an analysis of certain feasible storage sizes (i.e. 50, 100 and 150) and associated storage utilization limits (i.e. 0, 0.2, 0.4, 0.6, 0.8 and 1.0) has been combined and tested. So a system with a storage utilization of 0 is a fully push system, whereas one with 1 works on a pull way only. The resulting 18 combinations and its results can be seen for the critical KPIs in Figures 7.18 through 7.27.

Figure 7.18 shows that in the case of storage size 50 and 150, the LT increases as the storage utilization does. This is expected since a higher storage utilization enables the system to work on a Pull basis for a longer period of time. Lower storage utilization values allow the model to behave in a Push way, which as proved reduces LT considerably. In the case of storage size 50, variability increases as the utilization limit does. Again,
this is foreseeable since push systems prevent large fluctuations from occurring by taking a pro-active role in the expediting. Interestingly enough, that is not the case with storage size 100 and 150. As it can be seen in the graph, there is a reduced variability for utilization values of 0.8 and 1.0. This proves that LT is not solely influenced by the utilization limit but also by the storage size. There is thus a combination that will improve LT while reducing variability as well. This is contrary to the effect on the TP indicator as it can be seen in Figure 7.19 since the data shows that an increase in the storage utilization always reduces TP. There is a large decrease particularly for storage size 50 at storage utilization 1, however, for the rest, all TP values stay within the 41 and 42.5 BUPs per hour.

Assessing the effect of these variables on the utilization of airside and landside docks is also done. Figure 7.20 shows that, as anticipated, the utilization of airside docks does not change. From this, it can be concluded that none of these combinations block the system. Landside docks have a different behavior, as seen on Figure 7.21. In it a clear trend can be identified: The higher the storage utilization value, the higher the dock utilization. This reaches a stabilization value around 45% to 50%. A relationship with the storage size variable is also clear, as the stabilization point is reached sooner for higher storage sizes. So, while for storage size 150 the dock utilization already reaches the 45% value at a 0.2 utilization, that only happens at utilization 0.6 for storage size 50.

Finally, the effect of these variables on the truck turnaround time and truck load indicators is evaluated. As Figure 7.22 shows, the turnaround time clearly increases as the storage utilization does. The graph distinctly shows a steeper slope for higher storage sizes. The rationale behind it is that a smaller storage size requires less trucks to be called in order to expedite the cargo once the system moves from pull to push. On the other
hand, a large storage facility has many more BUPs to ship during this change. So, for example if a facility moves from pull to push at 0.5 and has a capacity of 50 BUPs, it needs to expedite 25 BUPs or 5 FTL. In the case of a storage size of 150 that would mean 75 BUPs or 15 trucks, assuming they can all be consolidated in FTL. In these cases, trucks endure longer waiting times due to a peak in truck requests. The effect of storage size is also evident on the variability per sample. It can be concluded then, that higher storage sizes impact truck turnaround time negatively as the system moves from push to pull. Push systems offer the smaller turnaround times. It is important to contrast these results with the truck load, seen in Figure 7.23. Truck load is at its maximum (i.e. 5 BUPs) for the lower storage utilization values. Naturally, a FT that functions on a push basis will attempt to optimize truck load in order to free up capacity as quick as possible. As the storage utilization increases, so does the limit at which the system moves from pull to push. It can be seen that the truck load stabilizes around 2.5 BUPs per truck for higher utilization values. The influence of storage size on truck load is also identifiable, as smaller storage sizes allow the system to reach the storage utilization value easier, making it work on a push way more frequently and increasing thus truck loads.

![Figure 7.22: Storage Size and Utilization -Turnaround Time](image1)

![Figure 7.23: Storage Size and Utilization -Truck Load](image2)

### 7.4.4. Validation of the dolly capacity for the single handler

In spite of it not being a critical configuration variable by itself, the capacity of the 3rd party in charge of handling and transportation between cargo handlers and the FT is validated. Selecting a value that is too low will increase the LT in an undesired manner, turning the Single Handler design alternative into an unfeasible one. It is for this reason that a validation of the number of dolly trains is performed and subsequently, a value chosen for the actual experiments.

In order to fully understand the results, it is important to recall that a dolly train has a maximum carry capacity of 5 BUPs. So, for example 5 dolly trains represent a capacity of 25 whereas 10 would mean 50 BUPs. Figure 7.24 and Figure 7.25 show that a capacity of 5 (i.e. 25 BUPs) does not suffice and as a consequence, LT increases or TP is reduced. However, from 6 dolly trains on, a stabilization is reached and there is no statistical difference between the samples. Even though the change in handler configuration and the associated airside handling capacity affects mainly the arrival pattern at the FT, it is important to understand how this changes the landside KPIs. As it can be seen in Figure 7.26 and Figure 7.26, there is indubitably an effect on the Truck Turnaround Time and Truck Load. Now, it is relevant to point out that only in the case of 5 dolly trains there is a statistically significant difference. And even so, these differences may actually not be relevant since the biggest one is under one minute in the case of turnaround time and a mere 6% for truck load. This is a clear example of scenarios that are statistically different but whose differences proof to be trivial in real life. Based on this, the capacity of the 3rd party handler will be of 8 dolly trains.

### 7.4.5. Expert analysis

Even though performing a robust analysis of the model based on the opinion of experts is challenging since the FT still does not exist, it is viable to discuss the main results of the model. The model conceptualization has been reviewed with the supervisor of this research at Schiphol Cargo, Hendriena Ritsema and it has been agreed upon. In addition to this, interviews were conducted with industry experts from different sectors
(i.e. cargo handlers, freight forwarders and trucking companies) in order to understand if the design seems possible and what the current performance metrics are. For further details on the interviews see Appendix A while the specifics of the performed process analysis can be consulted in Section 4.5.

With regards to the airside handling, 67% of the aircrafts have a turnaround time between 2 to 4 hours. The LT at airside in the case of this model is for the current demand baseline and in all feasible designs below 4 hours. A direct relationship between turnaround time and airside handling cannot be stated but having a reference data is the best approximation that can be done. Reinforcing this point is the fact that Dnata’s goal is to have BUPs ready for pick up under 2 hours, however, that is not the majority of the volume since a 90% is handled between 7 and 8 hours. According to Kervezee (2016), even if the BUPs are ready, it is hardly picked up on time. On the landside, the truck turnaround is of around 1 hour, which is larger than the range resulting from the model (i.e. between 12 and 36 minutes). This is as expected though, since trucks are called only once the shipment is ready. Even if these values cannot be compared one to one, they serve and fulfill the purpose of understanding if the model is mistakenly different from the current cargo operations at AAS.

To conclude the validation, it can be confirmed that the model is able to describe the real-life operations of a FT and the associated airside and landside distributions within the specified scope and under the mentioned assumptions. These assumptions and simplifications will obviously create a gap between the model results and the actual operation, however, these are understood and judged as an acceptable compromise in order to fulfill the requirements of this project.

7.5. Experimental plan
In this section the treatment specification (i.e. run length and replications) is defined and the specific run configuration described.

7.5.1. Run length and replications
The operation cycle of cargo transhipment is one week and the arrival pattern tends to repeat itself every week. The ground rule for determining run length by Alexander Verbraeck states that a simulation needs to be run at least 3 times the longest cycle time. It is for this reason, that a run length of one month is decided upon. Standard month of 4 weeks and 28 days is used, which translates into 672 hours.

In addition to this, the replication number needs to be defined. According to Schriber and Brunner (2000),
a replication is "a simulation that uses the experiment's model logic and data but its own unique set of random numbers". By doing so, it is able to create unique statistical results. As such, these are independent of each other and can be seen as an instance of a statistical experiment (Corman and Duinkerken, 2015). By testing different replication numbers, the outcome of the model runs can be compared. If the difference is significant, it means that the similarity between runs is not guaranteed. The number of replications should ensure that the half-width or margin of error of the KPIs is below 5% (Kallen, 2015). This applies evidently for a level of confidence of 95%. If the level of confidence were to change, the associated significance factor would change respectively.

An initial set up with 10 replications is ran on the defined KPIs in order to define if more replications are necessary. Simio calculates the half-width on its experiments module and it becomes then clear that 10 replications is not enough. It is for this reason that the replication number is increased to 25 with the above stated run length of 672 hours.

7.5.2. Start up time
There are two types of simulation in terms of run length: Terminating and Non-terminating simulations. In the first case there is a specific end time or state (e.g. closing time of a store) while in non-terminating simulations one can differentiate amongst transient and steady states (Corman and Duinkerken, 2015).

When dealing with a non-terminating simulation, as in the case of this research, it is critical to understand if a start up time is required before reaching steady state. A steady state is one in which the performance is no longer influenced by the initial state of the system. By excluding the effects of empty queues, idle equipment, setup times and resources warm up period, more accurate results can be reached. As an example, a factory that runs 24x7 could be analysed without considering the warm up or start up time. However, if this same factory went through a maintenance shutdown, upon restarting, a warm up time should be considered.

In this research the operation always starts from zero since in principle, no BUPs should stay overnight. In spite of it being a 24x7 operation, there is close to no cargo arriving during the night and early morning hours. One can thus view this system as one that restarts every day and by consequence, does not need a warm up time to reach its steady state. Furthermore, its ability to reach steady state quickly on a day to day basis should be assessed as well. Based on this, no warm up period is considered.

7.5.3. Run configuration
The run configuration and alternatives definition will be done based on Table 6.2. As it was mentioned previously, due to time constraints not all 8 available combinations will be tested. The run configuration is shown in Table 7.10. It is also worth noting that, based on the assessment performed in the previous section, the values for the configuration variables has been decided upon and can be seen in Table 7.9

<table>
<thead>
<tr>
<th>Configuration Variable</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airside Dock Doors</td>
<td>10</td>
<td>doors</td>
</tr>
<tr>
<td>Storage Size</td>
<td>75</td>
<td>BUPs</td>
</tr>
<tr>
<td>Pre-Stacking Size (no storage)</td>
<td>25</td>
<td>BUPs</td>
</tr>
<tr>
<td>Landside Dock Doors</td>
<td>5</td>
<td>doors</td>
</tr>
<tr>
<td>TNT</td>
<td>2</td>
<td>[hour]</td>
</tr>
</tbody>
</table>

In the case of the single handler, and as argued in the previous section, the capacity at airside for the 3rd party handler will be of 8 dolly trains (i.e. 40 BUPs) for the base case. However, as the demand increases, it will also change accordingly (e.g. 50% demand increase result in 4 more dolly trains for a total of 12). All following designs will share these same values. The steps followed in order to adhere to the run configuration are:

1. **Handler Configuration at Airside**: Design A, considered the "base case", will be tested in two different handler configurations (i.e. Single and multiple handler) for three demand scenarios based on the current baseline. The three demand scenarios reflect the expected growth based on a stalemate situation (Growth of 1x current demand), conservative growth (1.5x current demand) and finally, an optimistic growth (2x current demand). In total, 6 runs will be performed. A handler configuration will be selected based on the KPIs (see Table 7.2).
2. **FT Design Alternatives:** The selected handler configuration will be used to model the subsequent designs (B-D) on the conservative demand scenario. In this step, 3 runs will be executed.

![Experimental Plan - FT designs](image)

Finally, the KPIs will be contrasted and assessed in order to define the FT Design which performs relatively best.

**FT Design A**
The first design includes temporary storage and has a non-restricted departure pattern, making it thus a push system. The storage size is defined at 75 BUPs because a storage size of 50 has been tested and proven to deliver positive results on the KPIs. The additional 25 BUPs are added for consideration of the BUPs in the pre-stacking area. As explained in more detail in "FT Design C", the model considers 5 landside docks which multiplied by the truck capacity equals 25 BUPs. This design has a push system configuration, which is why a storage utilization value of 0.2 is used. After a 0.2 ratio of storage utilization (i.e. after 15 BUPs enter the storage area), the system will move to push.

**FT Design B**
Similarly to design A, this design has 75 storage positions. What is distinct in this design is the fact that the system has a pull configuration. At a storage utilization of 0.8, the system will only move to push once the storage has reached 60 BUPs.

**FT Design C**
In this case, there is no storage available. However, the interpretation of storage is that of a dedicated area where BUPs can be stored temporarily. This does not consider pre-stacking, which is a necessary task specially in a scenario with no storage. Even in systems that run fully on a JIT way, pre-stacking is performed and required in order to ensure a smooth loading process. Since the model makes use of 5 landside dock doors and the maximum capacity of a truck is 5 BUPs, a storage size of 25 is used. For the purposes of this research and in order to simplify the implementation of the model in Simio, the areas are not considered as separate ones. This has no effect on the results because the internal operation of the FT is not part of the scope. Just like in design A, this design behaves like a push system after the storage utilization has come to 0.2 (i.e. after 5 BUPs the system moves to push).

**FT Design D**
Finally, Design D has only the pre-stacking storage like Design C but makes use of a pull system configuration. This translates into an increased storage utilization ratio (0.8), enabling the system to work on a pull way until 20 BUPs are in the pre-stacking area.

These four designs will all yield different results and improve or deteriorate the KPIs in distinct ways. In the next section these results will be analysed and the optimal design for the possible desired goals (i.e. minimized LT, maximize TP, minimize turnaround time, etc.) presented.

### 7.6. Model results

The model is run on both handler configurations for all three demand scenarios (i.e. base demand, conservative and optimistic) and the results are analyzed with the help of JMP Statistical Software. All KPIs will be described through their mean, standard deviation and distribution. The goal of this analysis is to understand whether or not different designs or configurations are statistically equivalent or different. In addition to this, it is necessary to understand how large the differences truly are since a value might be statistically equivalent but not relevant in a real-life operation. As Lane (2015) states "finding that an effect is significant does not tell you about how large or important the effect is."

It is important thus to present the reader with a short summary on the concept of hypothesis testing and how it will be applied to this analysis. For more information, the reader is referred to Appendix B.4.1. Statistics are used in wide applications in order to determine if experimental results can be generalized. This is called...
statistical inference (i.e. a conclusion is reached on a population based on random sampling.) As part of this, it is critical to determine if the experiment "treatments" had an effect or not, which is done through hypothesis testing. The first hypothesis is that there is no effect of the treatment, which is why it is referred to as the null hypothesis \( H_0 \). There are errors associated with this decision making process (i.e. Type I (\( \alpha \)) and Type II Errors (\( \beta \)). The \( p \)-value relates to type I error and according to Lieber (1990), it is "the probability of committing type I error in a given experiment". \( H_0 \) is rejected or accepted based on the acceptable type error I. Type II error (\( \beta \)) is reduced by increasing the sample size.

In order to test if the differences between samples is significant, several steps will be taken in which means and variances are tested for statistical significance. The approach used is that of Neyman and Pearson and relies on a pre-defined \( \alpha \) value. If \( p<\alpha \), then \( H_0 \) is rejected. In this case, the magnitude of the significance is not important (Lane, 2015). In both cases, if the null hypothesis is rejected the alternative hypothesis \( H_1 \) is accepted. On the contrary, if \( p>\alpha \) there is not enough evidence to reject \( H_0 \). In the following sections, two tests will be performed (i.e. mean comparison and unequal variances).

Defining what is relevant or not is more challenging since there are no rules or guidelines. Nonetheless, relevance limits are defined based on the tests performed at the Verification and Validation phases, as well as on the real-life operations. Table 7.11 shows the KPIs and the respective boundaries. So, for instance an improvement above 10 minutes is considered relevant for truck turnaround time, whereas in the case of waiting time that is 5 minutes. The reasoning behind this difference lies in the fact that delays could occur during value-added activities like loading, whereas waiting time is fully a waste. In the case of BUPs, it may seem like an improvement of only 1 BUP is negligible. However, considering that on a daily basis that amounts to around 12 BUPs and the TP is critical towards ensuring the success of the FT, the limit is set at 1.

### Table 7.11: Definition of relevance limits for KPIs

<table>
<thead>
<tr>
<th>KPI</th>
<th>LT</th>
<th>LT</th>
<th>TP</th>
<th>Turnaround Time</th>
<th>Waiting Time</th>
<th>Truck Load</th>
<th>Truck Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance</td>
<td>&gt;10 min.</td>
<td>&gt;10 min.</td>
<td>&gt;1 BUP</td>
<td>&gt;10 min.</td>
<td>&gt;5 min.</td>
<td>&gt;10 min.</td>
<td>&gt;20%</td>
</tr>
</tbody>
</table>

This section is arranged based on the experimental plan previously presented. Hence, Section 7.6.1 presents the results for the run of both airside handler configurations against three demand scenarios. In Section 7.6.2 the handler configuration is chosen for the subsequent experimentation step. Finally the FT design selection will be performed in Section 7.6.3.

#### 7.6.1. Handler configuration at airside

Each handler configuration is run for the base demand scenario in FT design A, which is considered the most likely. The goal of this analysis is to determine which airside configuration results in improved KPIs. Subsequently, it can be stated that our null hypothesis for the mean and standard deviation comparisons are:

\[
H_0: \mu_1 - \mu_2 = 0 \\
H_1: \mu_1 - \mu_2 \neq 0
\]

The detailed KPI results of each replication for all demand scenarios and both airside handler configurations are too large to show. However, summary statistics can be seen in Table 7.12.

Statistical tests are run on all KPIs and the results of the statistical significance on equal variances and mean comparison is summarized in Table 7.13. It is worth mentioning that even though the test checks for significance on variances, results are presented in the standard deviation statistic. This is the case for all tables and graphs in this and subsequent sections. Tests are performed for all 21 combinations but in order to aid the reader, these are not presented individually but on this table. Following this, the relevant KPIs will be presented in further detail. Table 7.13 is composed of rows for each demand scenario and columns that contain the mean and standard deviation for each KPI. In each cell, the result of the test is specified. So, if there the cell is blank \( p>\alpha \) and hence \( H_0 \) failed to be rejected, accepting thus that there is not enough evidence to reject it. When \( H_0 \) is rejected and the alternative \( H_1 \) is thus accepted, the letter of the Multiple Handler Configuration is presented ("M" stands for Multiple Handler) Finally, the value within parenthesis states the pertinent difference based on the multiple handler configuration. For the mean, that is the specific unit of each KPI and for the standard deviation, the reduction contrasted to the single handler configuration.
Table 7.12: Summary Statistics for single and multiple handler configurations on demand scenarios - Output from JMP

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Demand</td>
<td>M (-0.09)</td>
<td>M (0.40)</td>
<td>M (-0.63)</td>
<td>M (0.30)</td>
<td>M (0.01)</td>
<td>M (+0.01)</td>
<td>M (-0.03)</td>
</tr>
<tr>
<td>Conservative</td>
<td>M (0.8%)</td>
<td>M (0.32)</td>
<td>M (0.6%)</td>
<td>M (+1.16)</td>
<td>M (+0.04)</td>
<td>M (+0.04)</td>
<td>M (+0.02)</td>
</tr>
</tbody>
</table>

As it can be seen in Table 7.13, several KPIs showed no statistical difference between handler configurations. On the contrary, other KPIs showed significant and relevant differences. The detail per KPI is the following:

- **LT Airside**: In most of the demand scenarios there are statistically significant differences, which means that $H_0$ is rejected and $H_1$ accepted. In the base demand scenario, the multiple handler configuration reduces LT Airside by 0.69 hours (i.e. 41.4 minutes) and reduces the standard deviation by half. In the conservative scenario no difference is identified for the means but for the standard deviations with a reduction of 8%. In the case of an optimistic scenario, the single handler configuration improves the indicator by 0.5 hours.

- **LT**: The results are quite straightforward for this KPI, with the multiple handler configuration improving the LT in 0.65 and 0.32 hours for the base and conservative demand scenarios, respectively. As with the LT Airside indicator, it also improves the variability.

- **TP**: There are no statistically significant differences between handler configurations for most of the scenarios. The only exception is in the optimistic demand scenario, in which the Multiple Handler configuration yields 1.16 BUPs more per hour.

- **Truck Turnaround Time**: In spite of the fact $H_0$ is rejected in two demand scenarios (i.e. base and optimistic), this KPI seems to be of little relevance due to the small magnitude of the improvements. The improvements range from 0.01 to 0.04 less, which translates to 0.6 to 2.4 minutes. Per truck this is considered not relevant but as a system it might have an impact.

- **Truck Waiting Time**: The single handler configuration reduces this indicator by a maximum of 2.4 minutes. However, as mentioned above, in spite of being statistically significant it might not be pertinent.

- **Truck Load**: In all three demand scenarios one configuration improves the indicator. The values however, are between 0.02 and 0.03 more BUPs per truck, which can be dismissed.

- **Truck Reduction**: Similarly to the Truck Load KPI, the improvements in this indicator are too little. It
can be stated that although there are statistical differences and $H_1$ is accepted for all demand scenarios, the impact may be negligible.

Based on the analysis, LT results as one of the critical KPIs, which is why the detailed statistical tests are presented in Figure 7.28. On the left side the graph shows each of the observations for multiple and single handler. The box plots, depicted in red, shows where the quartiles and mean lie. The lines extending out of the box are called whiskers and represent 1.5*(interquartile range). On the right side, the tests (i.e. equal variances and mean comparison) is presented. A t Test is used as part of the Oneway Anova and in it, the distribution of the mean differences can be seen. In orange, the Prob > |t| value is below 0.05. Therefore, the $H_0$ is rejected and the alternative $H_1$ of different means is accepted. Same applies to the analysis of variance.

When assessing how the airside configurations react under the demand scenarios, it is clear that the system, at its current storage capacity, is not able to cope with the increased demand. Figure 7.29 shows that indeed the multiple handler configuration performs better across the demand scenarios both for the LT Airside and LT. It is also obvious by looking at the graph that the increase in LT is correlated to LT Airside. This may not have to do directly with the airside operations per se since the configuration of the system is that when the FT’s capacity is depleted no more BUPs can be unloaded at the facility. Therefore, a blockage in the system impacts the airside LT directly. It can also be concluded from it, that in its current design the FT is not even able to deal with a 50% increase in demand (i.e. conservative scenario).

Considering the information provided on Table 7.13 and the individual analyses performed like the one
shown in Figure 7.28, it can be concluded that the airside handler configuration that yields better results and draws nearer to the premise of facilitating a seamless flow to the FT is that of a **multiple handler configuration**.

### 7.6.2. FT design alternatives

After having selected the multiple handler configuration, the remaining FT designs are run (i.e. B, C and D). The results will be analysed making use of an ANOVA procedure

\[ H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 \quad \text{and} \quad H_1: \text{The means are not all equal} \]

If the analysis included only two samples, a simple calculation of the differences of these two means could be performed and a t-Test conducted. However, that is not possible when analysing more than 2 samples. What is needed is a measure of the aggregate degree to which the group means differ (Lowry, 2015). This measure is actually the variability shown in the groups (i.e within groups and between groups). The analysis of variance (ANOVA) generalizes the t-test to more than two samples and allows the researcher to test for equal means. The question at hand is whether the differences in means is significant, meaning not the product of random selection. It is for this reason that not only the variability between samples or treatments is considered but also within each one. If the differences between treatments are considerably bigger than within the sample, then one could conclude that there is indeed a real effect (Lowry, 2016).

It is important to understand what the assumptions of ANOVA are. These are: i) Independence of error terms, also called independence of observations, ii) Normality and iii) Homoscedasticity or homogeneous variances (Scariano and Davenport, 1987). Because of this, the following step-by-step for assumption testing, as proposed by Virginia Polytechnic Institute and State University (2016), will be executed:

1. **Test for Normality**: ANOVA is tested and residuals are analyzed for normality through the Goodness of Fit. If \( H_0: \text{Data fits a normal distribution} \) is not rejected step 2) is followed, otherwise step 5). If so, \( H_1: \text{Data does not fit a normal distribution} \) is accepted.
2. **Test for Homogeneity of Variance**: If \( H_0 \) is not rejected on the unequal variances test, step 3) is followed.
3. **Traditional ANOVA**: Assume normality and homogeneity of variance.
4. **Welch's ANOVA**: Assume normality and allow heterogeneity of variance.
5. **Perform Non-parametric Kruskall/Wallis ANOVA**: Make use of an ANOVA test for distributions that do not follow a normal distribution. It tests whether samples originate from the same distribution. It serves as an extension of the Mann-Whitney U test when there are more than two samples. A significant test indicates that at least one sample stochastically dominates one other sample. (Dunn, 1964). However, it does not state where the dominance exists, which is why Dunn's test should be used as well in order to analyze the specific sample pairs.

**Test for Normality**

An ANOVA is used in order to obtain the residuals among samples. These residuals are then plotted into a distribution and the goodness of fit for a normal distribution calculated. In this case since the sample size is below 2000, the Shapiro-Wilk test is used. The results show that none of the analysed indicators is normally distributed at a significance of 5%. Based on this, non-parametric tests need to be used for the mean comparison. An example of the performed analysis is shown in Figure 7.30. On the left side, the distribution and normal quantile plot is shown; on the right side, the goodness of fit test.

**Non-Parametric Test**

As mentioned above, non-parametric tests need to be applied when the data is not normally distributed. The results for each KPI is elaborated upon on this section. Graphs will be included when relevant.

- **LT Airside**: In Section 7.6.1 it was stated that LT Airside and LT show an almost identical distribution across samples. Because of it, a correlation analysis was performed and a perfect correlation corroborated with a factor of 1. Subsequently, the analysis is performed and the resulting graph can be consulted in Figure B.5. Appendix B.4.2. The difference between the storage or no storage continues to be evident on this indicator. As mentioned in the previous section, LT Airside captures the decrease in the system's performance due to the demand increase and fixed storage capacity. The results of the ANOVA
7.6. Model results

Figure 7.30: Residuals Distribution, Normal Quantile Plot and Goodness of Fit Test for LT

show that A is statistically equivalent to B and C to D (see \( p\)-value>0.05 in the Nonparametric Comparison for all Pairs). It can be concluded that the push or pull configuration has no effect on the airside LT.

- **LT:** As with LT Airside there is a clear difference between storage or no storage, which is proved by the fact that the designs with storage (A and B) and with no storage (C and D) are considered statistically equivalent. It is worth mentioning that in this case, the \( p\)-values are slightly smaller than in the LT Airside analysis. The reason for this may lie in the added variability. As with LT Airside, the values are considered not acceptable in a real life application, which will be elaborated upon on Section 7.6.3. The summary statistics for this indicator are presented in Figure 7.31.

- **TP:** As Figure 7.32 shows, the difference between storage (i.e. FT Design A and B) and no storage (i.e. FT Design C and D) is quite clear. As the quantile statistics show, the difference is slightly above 10 BUPs per hour. In both cases, the designs with a Push configuration (B and D) have a higher variability, although this relationship is not particularly of statistic significance since all variances are unequal. In the case of the means, it can be concluded that FT Design C and D are statistically equivalent, which means that for a FT with no storage, a change in the system configuration (i.e. push or pull) has no effect on the TP.

- **Truck Turnaround Time:** This indicator is directly related to the Truck Waiting Time, which is why it is advised to go through both analysis (Figure 7.33 and Figure B.6 in Appendix B.4.2). It is clear that even though the means are considered to be significantly different, designs B-D show a similar behavior. In fact, the difference between these is in all cases under 1 minute. In contrast, design A shows a mean almost twice as large as design B-D. Turnaround time for these samples (i.e. B-D) is approximately 15 minutes whereas for design A it is 32 minutes. This indicator should be cross-checked with the Truck Load and the Truck Reduction as well, since they all comprehensively describe the landside distribution and explain why design A has the highest turnaround time.

- **Truck Waiting Time:** A test of correlation shows that this indicator is perfectly correlated to Truck Turnaround Time. It can be concluded thus that the sole moderator for truck turnaround is waiting time since the loading process seems to add little to no variability. Because of this, the results are considered not critical and are shown in Appendix B.4.2, Figure B.6. The ANOVA shows that the waiting time for A lies at approximately 20 minutes, whereas for samples B through D, that goes down to 3 minutes.

- **Truck Load:** The amount of BUPs per truck gives insight into the above mentioned indicators. It provides an answer to why the truck turnaround time increases so drastically for design A. As it can be seen in Figure 7.34, the relationship between turnaround time and truck load is inversely proportional. The precise reason will be explained in the next section. Truck Load has significantly different means but as with the last two indicators, the difference between design A and B-D is relatively large. For A, the mean is of 2.85 BUPs per truck whereas in the remaining designs it goes up between 4.37 and 4.9 BUPs.
• **Truck Reduction**: The final indicator under analysis supports the conclusions already reached for the landside KPIs. In this case, and as shown in Figure 7.35, means are equal. Design A is also the one that stands out with a reduction close to 0.48 (i.e. 48%) which is considerably lower than the one shown by designs B-D around the 70%. It is also worth noting that the truck reduction is higher for designs with a push configuration or no storage, which of course, turns the system quicker into a push one.
To conclude, the statistical analysis of the FT designs for the conservative demand scenario proved that only LT Airside, LT and TP have an effect through one of the treatments. In the first two, the treatment that has an effect is the existence of storage or not. So, the samples that are considered statistically equal are A-B and C-D. In the case of TP, both designs with no storage (C and D) are considered equal. For the remaining KPIs, samples have significantly different means and no conclusion based on the treatments can be performed. This analysis provided a detailed insight in the samples and on whether or not these differences are actually relevant in a real setting. In the next section, the selection of the FT design will be performed based on a comprehensive analysis.

### 7.6.3. FT Design selection

The last step in the analysis of results is selecting one of the FT designs. As it was shown in the previous section, the analysed treatments (i.e. storage existence and push/pull configuration) have an effect on certain KPIs while others are unaffected by them. First, the relationship between KPIs will be described and then, the effect of the treatments on these detailed. After this, a recommendation for a FT design can be made.

Two of the KPIs that proved to be affected by the treatments (i.e. FT Designs) are **LT and LT Airside**. The relationship between both indicators can be seen in Figure 7.36. From it, and the previous correlation analysis, it can be concluded that whichever effect the FT Designs may have on the LT Airside indicator, is also incorporated in the LT one. Based on this, LT Airside is considered not relevant for the current decision making. When looking solely at LT, there are several key take aways. First, **the existence of storage has an effect on the LT, and it is clear that having one greatly reduces the variability**. In addition to this and even if the push/pull configuration did not prove to have a statistically significant difference, the push designs (B and D) increase the variability. Finally, the mean values for these designs are considered unacceptable for the actual building of the FT. **An increase of**
50% in the demand, the conservative scenario, reduces the performance of the system considerably from a mean below 2 hours to around 4. And when considering design C and D, with times above 20 hours, it is clear that a FT, if built, would need to increase the storage size.

Next, the analysis of the TP showed that, only design C and D are statistically equivalent. However, when looking at Figure 7.32 it is clear that there are two different performances. The reason behind the non-equivalency of design A and B may lie in the increased variability associated with design B because of its push configuration. Even though the standard deviations are quite small, it is an increase of 40% to 60% when referenced against the pull configuration. It can also be concluded that a FT with storage increases TP by at least 10 BUPs per hour. Interestingly enough, the push/pull configuration does not impact the TP.

Finally, the KPIs associated with landside are discussed. These are Truck Turnaround Time, Truck Waiting Time, Truck Load and Truck Reduction. As it was the case with LT and LT Airside, Turnaround Time and Waiting Time have a correlation factor of 1. Based on this, Waiting Time will no longer be utilized. From Figure 7.37 it can be concluded that the truck turnaround time increases as the truck load decreases. This is to be expected since more trucks need to be called in order to expedite the same total amount of BUPs. The lower part of Figure 7.37 depicts this and also shows that the pull configurations (i.e. FT design A and C) generates smaller truck loads than their push counterparts, which is also fitting since truck loading is not maximized. This is also related to the FT storage size, which will define the amount of BUPs that need to be expedited. For design A (storage and pull) this proves to be particularly true. By having a storage capacity of 75 BUPs and working on a pull way until the storage utilization has reached 0.8, it needs to call on a high number of trucks when push expediting is required. As it was explained in Section 7.4.3, at least 25 trucks would be called to expedite 75 BUPs. This results in peak times at the landside docks and increases the waiting time and by consequence the turnaround time. This is also supported by Figure 7.38 where it can be seen that design A is indeed the one with the highest dock utilization at almost 30%. In contrast and even though the same situation arises in design C, only 5 trucks or slightly more are called due to the smaller storage size (i.e. 25 BUPs).

When analysing the truck reduction, a slight change can be observed in the upper graph in Figure 7.37. Truck reduction is maximized for designs with no storage (C and D), whereas design A, as stated above, causes the least amount of improvement. It is worth noting that even in the worse case (i.e. Design A), a reduction of almost 50% could be achieved when contrasted to calling trucks based on strict shipment per aircraft guidelines. This comes to proof the potential of a truck allocation strategy lead by the FT.

![Figure 7.37: Relationship between Landside KPIs](image-url)
utilization against the range of 14% to 19% from the other designs. As mentioned above, this is related to its storage capability and pull nature since it basically calls more trucks, occupying thus the docks more often. And then, when it moves to push, it does so for longer periods of time due to its storage capacity.

In conclusion, storage is required not only because it proved to reduce LT and increase TP in 10 BUPs per hour but specially because it reduces variability significantly. This matches the theory presented in which storage areas serve as buffers that modulate or balance the flow. Having storage has negative effects only on the truck reduction KPI, which was still notably high in the design options with storage. Consequently, a design option with storage is decided upon. Additionally, the system configuration that showed the better results in improving truck load and thus reducing turnaround times, is the push one. Based on this, **Design B is selected as the most favorable design**. As it can be seen in Figure 7.39, in spite of having 10 airside dock doors, the 1st line width requirement is of 35.5 meters, which is considerably lower than most of the existing facilities. The main reason is the fact that the storage area is considerably reduced due to the designed seamless flow. As complement, Table 7.14 shows the summary statistics for this design option for all KPIs.

![Figure 7.38: Airside and Landside Dock Utilization](image)

![Figure 7.39: Proposed Design B: Multiple handler configuration, storage and a push system](image)

| Table 7.14: Summary statistics for Design B - Storage and Push configuration |
|---------------------------------|-----------------|----------------|-------------|-------|--------|--------|
|                                  | **Mean** | **Std Dev** | **Min** | **P25** | **Median** | **P75** | **Max** |
| LTAirside                        | 3.650    | 0.494        | 2.53    | 3.244   | 3.701    | 3.895   | 4.88   |
| LT                              | 4.123    | 0.493        | 3.02    | 3.762   | 4.172    | 4.369   | 5.23   |
| Throughput                      | 64.74    | 0.808        | 62.48   | 61.48   | 64.03    | 64.79   | 68.52  |
| Turnaround Time                 | 0.239    | 4.94         | 0.24    | 0.239   | 0.230    | 0.230   | 0.24   |
| Waiting Time                    | 0.047    | 4.94         | 0.05    | 0.047   | 0.047    | 0.048   | 0.05   |
| Truck Load                      | 4.56     | 0.02         | 4.48    | 4.54    | 4.55     | 4.58    | 4.61   |
| Trucks Reduction                | 0.068    | 0.003        | 0.069   | 0.067   | 0.068    | 0.070   | 0.074  |
### Research Sub-question 5

**What are the required actor configurations under the presented alternatives?**

The assessed actor configurations are that of a **single handler and multiple handlers**. In the first case, cargo handlers unload the aircraft and drop off the BUPs at their own facility. The single 3rd party handler would pick up these BUPs as part of its two milkrun routes and unload them at the FT. In the case of multiple handlers, the process would be similar to the one conducted nowadays with the difference that handlers would need to drop off BUPs at the FT in addition to their normal transport flow. Both options were tested on the KPIs for three demand scenarios (i.e. base demand, conservative and optimistic).

Thorough statistical analysis was performed with the goal of understanding whether or not these airside configurations have an effect on the KPIs. As Table 7.13, Figure 7.28 and Figure 7.29 showed, the configuration that yields better results and draws nearer to the premise of facilitating a seamless flow to the FT is that of a multiple handler. It performs consistently better than the single handler configuration in terms of means and shows a smaller variability as well. This is to be expected, as the single handler configuration adds process steps, waiting times and creates bottlenecks at airside. Based on this, the **multiple handler** is proposed as the actor configuration. However, Schiphol Group should assess which configuration to implement based on the engagement and performance of the handlers. If this is low or not sufficient, a single handler configuration should be implemented.
Research Sub-question 6

What are the recommended distribution alternatives under a number of scenarios for the FT?

Once the airside handler configuration was determined, the four FT designs were run for a multiple handler configuration according to the experimental plan (see Table 7.40). Design A and B both have storage while C and D only have a pre-stacking area. A and C are Pull whereas B and D Push.

After completing the runs, the results were analysed making use of statistical theory. The goal of this analysis is to understand whether or not different designs or configurations are statistically equivalent or different. In addition to this, it is necessary to understand how large the differences truly are since a value might be statistically equivalent but not relevant in a real-life operation (Lane, 2015). The null and alternative hypotheses are thus:

\[ H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 \]
\[ H_1: \text{The means are not all equal} \]

Each KPI went through non-parametric tests in order to verify if the design "treatments" had an effect on their performance. LT and LT Airside proved to be affected by the existence of storage. Both designs with storage (A and B) are statistically equivalent. The existence of storage greatly reduced the variability, which is in accordance with the theory that storage areas serve as buffers that modulate or balance the flow. Another take away is the fact that the current system configuration (i.e. storage size 75 and dolly capacity) is not able to cope with a 50% increase in demand. As a matter of fact, the LT increased from approximately 1.6 hours for the base demand to around 4.

Throughput (TP) also showed that storage is an asset since it increased the output by at least 10 BUPs per hour. Interestingly enough, the push/pull configuration did not affect the TP. Finally, the landside indicators showed that the truck turnaround time increases as the truck load decreases. This is expected since more trucks need to be called in order to expedite the same BUP amount. The pull configuration generates smaller truck loads than their push counterparts, which is logical since truck loading is not maximized.

All designs achieved a reduction in the amount of trucks. The smallest improvement was of 50%, which comes to proof the potential of a truck allocation strategy lead by the FT. The dock doors also showed a statistically significant difference between designs with no storage and storage. The dock utilization variability for FT designs with storage is considerably lower.

To conclude, the distribution alternative that is recommended is FT Design B since it includes storage and functions on a Push way, enabling the FT to perform truck allocation to serve and improve their efficiency, while improving truck load, turnaround times and reducing the number of trucks visiting the FT.
Research Sub-question 7

What are the benefits and shortcomings of the recommended alternatives?

The benefits from Design B with a multiple handler configuration are the following:

- **Reduced variability:** The existence of storage proofs to equalize the variability produced at airside, which results in a more stable output flow. This is not only reflected on the almost three-fold reduction in variability for LT but also on the airside dock door utilization. A system with no storage (i.e. only pre-stacking) is unable to prevent an overrun on the airside handling and FT drop-off.

- **Increased throughput:** Designs with storage increase TP significantly different than designs with no storage. In fact, design A and B increase it by 10 BUPs per hour, which is an increase of almost 20% when contrasted to designs C and D.

- **Increase in average truck load:** Since design B is categorized as a Push system, it loads an average of 4.56 BUPs per truck, which is comparable to its no-storage counterparts. Design B enjoys the perks of having storage without compromising landside efficiency.

- **Reduction in truck turnaround time:** Current turnaround times are around 60 minutes, with considerable peaks during weekends, evenings and Monday mornings. The proposed design manages to reduce that greatly. 90% of the visiting trucks had a turnaround time around 15 minutes.

- **Reduction in truck visits:** Even though truck reduction is larger for designs with no storage, design B is able to reach a 50% reduction when contrasted to calling trucks based on shipment per aircraft guidelines.

- **Sustainability:** The reductions in the number of visiting trucks and on their effective time at the facility would represent a reduction in the carbon footprint and a contribution towards achieving operational sustainability.

On the other hand, the shortcomings are:

- **Additional activities for cargo handlers:** Since the multiple handler configuration was selected as the preferred one, cargo handlers engagement needs to be high. They would have to either assign an exclusive dolly train for BUP units or extend their transportation route so that the dolly train can drop off BUPs on route. This would depend on the aircraft ramp and the handler’s facility location.

- **Not able to cope with a significant demand increase:** An increase of 50% in the demand, the conservative scenario, reduces the performance of the system considerably from a LT mean below 2 hours to around 4. And when considering designs C and D, with times above 20 hours, it is clear that a FT, if built, would need to increase the storage size from the assessed 75 BUPs.

- **Area requirement for storage:** Depending on which storage size is decided upon, the associated area would be required. Designs with no storage proved to be non-reliable or robust.

- **Effect of headcount:** One of the main reasons for substantial waiting times is the fact that there are less employees available during evenings and weekends. This is not solved by any of the designs, since the internal working of the FT is out of scope and the required headcount is assumed to be available.

- **Truck planning and allocation:** The system that yields the better results is one with a Push configuration, allowing the FT to define which BUPs go on which truck based on destination groups. This however, would require either a close partnership between handler and trucking company or for the handler to have resources assigned to these tasks exclusively. Achieving this level of cooperation could prove to be challenging.
In this chapter, the conducted research and its limitations are detailed in Section 8.1, following by the discussion on the assumptions of the model in Section 8.2 and finally, Section 8.3 elaborates on the applicability of the concept and its results.

8.1. Limitations

This section presents the existing limitations, both during the execution of this research and in the future. These limiting factors have an effect on the model design, the simulation and its results and, if built, on the implementation and development of the project. How this impact is counteracted is also explained in each section.

8.1.1. Data availability

As it was the case with previous studies, data availability poses a serious limitation in this project. Due to the fact that Schiphol Cargo performs no type of operational supervision on the cargo handlers, there is no data or KPIs to be analysed. The data obtained comes from previous estimations, interviews with experts or in the case of the arrival pattern directly from the Traffic Analysis and Forecast (TAF) department at Schiphol. In the case of the first type of data (i.e. estimations), there is the added complexity of having significant gaps between the perceptions of experts. This is a direct reflection of the existing operation and the fact the there are no common KPIs among parties. So, the airline keeps track of their Flown as Planned indicator for instance, while the cargo handler of the Lead Time until the shipment is ready for pickup whereas the trucking company records Waiting time at the handler and Transport time to the customer. By having disconnected KPIs, the parties of the air cargo chain operate individually and lose track of the interfaces between parties.

The impact of the data availability on the model is twofold. On one hand, the validation of the model by experts is partial and to an extent, biased based on their point of view solely. On the other hand, judging the performance of the handlers is speculative at its best. The fact that the proposed design has a throughput of 64 BUPs per hour can actually only be assessed against the performance of comparable FTs. However, that information is affected by process inefficiencies like a shipment that is ready waiting hours for pick up or dock allocations performed arbitrarily.

In order to counteract the impact this might have on the model and its results, distributions were used instead of single values when possible in order to account for stochasticity. The values for the distributions were defined with different parties. For example, the truck delay distribution was obtained from Pieters (2016) and Kervezee (2016) who represent the trucking and handling company, respectively. The airside flows are defined based on the transport time, volume share, unloading activities and customs requirements. Both the transport time and volume share are based on reliable data since distances and speed can be calculated and volume shares can be established from the information provided by the TAF department. Unloading activities are based on interviews with handlers and are deemed accurate. Finally, customs values are based on an interview conducted by Kallen (2015), which could not be verified again with Customs due to their policies. However, as only 10% of the cargo requires an inspection and from that only another 10% requires a detailed one, the impact on the arrival pattern is not considerable. Admittedly, there is an impact but this is on the FT itself as BUPs may have to wait for the remaining one to be cleared in order to be shipped. This
8. Research Discussion

is counteracted by the push/pull logic in the system and by the expediting of BUPs with more than 3 hours in the FT. So, if the capacity of the FT obliges the system to move to a push scheme, the BUPs will be expedited based on destination groups. The remaining BUP(s), still at Customs, will be sent after on another truck. Hence, the impact of the data availability is lowered and both the model and the results can be considered appropriate estimations of the assessed system.

8.1.2. Benchmark

The concept of a FT or cross-dock is not new. In fact, it has been widely implemented in the logistics sector and, specifically at Schiphol, several cargo handlers already have FTs. These are Dnata, KLM, Menzies and Swissport. The configuration of the FTs changes from handler to handler and there are even cases of collaborative FTs like that of the flower dedicated FT for Kühne+Nagel at Menzies. However, a FT that deals with cargo flows from several cargo handlers does not exist in comparable airports. In the case of Hong Kong International Airport, there are several cargo terminals and one shared facility, the Airport Freight Forwarder Centre. This facility though is not at 1st line but on 2nd line and provides space for freight forwarders for consolidation and distribution. On the opposite side of the spectrum, Fraport Cargo Services at Frankfurt International Airport performs all of the cargo handlings. As the sole handler in the airport, the performance of the cargo chain at Frankfurt benefits from economies of scale, reduced complexity in coordination activities and faster truck turnaround times. It is thus clear that the proposed FT at Schiphol is one that lies somewhere in between the exposed cases. In addition to this, collaborative concepts like code sharing and alliances, applied by airlines and the shipping industry quite successfully, are not extended to landside operations. Consequently, no direct benchmarking can be performed.

This, however, constitutes no major impact to the design of the model since the project itself is considered greenfield. This research makes limited use of previous research, in spite of the fact that there are several studies conducted on the overall problematic of the space constraints in South-East Schiphol. The reason for this lies on the research topic: An analysis of the airside distribution flows and the associated actor configuration combined with the push/pull working of the FT and the subsequent truck allocation. It is apparent that this research goes in-depth into the inter-dependencies and not necessarily into the individual factors, as previous research did. Also, at this point of the research, it is not critical to analyse the detailed performance of the FT but instead to understand in general terms how it behaves and what variables can be configured in which ways with the goal of ensuring a seamless flow.

8.1.3. Stakeholder engagement

The third component in the limitation section is that of stakeholder engagement. There has been research on the topic of collaboration at Schiphol and the conclusion of both parties is that Schiphol Group should act as a process manager for innovation and improvements in the efficiency of the processes (Ankersmit, 2013)/(Pieters, 2014). In the multi-actor context in which Schiphol functions, this is not an easy task. There is a wide range of actors at distinct levels of power and influence. For instance, there are very large players that have the power to block or advance projects, whereas smaller players are either sometimes unable to implement them individually or lack the required resources (e.g. IT, technical knowledge). Having understood this, it is evident that not knowing the willingness to participate of the actors is the most significant limitation to this research.

This research relies heavily on the collaboration of parties both at airside and landside, which is why its impact may be critical in the implementation of the FT. It is for this reason that several strategies to overcome this impact are included for airside and landside. In the case of airside, the proposed design makes use of a multiple handler configuration, which means all handlers should be engaged and committed to delivering the BUPs to the FT as quickly as possible. The gains and costs model is not part of this research but should be carried out in order to stimulate participation. The impact of a low participation can be offset by choosing a single handler configuration. In this case, the engagement of the handlers would go down from actually delivering the BUPs at the FT to simply leaving them at airside for pickup. The 3rd party would then perform a milkrun on airside to pick up the BUPs and drop them off at the FT. This option increases the variability of the airside process but remains feasible while requiring minimal cooperation from the cargo handlers. For landside the needed collaboration is between the FT operator and the trucking company. Of course, freight forwarders and shippers should be aware of the functioning of the FT and its regulations (e.g. BUPs with more than 3 hours of storage are pushed to a 2nd line facility). The way to minimize impact on the design would be to ensure that a neutral 3rd party manages the FT, as it was advised by Kallen (2015), and that the decision-making power lies at this level. In this way, the FT operator would be allowed to expedite based on destination
8.1. Limitations

or customer, push BUPs to a 2nd line when capacity constrained and participate in the truck allocation to an extent. With this in mind, Schiphol Group would need to implement the FT with stricter regulations in place, ensuring thus that the use of the FT does not deteriorate into a simple 1st line warehouse. In order to succeed at it, a stronger presence of Schiphol as the airport authority, to the likes of the Rotterdam Port Authority, would be required.

8.1.4. Validation

The validation aims to answer whether or not the model is able to respond to the real life questions and scenarios under study. As it was explained in Section 7.4 Validation, there is no standard way of validating a model and according to some experts there is no 100% proof validation. Historical data does not exist since the FT has not been built yet, which is why the validation of input parameters and distribution is performed against expert knowledge solely. In addition to this, runs are performed to validate the selected values for the configuration and assess these against experts opinions and previous research. How to select these variables and combinations is where the limitation lies.

The proposed model has 6 configuration variables which could be combined or evaluated individually for all 7 KPIs (see Table 7.1 and Table 7.2 for reference). A full factorial would assess each KPI individually and the possible combinations on the KPIs, which translates into roughly more than 250 analysis. Due to the scope and duration limit imposed on this research, a full factorial analysis is not feasible. Instead a validation strategy is defined (see Section 7.3.1) and only the most relevant interactions are selected. The final validation strategy can be consulted in Table 7.8.

The impact this has is primarily the fact that some interactions may have been neglected or overlooked and as a consequence, results may be non reliable. Figure 8.1 shows the configuration variables on the model concept. The performed validation assesses the TNT, the number of dock doors at airside and landside, the FT storage capacity in its interaction with the storage utilization and finally, the dolly capacity for the single handler configuration. In addition to this, all tests with the exception of the dolly capacity are performed on the multiple handler configuration as it is the current operation process for handlers. By doing so, values and results can be assessed with experts in order to validate them. Having them validate values for an airside handler configuration that does not exist yet (i.e. single handler configuration) would add uncertainty to the review and could result in wrong estimations for the values.

Figure 8.1: Configuration Variables

In this way, the most obvious and important interactions and variables are selected for the validation. First, those that serve as valves of the FT cargo flow are selected and subsequently the ones that define the mechanism of the FT in terms of push/pull. The impact of the configuration variables is the following:

- **TNT**: Delays the arrival of the trucks for pickup so a value that is too high will increase LT and the FT storage utilization, influencing the system to move to a push configuration quicker. A TNT that is too fast on the other hand, would reduce LT but would also be unrealistic.

- **Airside and Landside Docks**: The number of dock doors is critical and constitutes a 1st order change, which is why it is of the utmost importance to define a proper value. So, different dock doors combinations are tested and selected based on its influence on the performance of the system.

- **FT Storage Size and Storage Utilization**: This interaction constitutes the basis of the functioning of the FT as it proves the relationship between the push/pull mechanism and the associated required storage area. A set of 18 combinations is tested and the functioning of it successfully validated.
• **Dolly Capacity for Single Handler Configuration**: In order for this option to even be viable, enough dolly capacity needs to be in place for the airside milkrun.

It is clear that a basic understanding and validation of the system has been reached in spite of not being able to conduct a full factorial analysis. Actions are taken in order to ensure that, in a controlled way, the model is able to answer questions associated with the performance of the system and how variables influence the KPIs. In addition to this, having a design that is fixed in a set of variables (i.e. dock doors, TNT, dolly capacity) during the runs, allows for the FT design alternatives to be comparable to each other. Based on this, it can be concluded that the selective validation that has been performed poses no hindrance on the evaluation of the designs and its results.

### 8.2. Model Assumptions

As is the case with any other research, assumptions are made in this study as well. These range from the value of certain fixed parameters to more complex assumptions based on stakeholders participation and behavior. In this section, the key one’s assumptions are detailed and their impact on the results addressed.

#### 8.2.1. BUPs share

Even though the arrival pattern of aircrafts is based on information provided by Schiphol Group (2016d), the number of BUPs per aircraft is an estimate. For this research no volume calculations are performed, instead it is based on interviews with experts as well as previous research by Kallen (2015) that the average ULD weight is defined and based on it, the number of BUPs per aircraft estimated. A triangular distribution of 4 to 5 BUPs for full freighters and 0 or 1 for belly freight is used.

In order to assess future demand scenarios, the arrival pattern is increased by 50% in the conservative case and two-fold in the optimistic one. As a result, more aircrafts arrive at Schiphol, however, the number of BUPs per aircraft remains unchanged. This assumption does not contemplate whether or not the share of BUPs will increase or decrease in the future. The reason for this is that after conducting several interviews with experts from different parties (e.g. cargo handler, trucking company) it is evident that there is no clear idea or perception in terms of how the share of BUPs will behave in the future. For the detailed opinions of these experts see Appendix A.1, Appendix A.3 and A.5.

On one hand, with the growth of e-commerce big freight forwarders could expand their market share even further and as a consequence BUPs could increase. On the other hand, final customers may profit from the data transparency and book directly, turning the market into a more segregated one and reducing shipment size. The main problem is that the share of incoming BUPs is not controlled at Schiphol and the question of profitability directs the decision of shipping as a BUP or not. According to Kervezee (2016), it is more practical for agents to deliver the loose cargo and have the cargo handler make the combinations. In fact, e-commerce parcels are received as loose cargo in receptacles and broken down at the handler’s facility. So, even if there is an increase of ULDs due to the e-commerce boom, it will possibly not be shipped as a BUP. In summary, the number of BUPs per aircraft is an estimate and its share growth or decrease in the coming years is not considered due to the high uncertainty and ambiguous direction it might take.

This has of course an **impact** on the model. The impact will depend on the specific change in the share of BUPs. There are several scenarios that could occur, among these the most important are: i) An increase of BUPs both for belly and freighter cargo, ii) an increase on freighters only, iii) an increase on belly cargo only or iv) an overall decrease for both freighters and belly cargo. In the case of an overall increase, the arrival pattern of the FT would change due to the additional BUPs, which would create a strain on the system. As it was described in Section 7.6 **Model Results**, the proposed design is not able to cope with a demand increase of 50% within the desired lead time. In order to counteract this impact, additional storage area should be anticipated in the warehouse design. How much additional area ought to be included will depend on the cargo forecasts by Schiphol Group and on the desired push/pull limit, which depends on the stakeholder participation as well. The dock door configuration, however, is considered sufficient as the utilization at airside lies at 61% and at landside at 38%.

For the next two scenarios (i.e. increase only on freighters or belly cargo), the **impact** lies specifically in the required resources (i.e. dolly trains and headcount) for unloading and transport at airside. Receiving most of the BUPs from freighters would increase the number of dolly trains required, whereas an increase in belly cargo would require a higher frequency of transport. If most BUPs were to arrive as belly cargo, an airside milkrun could be implemented instead of the original point to point proposal. Lastly, a decrease in the share of BUPs would leave the system underutilized. However, as the warehouse design does not differ from
8.2. Model Assumptions

As it can be seen the impact on the model can be split into 1st and 2nd order changes. The goal is to minimize the risk of 1st order changes like building additional docks and changing or adding infrastructure. The proposed design of 75 storage spaces, 10 docks at airside and 5 at landside are able to successfully cope with the existing demand. However, for a demand increase the storage area should be enlarged. Based on this, Schiphol Group must agree on a forecast and define the additional storage area. Doing so ensures that no 1st order changes have to be performed. The remaining impacts can all be solved through 2nd order changes like an airside milkrun, additional dolly trains or if the volume is not enough, by renting out the warehouse or part of it.

8.2.2. Airside configuration

In this research, two airside handler configuration alternatives were presented and analysed. The assumptions made in both of these are different and have also distinct effects on the designs and results.

In this first case, the single 3rd party handler, it is assumed that current handlers agree with leaving the BUPs at their airside terrain waiting for the 3rd party to pick them up as part of its milkrun routes. However, no consideration of clearance areas or available area is included. If implemented, an additional study would need to be conducted in order to determine the available area for BUPs at each handler and combined with the arrival pattern, the required frequency of pick up.

For the multiple handler configuration, the challenge lies in convincing handlers to participate and proving that there are indeed financial gains to be made from the capability to expedite BUPs effectively. As it was mentioned in Section 8.1.3 Stakeholders Engagement the model of cost and gains has not been explored in either case and should be developed in order to ensure that the business model is indeed profitable for participating parties, including Schiphol.

The impact of not being able to fulfill any of these configurations would be critical since the airside LT is strongly correlated with the FT LT. Subsequently, the LT guarantee of 2.5 hours would be at risk. In addition to this, the premise of the FT would not even exist if BUPs cannot be brought quickly to the facility. Opportunely, this can be prevented by applying 2nd order changes:

- **Multiple Handler Configuration:** If handlers are willing to participate, performance should be tracked through a set of KPIs. In the case of poor performance Schiphol could introduce a smaller scale 3rd party at airside to pick up BUPs when LT at airside is above acceptable values. A similar version of this is already implemented in the Baggage Handling department. As a process that relies on the individual performance and collaboration of multiple handlers, Schiphol closely overviews the baggage handling KPIs. This process is key in the quality perception of Schiphol, which is why issues (e.g. connection loss) are not acceptable. Because of it, Schiphol hired a group of neutral baggage handlers that perform transfers in peak and critical moments. This is a non-optimal measure that however, ensures the process stays up to requirements in moments when collaboration is strained. Another possibility is that handlers are unwilling to drop off the BUPs at the FT, in which case the single handler configuration should be introduced.

- **Single Handler Configuration:** In this case, the assumption is that the cargo handlers agree on leaving the FT destined BUPs at their airside area for later pick up. However, the area may be constrained or limited, in which case, the frequency of the 3rd party milkrun can be increased so that only a small number of BUPs is waiting for pick up at a time.

Based on this, the airside configuration proposal is deemed feasible in spite of the high uncertainty associated with the handler’s participation. 2nd order changes can be taken in order to ensure the implementation of the FT is successful.

8.2.3. Operations 24x7

The final assumption is that of a 24 hour, 7 days a week operating FT and landside distribution. Even though aircraft arrivals are limited during night times, the operation of the FT is modelled as a 24x7 one. Naturally, during night hours, the arriving BUPs decrease and the FT operation focus solely on expediting and loading trucks. This allows the FT to expedite on a more regular way and as a consequence, reduce truck visits peaks. With the goal of ensuring 24x7 operations, two main assumptions are made: i) Headcount is available at the FT as required and, ii) Truckers will come and pick up the cargo when called.
In reality though, there are distinct evening peaks not only because of the arrival pattern of aircrafts but mainly due to the lower headcount and the truck planning. Authors like Pieters (2014) and Ankersmit (2013) point out to the fact that headcount at the handler is considerably lower during evenings and weekends which creates longer waiting times for truckers. Aggravating this is the fact that the peaks are often caused by the trucking company themselves. As (Pieters, 2016) from Jan de Rijk mentions, most pick ups are scheduled in the evenings so that the cargo can be transported at night and reach its destination at opening time. These schedules have a large variability due to the high uncertainty regarding waiting times at pick up and drop off locations. Furthermore, the driver as a resource is highly restricted and is only allowed to work for a certain number of hours before taking his or her rest time.

An improvement to the model would have been to include a working schedule, which can be done in Simio. However, due to the lack of data associated with the rest schedules of truck drivers and the high variability associated with it, it was not modelled. Also not considered is the drop off time windows at the trucking company themselves. As (Pieters, 2016) from Jan de Rijk mentions, most pick ups are scheduled in the evenings so that the cargo can be transported at night and reach its destination at opening time. These schedules have a large variability due to the high uncertainty regarding waiting times at pick up and drop off locations. Furthermore, the driver as a resource is highly restricted and is only allowed to work for a certain number of hours before taking his or her rest time.

The impact of these assumptions on the model are detailed in the following paragraphs:

- **FT Headcount**: A lack of employees in the FT would impact the loading time of the trucks and as a consequence, the waiting and turnaround times. In addition to this, the dock utilization would possibly increase as trucks cannot turnaround as quickly. This is contrary to the goal of having seamless distribution at both ends of the FT but is not considered a critical impact. The reason lies on the fact that Schiphol Group would have control and influence on the FT and could request the 3rd party handler to increase the headcount permanently or as needed. This is considered a 2nd order change and is judged thus as a small impact on the results presented.

- **24x7 Pick Up**: This assumption is composed of two factors: Trucker availability and truck planning. The first is related to the assumption that truckers can pick up cargo upon request, irrelevant of time. The impact is minimized by the fact that truckers work evenings and early mornings as it is. Their restriction lies on the amount of working hours not the specific time frames. Hence, the requirement for a 24x7 operations can be considered feasible from the truck driver's perspective. The second factor is that of the truck planning. This model assumes that the trucking company is informed of the shipment arrival and after the TNT has passed the truck is available. A final confirmation is then sent for the truck to come pick up the cargo. Unfortunately, this is an assumption that has to be met. The model relies heavily on a collaboration between trucking company and handler, which translates into a shared truck planning between parties. This is also related to the capability of the FT operator to expedite BUPs and consolidate based on destination when working on a push way. Basically, if this assumption is not met, the FT loses its push/pull mechanism and its performance would degrade considerably. With the goal of preventing this, Schiphol could engage some key trucking companies who would be willing to participate in this effort. An implementation ranging across all trucking companies is not only challenging but realistically speaking, unattainable. A partnership with few selected trucking companies with enough volume is thus advised.

To conclude, all of the existing assumptions can be offset either by implementing 2nd order changes or by ensuring that before the FT is built, key variables like the storage area and push/pull limit are defined. The critical assumption that must be met and would impact the FT design most is that of the collaboration with the truck company and the resulting 24x7 operations. Figure 8.2 shows the three main assumptions of this research, and summarizes the impacts and the actions that Schiphol can take in order to offset these.

### 8.3. Model concept

The goal of facilitating a seamless flow at a FT through its distribution processes is not new. As a matter of fact its underlying foundation, cross-docking, can be defined according to Van Belle et al. (2012) as "the process of consolidating freight with the same destination... with minimal handling and with little or no storage between unloading and loading of the goods." In order to achieve this, the synchronization of incoming and outgoing vehicles needs to be flawless. Buijs et al. (2014) also defines the coordination of receiving and shipping trucks to the appropriate trucks in the proper sequences as a key operational task.

The developed research looks into the required distribution behavior in terms of input and output, in order to guarantee a seamless flow. In parallel, it investigates the role of a push/pull configuration and tests these boundaries to understand to what extend a FT can function on a Pull or Push only basis. This is an
interesting approach since cross-docks are considered push systems and yet the existing FTs at Schiphol work on a pull principle with the exception of the milkrun one. Within the air cargo supply chain and particularly for the RFN trucks, it is clear that a full push system would not work due to the uncertainties associated with landside (e.g. rest hours, congestion, etc.). Nonetheless, this model is able to test the KPIs on a push-pull mixed configuration with tendencies towards a particular configuration.

In addition to this, it borrows proven concepts from other industries like the airline and maritime industry. Airlines have grouped themselves into alliances for almost two decades. As such, they strengthen each others’ networks through code sharing without having to invest in more aircrafts or personnel, which reduces costs significantly. This concept is also applied in the maritime industry with around 90% of the ocean freight being carried by only four alliances (Wang, Dan, 2016). What is striking is the fact that this strong collaboration and cooperation between what are in fact market competitors, has not spread over to their partners in the supply chain. So, cargo may be booked through an airline, transshipped on a code sharing flight and finally, unloaded at Schiphol. And yet, the truck booking is done individually by airlines without any type of horizontal collaboration.

Through this design, the concept of a centralized truck planning and allocation can be tested, showing that the gains are significant and without a doubt, worth exploring further. Perhaps it can also serve as an incentive for parties in the chain, and specially contractual partners, to engage each other and apply the existing knowledge from already existing horizontal collaboration initiatives.

Another approach explored is the “Extended Gate” used by the Port of Rotterdam. So, the proposal is to push BUPs to 2nd line facilities in the Amsterdam area or further away, instead of having them stored in valuable and limited land like that of the 1st line. In fact, the RFN cargo is already subjected to this concept in a way, declaring customs and taxes at the destination and not at Schiphol. Figure 8.3 shows the concept of the model and the included approaches. At airside the concepts of point to point transport applicable to the multiple handler configuration and the milkrun concept, used in the single handler one are shown. The FT has storage and the pre-defined storage utilization limit defines at which point the system moves from pull to push. On landside it shows how the truck planning and scheduling draws from concepts like the Extended Gate Concept and code sharing by airline alliances.

This model shows that even a *non-optimal* design that is based on trade-offs between providing storage but keeping the area requirement low, increasing TP while maintaining a healthy dock utilization, reducing LT while maximizing the truck load and many more, can be applied to a complex system like Schiphol.
Conclusions and Recommendations

In this chapter, the conclusions to the main research question through its sub-questions are presented in Section 9.1. Following this, the major scientific contributions of this research are laid out in Section 9.2 and finally, recommendations for Schiphol Cargo and further research are offered in Section 9.3.

9.1. Conclusions

The goal of this project is to provide an answer to the main research question:

**How can the input and output distribution processes of a fast track at Amsterdam Airport Schiphol facilitate a seamless flow in the context of a multi-actor environment?**

The input and output distribution processes of a FT need to be designed in a way that variability is reduced and issues or disturbances arising in one end of the chain (i.e. airside or landside operations) do not permeate in other areas. In fact, airside lead time proved to strongly modulate BUPs overall lead time. It is for this reason that a storage area is considered a must. After the performed testing, this notion is not only confirmed but its impact is also established.

Airside operations need to be as fast, lean and stable as possible, which is why additional steps like the ones caused by handling being performed by a 3rd party should be avoided if possible. Nonetheless, if the commitment and engagement of the cargo handlers is not substantial, this configuration should be implemented since it remains feasible. In that case an operation based on an airside milkrun is favored in order to avoid the challenges of implementing a planning and scheduling platform between handlers and the 3rd party.

On the landside process, it is vital to ensure that once a truck has arrived and a dock has been assigned, BUPs are effectively loaded in the truck. This means, no waiting times at the dock doors. As limited resources, dock doors serve as the last regulators of flow, which is why their capacity ought to be spent only on value added activities like loading. Additionally, there should be a clear understanding of where the utilization limit of the FT is. It is based on this that the push/pull nature can be defined and consequently fine-tuned according to the needs of the FT operation. The decision-making power needs to rest in the FT operator so that the dynamism of the system can be sustained. This adjustment is key in determining both the average truck load and the truck turnaround times (i.e. loading and waiting time). For larger storage areas, this threshold should be lower in order to prevent congestion from occurring due to a large number of trucks being called in these "peak" moments. These improvements would contribute not only to a seamless flow, but also to the sustainability of the cargo operations at Schiphol.

The rest of this section will provide the answers to the sub-questions presented in Section 2.4 Research Questions, which also constitute the foundation of this report.

1) **What are the characteristics of the current distribution processes?**

The cargo market at Schiphol is one that is highly competitive. In 2015, Schiphol ranked as 3rd just behind Charles de Gaulle and Frankfurt. Out of 1.6 million tonnes it handled, almost 50% represents import flows
The airside capacity is dictated by its 5 runways, 97 connected and 110 disconnected stands. Of course, a key component in growth planning are the regulations associated with noise and disturbance reduction. Schiphol offers connection to more than 300 destinations, making it thus an important regional logistics hub both for passengers and cargo. Currently freighters carry 60% of the cargo while representing only 3.6% of the movements. This is understandable due to their average load of 55 tonnes against less than 2 tonnes for belly freight. Nonetheless, belly freight is expected to increase, as airlines aim at optimizing their belly space and network. This proves to be specially compelling with the industry shift towards Asian and Middle Eastern Carriers.

Also affected by this shift in market share are the cargo handlers. Schiphol is the European airport with the most cargo handlers active (i.e. 7 handlers). These offer basic services as aircraft unloading and loading, cargo break down and build up and cargo storage but also express handling in certain cases. For express handling, a pick up under 3 hours is guaranteed. Four of the handlers even have a FT in this 1st line. However, and in spite of the positive outlook for Schiphol as a logistics hub, cargo handlers are struggling. The open market has not played out as expected making them compete on quality, but instead, has forced them to lower their margins further and further. As a consequence, the focus is not on innovation or continuous improvement but on day to day operations. The fact that there is no contractual relationship between handlers and trucking companies only aggravates the inefficiencies. For instance, 60% of the shipments are stored between 8 and 18 hours and only 23% are picked up under 4 hours. Storage on the 1st line is not a problem under the current layout, nonetheless, it will probably be one once all cargo operations are transferred to Schiphol South-East.

The above stated issues are manifested on the landside operations, specifically with long turnaround times (i.e. 1 hour) and extensive waiting times during peak times or low headcount moments (i.e. evenings and weekends). As a matter of fact, slot assignment is performed only for Amsterdam destination trucks, which represents 50% of the cargo. The other 50%, destined to the RFN, is not scheduled. The uncertainty is such that dock allocation is performed only once the trucker checks in personally at the office.

2) What are the requirements in terms of input and output of the FT?

The input should be able to handle between 13 and 23 tonnes per movement and do so while ensuring no bottlenecks are present during the reception of cargo. Unloading needs to be possible for multiple cargo handlers. All required inspections need to be supported before entering the FT.

In terms of output, the FT should allow cargo to be loaded at the designated dock in a way that minimizes storage time. The allocation of the docks should be performed considering: route, type of distribution (e.g. milkrun, destination based, others), priority and arrival pattern. Turnaround times should be reduced and capacity constrained situations (i.e. night shifts) considered for slot assignments. This should all be supported by a system that makes use of the existing initiatives (i.e. ACN Card, Elink) and does not rely on warehouse personnel for tactical decisions as dock allocation, priority treatments and performance tracking.

3) Which distribution and cross docking design variables have a critical influence on the functioning of the FT?

The critical variables are related to both airside and landside distribution and incorporate interface variables. Having said this, it is worth stressing that no design variables regarding the internal operation of the FT are considered. The first variable is the Arrival and departure pattern since it defines the required service rate from the FT. It can be restricted or non restricted, which determines the push/pull configuration of the system. Another variable is pre-emption, which defines if a specific unit has priority over the loading of another truck. Due to the nature of the industry and current practices, this is considered an outlier case and will not be used further. The service mode is also strictly defined because there is no interchangeability between airside and landside docks due to customs regulations. The number of airside and landside docks is also considered critical and will be assessed during the modeling and evaluation. It directly impacts the truck scheduling and planning, making it one of the most important variables. The amount of docks will depend on the desired dock utilization, truck waiting time and expected volumes, among others. The existence of temporary storage is also evaluated in order to determine if the distribution can cope with the process variability without a storage buffer. Other critical variables associated with the FT like the shape (i.e. I) and internal transportation are not assessed but taken for granted. Finally, the distribution variable is also considered since it is critical in order to ensure a continuous flow at the FT.
9.1. Conclusions

4) What are the theoretically viable alternatives to design a distribution process that facilitates higher FT throughput?
The critical design variables can be combined into 8 FT designs, however, only four of these are considered feasible. In these, alternatives are built through the variation of the two critical design variables (i.e. storage existence and departure pattern). As already mentioned, the departure pattern defines the push/pull configuration of the system. As such, a restricted departure pattern behaves in a pull way, while a non-restricted one, in a push way. In addition to this, the distribution variable is incorporated, assessing thus a multiple or single handler airside configuration. Since a shared facility does not exist at Schiphol currently, it is valuable to understand if a single handler distribution (i.e. neutral 3rd party) could perform the pick up at the cargo handler’s airside and drop off at the FT. This could serve as a solution if handlers are not willing to deliver the BUPs to the FT themselves. Table 9.1 shows the final configuration, and the experimental plan.

Table 9.1: Experimental Plan - FT designs

<table>
<thead>
<tr>
<th>FT Design</th>
<th>Temporary Storage</th>
<th>Departure Pattern</th>
<th>System Configuration</th>
<th>Storage Existence</th>
<th>Single Handler</th>
<th>Multiple handles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Yes</td>
<td>Restricted</td>
<td>Pull</td>
<td>0.8</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td>Non-Restricted</td>
<td>Push</td>
<td>0.2</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>C</td>
<td>No</td>
<td>Restricted</td>
<td>Pull</td>
<td>0.8</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>D</td>
<td>No</td>
<td>Non-Restricted</td>
<td>Push</td>
<td>0.2</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

5) What are the required actor configurations under the presented alternatives?
A thorough verification and validation of the model is performed and based on it, certain configuration variables are determined. These are: 10 airside dock doors, 5 landside dock doors, 2 hours TNT and a capacity of 8 dolly trains for the single handler configuration. After performing the simulation and running the stated experimental plan, statistical analysis are performed in order to determine if indeed a specific handler configuration was significantly different in terms of performance. As Table 9.2 shows, the configuration that provides better results is that of a multiple handler. It performs consistently better than the single handler configuration in terms of means (e.g. reducing LT by 40 minutes for the base demand scenario) and shows a smaller variance as well (e.g. 50 to 70% less). This is to be expected, as the single handler configuration adds process steps, waiting times and creates bottlenecks at airside. Based on this, the multiple handler is proposed as the actor configuration.

Table 9.2: Summary of statistical comparison for airside handler configuration

6) What are the recommended distribution alternatives under a number of scenarios for the FT?
Having resolved which airside handler configuration is the best, the specific FT designs can be tested. Results are analysed in order to verify if the design “treatments” have an effect on the KPIs performance. Additionally, correlation tests are performed in order to understand the relationship between the KPIs. From this, it becomes clear that LT airside and LT and Waiting Time and Turnaround Time are perfectly correlated. This represents valuable information since it proves that any increase at airside operations affects LT directly and that the main driver for truck turnaround time is not the loading process itself but the waiting at the gate.

As Table 9.3 shows, LT is affected by the existence of storage and its presence greatly reduces variability. It not only reduces variability in LT but also on the dock utilization. This of course, is supported by theory since storage areas serve as buffers that modulate the flow. In terms of TP, storage also proves to be beneficial, increasing the output by 10 BUPs per hour. In addition to this, the landside KPIs confirmed the relationship between truck load and the amount of truck visits and by consequence, the truck turnaround time. It was established that a pull configuration generates smaller truck loads than a push one. And yet, even having short periods of time in which the system behaves on a push way, reduced the number of truck visits by 50%. This serves as an indication of the potential of a truck allocation strategy lead by the FT.
Table 9.3: Statistical results for the FT designs

<table>
<thead>
<tr>
<th>FT Design</th>
<th>LT Throughput</th>
<th>Turnaround Time</th>
<th>Truck Load</th>
<th>Trucks Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std Dev</td>
<td>IQR</td>
<td>Mean</td>
</tr>
<tr>
<td>A</td>
<td>4.54</td>
<td>0.410</td>
<td>0.57</td>
<td>62.16</td>
</tr>
<tr>
<td>B</td>
<td>4.13</td>
<td>0.490</td>
<td>0.59</td>
<td>64.07</td>
</tr>
<tr>
<td>C</td>
<td>19.66</td>
<td>5.973</td>
<td>10.32</td>
<td>52.72</td>
</tr>
<tr>
<td>D</td>
<td>25.21</td>
<td>6.934</td>
<td>10.37</td>
<td>51.41</td>
</tr>
</tbody>
</table>

Based on the performed analysis, it is concluded that the recommended design is one that has storage and works mostly on a push configuration. Such a design does not only improve the assessed KPIs but it also reduces the variability of the system, facilitating a seamless flow in the FT. Design B has these characteristics and is thus the advised design.

7) What are the benefits and shortcomings of the recommended alternatives?

The recommended design has multiple benefits, however, it is not exempt from its share of shortcomings. The design reduces variability and ensures thus a more stable input and output flow at the FT. This is not only reflected on the almost three-fold reduction in LT variability but also on the landside dock door utilization. By ensuring stable FT and landside operations, the design is able to prevent uncertainty from extending to the airsides handling processes. It does so, while increasing throughput and improving the efficiency of landside operations, a particularly critical in the real life cargo operations at Schiphol.

By allowing the FT to perform an active role in the truck allocation, which is basically the foundation for the Push logic in the model, the average truck load is increased to 4.56 BUPs per truck. As a consequence, only half of the original trucks requested is actually called to visit the terrain. Subsequently, truck turnaround times decreases to around 20 minutes for 90% of the visits. This of course has a repercussion in terms of sustainability since it reduces the carbon footprint and emissions at Schiphol.

The shortcomings should also be addressed, primarily because they are related to implementation challenges or limitations of the model, which may change the magnitude of the results. First, and most importantly, it is clear that the design is not able to cope with a demand increase of 50%. It proved sufficient for the current demand scenario, however, if built, additional analysis should be performed in order to verify what the appropriate size of storage should be. This would of course go hand in hand with the area requirements.

Finally, the main shortcoming is that in spite of showing clear improvements in key indicators, it still relies solely on the willingness of stakeholders to adopt the initiative and embrace a close partnership with truck companies and the FT operator. This challenge is considered and minimized, within the possibilities, by presenting Schiphol Cargo with a set of feasible 2nd order actions.

9.2. Major contributions of this research

9.2.1. Contribution to science

The majority of the research on cross-docking has focused on the specifics of each factor, not going in depth in the inter-dependencies among these (Van Belle et al., 2012). This is true both for the interface between airsides and FT and the one between FT and landside. Based on this, two knowledge gaps were identified in the early stages of this project. The scientific contribution of this research lies precisely in answering these questions and filling thus the associated knowledge gap. The gaps and their respective answers are the following:

Gap 1: What is the transport process and actor configuration at airside that meets the fast track’s needs for higher 1st line productivity?

Up to this point, research at airside has mostly focused on improving the ground handling services in order to reduce aircraft turnaround time. As extremely expensive resources, aircrafts make a profit while flying and service times are thus considered a waste. This is specially true for passenger aircrafts. In the case of freighters, the need for reduced and efficient handling exists but is not exacerbated by the punctuality requirements associated with transporting passengers. Current practices involve a point to point transportation from aircraft to 1st line facility. So, each handler loads, transports and unloads cargo at their own facility. This is applicable to all existing airside cargo handling. As a matter of fact, even in the case of shared facilities like the Airport Freight Forwarding Centre (AFFC) in Hong Kong International Airport, there is individual handling performed at airside. The center serves as a consolidation at 2nd line but freight forwarders still need to
pick up/drop off cargo at the different 1st line facilities. Another case is that of Frankfurt International Airport, whose only handler, Fraport, transports from point to point as well.

A study of different airside configurations has not been done yet, not in general and certainly not applied to a shared facility in the 1st line. This research proposes two types of airside handling: multiple handlers with point to point transport and single handler with milkrun transport. Processes are designed accordingly and contrasted with the goal of understanding which option reduces non-value added activities the most. These two alternatives are modeled and through a simulation based on the case study of Amsterdam Airport Schiphol, tested on a set of KPIs. A statistical analysis is performed and from it, it can be concluded that the multiple handler configuration reduces lead time and variability. Since the design for a FT assumes a seamless transport flow, this option is considered the best. However, the true scientific contribution lies in the fact that the trade-offs between configurations are now understood and quantified for the case of Schiphol. This can be certainly generalized to other airports by simply changing the parameters and input data.

Gap 2: How can the truck scheduling and planning at landside contribute to a higher fast track throughput at Amsterdam Airport Schiphol (AAS)?

As mentioned before, the inter-dependencies between factors and how several problems can be addressed by one approach is still an undeveloped topic in literature. In fact, incorporating the scheduling and planning of trucks with the push/pull functioning of a FT and evaluating it on a case study constitutes a valuable contribution to the scientific community.

In this research, the truck routing and the associated Vehicle Routing Problems (VRP) are out of scope due to the lack of data regarding trucker’s schedules. Instead, the focus is on the truck planning and scheduling as a critical component of the push/pull system logic. The reason for this is that a highly variable landside operation is an obstruction towards achieving the goal of a seamless flow. With this purpose, the landside process has been analysed and incorporated in the simulation model. In it, trucks are notified of a shipment arrival upon aircraft landing. From this moment on the TNT begins and it is only after its completion that a truck can be called for pickup. This confirmation is performed by the FT, which has decision-making power to define how many and which BUPs to load on which trucks.

The reality is that a push/pull nature is not solely defined by the type of action (i.e. upon request or in anticipation) but also by how and where decisions are made (Pyke and Cohen, 1990). What is interesting in this research is the fact that the decision power changes from upstream (i.e. airlines or freight forwarders) to downstream (i.e. FT or trucking company) based on the utilization of the facility. And the utilization in itself strongly influences the performance of the system since the purpose of the FT is to transship BUPs with minimal to none storage time. It can be concluded thus, that there is no specific truck scheduling or planning that can guarantee the success of the FT. Instead, this research has proven that a dynamic system is required in which the FT operators can track the performance and based on it, make the decision to change from pull to push. The testing and analysis of this balance on a set of KPIs contributes to the scientific community and is applicable not only to air cargo but also to other cross-docking facilities that target a seamless flow.

9.2.2. Contributions to society

An improvement in the competitive position of Amsterdam Airport Schiphol is related to many factors like its network, infrastructure and cargo facilities. An airport that can have high quality and efficiency in both passenger and cargo handling is one that is attractive for airlines as well. This creates industry around Schiphol and in turn, jobs. In fact, a study conducted by InterVISTAS Consulting (2015), a company of Royal HaskoningDHV, calculated that the air traffic at Schiphol created 81 000 direct jobs and 60 300 indirect ones. Naturally, this has an effect on the economy of the Netherlands and its competitiveness.

Further, the fact that this design contemplates pushing BUPs from the 1st line facility to 2nd line facilities off-airport could also be interpreted as an opportunity to create additional job poles. An example is Venlo and the development it has had as a logistics hub following from its strategic position and seamless connection with the Port of Rotterdam. In addition to this, a significant truck reduction is proven feasible. This reduction in the number of truck visits causes a reduction in congestion and a decrease in emissions. As a consequence, the quality of life of the inhabitants of the Schiphol area is improved and the carbon footprint of the cargo operations at Schiphol reduced.

9.2.3. Contributions to the industry

The air cargo industry at Schiphol is a highly competitive one, where parties rarely collaborate with each other. The reason behind this may be lack of knowledge or support in their organization but also a lack of
9. Conclusions and Recommendations

Trust among parties (Ankersmit, 2013) (Pieters, 2014). In fact, a recent round table with freight forwarders conducted by the Schiphol Cargo department showed that there is an agreement on the fact that information sharing is the future. The disagreements lie in with whom this information is shared, business partners or all members of the chain. Building the FT with a full truck collaboration is highly unlikely in this environment.

But even so, this research can be seen as a validation on the functioning of a push/pull FT with collaborative trucking. The specific values and parameters are to be defined by the parties themselves. However, they are empowered to do so because of the results of this research. It can help Schiphol Cargo lead the discussion with regards to the needs of each party and the desired performance. Based on it, a pilot can be carried in order to test out the selected parameters and more importantly, the business process and the associated collaboration. The relevancy of the contribution of this research to the industry will depend entirely on Schiphol engaging with the parties and creating the discussion space.

9.3. Recommendations

First, Section 9.3.1 presents recommendations regarding the next steps to be taken by Schiphol Cargo in order to fulfill their objective of achieving an excellent visit value, achieving operational excellence on ground and becoming a leader on innovation and technology (Cargo Department, Schiphol Group, 2016). Following this, recommendations for further research are presented in Section 9.3.2.

9.3.1. Recommendations for Schiphol Cargo

**General recommendations**

Based on the role of Schiphol Cargo as an influencer and neutral adviser in the cargo industry at AAS, it is critical to ensure that not only the strategy is clear, but also the accompanying tactics. In an environment in which cargo handlers and freight forwarders are focused on cost margins and not innovation or collaborative efforts, it is utterly important for Schiphol to lead the conversation and persuade parties to take a part in it.

For instance, there are initiatives already in place by certain parties like the Milkrun, import airside delivery and truck slot assignments. However, in these and in spite of having proved a partial success, Schiphol Cargo has taken a role of an observer instead of one of an active player attempting to copy or standardize these efforts to all other parties. One of the clearer cases is that of the Milkrun, a one-year pilot that started with 5 parties and closed with more than 16 participating companies. Their data shows that a reduction of 40% of the truck movements was achieved, the truck load was almost doubled from 2.5 to 5.2 tonnes per truck and the CO2 emissions were reduced by 30% (ACN, 2016). This project is being led by ACN and participation is strictly voluntary. The open market and non-regulatory role of Schiphol is justifiable but a more active role, as that of the port authority of Rotterdam could work in turning such a pilot into a standard industry practice.

Using other industries as benchmarks, it is clear that in some cases, the sector benefits from clearer and stricter regulation. The Port of Rotterdam can be taken as an example. The port authority has gone beyond the landlord role and has provided a specific vision and road map towards “Smart Port 2030”. It also works tirelessly in ensuring that the port strategy is linked with that of the individual companies. As such, it has become not only a regulatory body but also a driver of innovation that spans across individual operations guiding towards collaboration and information sharing. As a consequence, it has assisted in the development of concepts like the "Extended Gate" or even facilitated the paperless transfer by rail between different Maasvlakte terminals with the help of Dutch Tax and Customs Administration (Port of Rotterdam, 2016). This recommendation is not directed at turning Schiphol into a strict regulatory body but instead into an innovative partner and facilitator in the supply chain.

In addition to this, it should stimulate and actively encourage cargo handlers to improve their efficiency. Joint research in operational efficiency and collaborative efforts could be carried out. As a matter of fact, performing joint research with these parties, as is done by KLM with Schiphol Group or the SIM institute for passenger services, would provide valuable and more insightful results than the ones from an individual research like this one.

**FT specific recommendations**

Thorough and extensive research has been performed with the goal of exploring logistical concepts to solve the 1st line area constraint. Schiphol Cargo should further develop the concepts that proved to be valuable and assume ownership of these projects. Judging which concepts have value or not is a task to be executed by Schiphol Cargo in collaboration with their partners. Nonetheless, this recommendation is focused on the results of the present research concerning the FT and the associated distributions.
This research has defined the possibilities of two different airside handler configurations (i.e. multiple handlers and single handler). These configurations have been studied with a simulation model and based on the results, Schiphol Cargo now has an understanding of the trade-offs between alternatives. In addition to this, the concept of a FT with a push/pull logic and collaborative trucking has been developed and assessed. Again, now the decision-makers at Schiphol Cargo have evidence of the benefits of collaboration and assigning a larger decision-making power to the FT operator.

The proof that a FT with collaborative trucking could enhance the operational excellence of the air cargo chain at Schiphol has been presented in Section 7.6.3 FT design selection. However, it is necessary to also close the loop on the previous FT research, specifically the one performed by Kallen (2015). A one-to-one comparison is difficult due to the dissimilar configuration variables, specific research topics and scope. For example, Kallen (2015) looked into the internal design of the FT whereas this research assesses only the presence of storage and additional interface variables. However, the overlapping variables and the performance indicators are presented in Table 9.4. It is worth noting that even though the base demand may not be identical, both authors executed these runs with a 50% increase in volume. Because of this, a rough comparison can be done.

The first difference lies in the amount of airside docks and storage positions. Since this research is focused on ensuring a seamless flow, the unloading capacity at airside is increased to 10. With the goal of keeping the FT on a transshipment mode, as much as possible, the number of storage units is reduced to 75. As a consequence, the LT increases to an unacceptable level (i.e. 4 hours). Considering the fact that the LT is well below 2 hours for the based demand, the recommendation is for Schiphol to increase the amount of storage positions.

Apart from this, it can be concluded that the push/pull logic and the associated collaborative trucking allowed the system to increase its TP two-fold, which of course creates an increase in truck movements. When combined with the truck load results, it is clear that in spite of the increased number of trucks, cargo is being loaded more efficiently in trucks (i.e. 4 BUPs to 4.56). In parallel, the transshipment nature of the system is more apparent as the storage time is reduced by 67% to only 30 minutes. The airside dock utilization is also higher and the landside one lies somewhere in the middle between Kallen (2015)'s design. These are all within acceptable operating values. Lastly, the occupied area is half the area required for the manual design and double the area in the automated one. In terms of occupied 1st line, the results are similar.

Table 9.4: FT performance comparison. Designs by Kallen (2015) and Schuppener K.

<table>
<thead>
<tr>
<th>Configuration Variables</th>
<th>Unit</th>
<th>Manual</th>
<th>Automated</th>
<th>FT Design B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landside Docks [#/]</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Airside Docks [#/]</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Total Storage Positions [#]</td>
<td>167</td>
<td>120</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance Indicators</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TP [BUPs/month]</td>
<td>18433</td>
<td>16895</td>
<td>41794</td>
<td></td>
</tr>
<tr>
<td>Lead Time Airside [hour]</td>
<td>1.73</td>
<td>1.96</td>
<td>4.13</td>
<td></td>
</tr>
<tr>
<td>Lead Time Import [hour]</td>
<td>1.58</td>
<td>1.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead Time Perishables [hour]</td>
<td>1.36</td>
<td>1.54</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>Storage Time [hour]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Movements [#]</td>
<td>4592</td>
<td>4225</td>
<td>9165</td>
<td></td>
</tr>
<tr>
<td>Truck Load [BUP]</td>
<td>4.1</td>
<td>4</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>Airside Docks Utilization [%]</td>
<td>36%</td>
<td>36%</td>
<td>61%</td>
<td></td>
</tr>
<tr>
<td>Landside Docks Utilization [%]</td>
<td>46%</td>
<td>17%</td>
<td>38%</td>
<td></td>
</tr>
<tr>
<td>Occupied Area [m²]</td>
<td>6460</td>
<td>2200</td>
<td>3373</td>
<td></td>
</tr>
<tr>
<td>Occupied 1st line width [m]</td>
<td>68</td>
<td>22</td>
<td>35.5</td>
<td></td>
</tr>
</tbody>
</table>

Based on this, it can be concluded that a FT is indeed a logistical concept that would benefit Schiphol and that it should be implemented ensuring that both the airside and landside distributions contribute to a seamless flow. How to guarantee that the distributions fulfill this criterion may seem challenging, however, the possible courses of action have also been defined in this research.

In terms or airside, Schiphol Cargo has several options that could be applied based on the participation.
and performance of the cargo handlers. The ideal scenario is that handlers are willing to drop off the BUPs at the FT and they do so in accordance with the defined Service Level Agreements (SLAs), which should be set based on the desired performance. Either way, Schiphol Cargo should either appoint a person to track the KPIs or should empower the FT operator to take action when the BUPs are being delivered too slowly or in poor quality. If eventually, the performance of the handlers is not sufficient at specific moments, Schiphol Cargo could consider introducing a smaller scale 3rd party handler that would perform an airside milkrun during these moments. However, if the performance is altogether not sufficient, the single handler configuration must be implemented. The only possible hindrance would be related to airside area concerns but Schiphol Cargo could always just ask the single handler performing the milkrun to increase the frequency and add resources so that the wait time of BUPs is minimized.

For landside, the implementation requires a robust collaboration with the trucking sector. First, Schiphol Cargo should foment the development of the existing milkrun. For it, it should engage in the pilot led by ACN. At this point, intending to take ownership or leadership is not recommended. In contrast, the advice is to play a motivator role in the industry with the goal of increasing participation and volume. This is of critical importance in order to turn the milkrun pilot into a standard operating practice of the air cargo industry at Schiphol. At the moment only Menzies and Swissport participate, meaning that more than half of the volume is left untapped. Additionally, it should continue pushing for innovative solutions to existing hurdles in the milkrun, like the Geofencing initiative, and introduce shared platforms that are easy to implement (e.g. Microsoft Sharepoint). Once the milkrun has become a standard in the industry, second phases like code sharing for trucking companies could be considered. Furthermore, the business practice of pushing BUPs that have been stored for more than X amount of hours should be discussed and defined. For this, the research conducted by de Wit (2014) can be used. In an initial phase, though, building the CPD may not be such a wise decision. Instead, the recommendation is that, once an agreement has been reached with all parties, an existing warehouse is selected for this purpose with a neutral 3rd party as the operator.

The specific steps that Schiphol Cargo is recommended to follow to implement the FT are presented below. This step-by-step is in no way fixed and Schiphol Cargo may have to repeat steps iteratively, as is the case with any type of continuous improvement effort.

1. **Pilot definition:** The reality is that in order to test out the concept of the push/pull FT and the collaborative trucking there is no need to actually build it. A pilot could be performed at any cargo handler’s facility since no roller-bed or additional equipment is required. Schiphol Cargo is advised to select an influential handler (e.g. Dnata, Menzies), freight forwarder and an associated trucking company. In addition to defining an initial set of desired participants, the type of cargo should be also clear. Recommended cargo types are BUPs, perishables and flowers. This will, of course, have to be adjusted to the volume composition and type of the participating cargo handlers. The strict rule though is that the same cargo type should be applied to all participating handlers.

2. **Engagement of parties:** Having defined the strategic key participants and the cargo type, Schiphol Cargo should approach them and incentivize their participation in the pilot. The goal of this step is not to provide a detailed and fixed pilot plan to the handlers but to awaken their interest and curiosity in it.

3. **Definition of business model:** In spite of the fact that research has been conducted around the topic and a head start has been made, Schiphol Cargo still needs to have a group discussion or working session with the pilot participants in order to define what the business model will be. A model of cost and gains should be drafted as well. It is after this step that parties become committed to the pilot.

4. **Process design:** Once the participants are in agreement on the business model, the process can be designed. This will include the individual process mappings for each party and most important, for their collaboration. In addition to this, KPIs need to be defined considering the needs per actor while making sure that they encompass the whole chain and the existing interfaces. Schiphol Cargo could present the KPIs used in this research and previous ones as a brainstorming starters. Furthermore, Service Level Agreements (SLAs) between parties ought to be defined and agreed on.

5. **Communication plan:** Despite the low number of initial participants in the pilot, collaboration should not be considered a given. In fact, a communication plan should be developed for the purpose of securing the commitment of the employees at each company, stating applicable procedures and the goal of the pilot. This communication plan should also be extended to include other stakeholders.
6. **Execution and Control:** During the implementation and execution, Schiphol should assign a person with operational experience to follow up on the pilot, provide daily tracking and serve as an *escalation point* so that all issues can be solved centrally and in a standardized way. Weekly meetings with all parties should be held with the goal of performing post-mortems on the solved issues and negotiating a systemic solution to recurring ones. In order to perform a transparent and effective performance tracking, a website must be created where participating members can access the KPIs and record quality excursions.

7. **Closure and reset:** Based on the performance tracking, Schiphol Cargo will be able to identify a stabilization point, after which the pilot can be considered successful. It is at this point, that the pilot can be closed, meaning that the learnings, improvements and changes made to the initial concept are to be discussed and agreed upon. This constitutes the *reset* of the project. Only after this can additional parties join in.

### 9.3.2. Recommendations for further research

Based on the research scope, the limitations and the discussion presented, this section gives recommendations for further research on topics relevant to the improvement of the air cargo supply chain at Schiphol.

**Interaction of configuration variables**

As it was stated in Section 7.4 *Validation*, a full factorial is not possible in this case due to time constraints. However, it should be conducted with the intention of understanding all possible interactions, their significance and possible impact on the performance of the FT. This simulation and statistical study would build on this research and allow all parties to have a better grasp on the variables and what their values should be. This is a key part of the implementation efforts since the participation of the stakeholders is considered as the most challenging factor to assure by all authors. In fact, an outcome of such a study could be to present lower and upper boundaries to the variables that could serve as a tool for the negotiation among parties.

**Joint research**

Even though extensive research has been carried out in order to understand the main issues in the cargo industry at Schiphol and possible logistical concepts have been explored, there is still the need for a thorough study that involves several parties and provides results based on data gathered in the day to day operations.

It is for this reason, that a joint research between cargo handler, truck company and freight forwarder is advised. Schiphol Cargo has allies in several companies that would be more than committed to allowing a research project that involves the parties along the chain. An idea would be to tap into the desire of a better partnership and collaboration between Dnata and Jan de Rijk and facilitate a research that would perform a diagnostic on the main causes for waste, perhaps performing an FMEA (Failure Mode and Effect Analysis) to identify the top causes of failures in planning, dock allocation and loading.

**Landside distribution**

On the topic of landside distribution, there should be additional research conducted. Even though there have been studies made regarding the time spent at the Schiphol region and the possible number of visits between handlers, these studies lack data and the RFN component. The topic of RFN, the number of clients (i.e. freight forwarders or final clients) visited on route and the number of mandatory stops and associated rest hours for the truck drivers remains mostly an enigma. It would also be interesting to assess the impact that queuing at the handler’s terrain has when considering the rest hours of the trucker and the cases in which queues have to “be exited” because of the rest schedule. A robust study into the trucking companies critical resource, the driver, should be sponsored.

If more data was available, a Vehicle Routing Problem with Time Windows (VRPTW) could be performed in order to define the optimal set of routes and visiting moments for a set of customers with a specific fleet of trucks. At the moment, the truck allocation is performed by the trucking company and the goal of optimizing the truck load is kept, however, this is not always feasible due to the low or unequal level of cooperation between handlers and trucking companies (Pieters, 2016).

**Removal of unnecessary transshipment**

In the most basic business model, cargo handlers are in charge of airside handling, pallets build up and break down and stacking and storage. Interestingly enough, once the cargo is picked up by the trucking company, it
is sometimes taken to the trucking company’s facility and only after to the freight forwarder. There, it is stored and then picked up again to be taken to its final destination. This trip again is not always direct and sometimes, a stop is made again at the trucking company’s terrain. The milkrun pilot already mentioned eliminates storage at the handler’s facility completely (Brink, 2016). The removal of unnecessary transshipment should be researched upon and the possibility of eliminating the stop at the freight forwarder altogether analysed. This could proof to be feasible in particular for BUP cargo that does not require any additional services (i.e. break down or build up), allowing the truck company to pick up the cargo at the handlers and take it directly to the final customer. The base for such an initiative would undoubtedly be the concept of cross-docking at the 1st line, researched in this project as a FT.

Stakeholder engagement
As part of the extensive research conducted around the South-East development problematic, Pieters (2014) identified the low degree of cooperation among actors due to their commercial interests, the economic environment and the low willingness to invest. However, all research has been conducted from an engineering perspective (i.e. logistics or transport engineering students). At this point, the technical research and results are considered robust enough to validate the fact that logistical concepts like a CPD at 2nd line and a FT with collaborative trucking would significantly contribute to a more efficient use of the existing 1st line capacity and improve the performance of the system. All researchers mention the stakeholder engagement as a key factor in implementing any of the concepts successfully. In fact, having a proven concept does not guarantee full and straightforward implementation as the Milkrun pilot proved. Because of this, the research should switch from a purely technical one to one that is rooted in behavioral sciences and innovation management. Doing so might just aid Schiphol in solving its biggest hindrance in achieving its goal of operational excellence.

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A.1. Steven Ankersmit- ACN Graduate Intern in 2013- 9th June 2016

What are your thoughts on Schiphol's current transport collaborations?

For outbound flows E-link or some other platform to collaborate on is required. Now it is more about cost saving. The milkrun for export can only be fully deployed when a solution like E-link is present. For import it is easier to collaborate with partial information.

The problem is that ACN has a limited influence so they can only help on certain collaborations. Other more powerful actors, like airlines, not necessarily influence the system to improve quality, but simply to reduce costs. For instance, the airlines have a preferential situation since they choose the cargo handlers. This is done basically based on cost and it causes problems since the handlers are not always ready in terms of facilities, equipment or employees. The handler is the one that needs to invest in fixed costs, however when the airline leaves, they are stuck with them. At AAS it is worse since there is already an overcapacity and it is more threatening now, which is why most of the handlers are on survival mode and are thus unwilling to perform investments. Quality is measured for the airline as “Flown as planned”, however they have no focus whatsoever on the Last Mile. There are a lot of inefficiencies on that leg of the chain and since the airline does not choose a handler based on that, there is no real incentive to improve. Most players are not thinking strategically but on a shorter term, which is why the airport authority seems to be the only part that can perform those investments decisions.

Can you elaborate on the milkrun concept and project?

In 2013, when I was doing my thesis, there was a lot of resistance since parties were willing to collaborate, partly, but not to invest. More than 40 companies were contacted and only a limited number of them was willing to participate in a subsidized pilot. There were important parties like KLM against it since they thought the subsidy was unfair. However, their resistance or power in the industry has diminished and stopped representing a deal breaker for the milkrun pilot.

The early concerns of privacy and costs were offset through the work of Dimitri Brink from Panalpina. He has more than 20 years in the industry and a strong motivation. The idea of having different sections and such was dismissed since it would reduce the operational efficiency.

Another factor of success was the system around the Milkrun since it provides transparent and real life information to the forwarders and handlers. The system is designed to be flexible in terms of times, routes, etc. However the type of cargo is defined as general, hard cargo. It might be possible to handle other types of cargo, although in that case 2 systems might be better. One single system handling it all might be too complex.

In terms of routes, the milkrun does not work with fixed ones. In this way, the process is LIFO. Participants agreed to have a changing route dependent on the arrival of shipments. The truck driver has all the necessary information in a smart-phone. On the other hand, the employees at the handler’s are aware of the importance of the Milkrun and its impact.

Results are positive, it is not only the reduced amount of movements but also an improved reliability at the freight forwarders. This translates as well, into more reliable deliveries to end customers.

How was your simulation performed?

The case study was based on information provided by Cargonaut and the the logic behind it was based on
stakeholders' opinions. So, they said they would rather have a truck wait at Handler A until FTL than share one truck among handlers so that it would be FTL instead of LTL.

In it, I advised for general cargo be used due to the volume. However, since in your case, the analysis is for BUPs, it is important to understand the assumptions and how the average shipment size might change in the future.

On one hand, with e-commerce big freight forwarders might get more market share and the BUP share might increase, as well as the average shipment size. Freight forwarders would love to build up more pallets but the airlines have hard requirements on size and shape. On the other hand, the market might become more segregated and thus shipment size reduced.

The export part could be controlled at Schiphol, however for import, there are bigger limitations. Do the other handlers at origin airport care enough to actually set up the BUPs as one destination only? What would the volume be if it's just BUPs? It needs to be profitable.

**What are your thoughts on priority treatments?**

Perhaps there could be a standard and premium service offered in the milkrun, although more volume is required to make it feasible. Then, if there are changes in priority, how do you have resources on stand-by and do you handle the other customers and changing environments? Perhaps 12 hours before shipment priorities could be assigned but at the moment it seems non-feasible.
A.2. Dimitri Brink- Business Unit Manager Panalpina-13th June 2016

In 2013 Steven Ankersmit and Sebastiaan van der Meij conducted a research with ACN. At that time, a pilot for a milkrun was created. There were several parties involved, however once the research was finalized, the project was left unattended. Dimitri Brink, seeing the potential of it, became the industry leader of the Milkrun effort, using his experience, weight in the industry and extensive network to lobby for its implementation.

What were the key factors in being able to successfully implement the Milkrun?
The effort, ideas and research from Steven and Sebastiaan were already there. However, the industry paid no attention to them because they were students. By having in the first place a strong steering committee with the right connections in the industry, we were able to take proper ownership and push the project forward. Second, the ICT Platform was created. This facilitated the process immensely by eliminating the manual work involved. Sadly, this industry is still lagging behind in terms of ICT solutions. By having a strong ICT platform that allowed information to be transparent to the involved parties, we were able to diminish their resistance to participate.

How was the ICT platform developed?
It was developed with the help of a subsidy, which provided almost 50% of the €50 000 needed. The business model is such that if other airports want to implement the milkrun system they can do and buy the platform directly from ACN. The revenue goes then to this organization and is able to re-invest it. TNO helped to create the reports and performance data around the implementation.

How did you foment this collaboration?
There had been mistrust initially and concerns regarding privacy of information and such. However, the way in which we convinced the parties was by relying on the hard facts. Once you look at the possibilities in terms of CO2 reductions, cost reductions and efficiency improvements, it is quite obvious that collaboration is needed. In the end, cargo handlers are benefited due to a more reliable information and thus optimized processes and forwarders, in spite of paying for the milkrun, save money on purposeless transport.

The key was to dive into our common interests: Environment, optimization of the supply chain, feasibility and becoming a front runner in the European cargo market. If we had gone to the numbers (profit) initially, it would not have been adopted by many since initially there are no direct cost reductions. However, on the second phase of implementation, cost reduction are indeed achieved by reducing the associated trucking costs of almost 60 euro per hour.

What are some of the achievements during this year?
The achievements are great! Just look at the fact that we have reduced truck movements by more than 40%, reduced CO2 by 30%, increased truck loading twofold and increased the amount of participating companies from a handful to more than 25.

How does the process work?
Cargo handlers pick up the loose cargo from the airside. They have to do so usually within 8 hours of landing, according to the contracts with airlines. They have at least 2 dedicated docks for the milkrun and a truck waiting for loading. A maximum of 4 freight forwarders are loaded in each truck. The loading is performed on a LIFO manner - Last cargo in will be the first one to be delivered. The promise is to deliver within 8 hours for ULDs and within 12 hours for loose cargo. In terms of liability, by having a milkrun we have extended the airline liability all the way to the delivery at the forwarder. The truckers all have the app on their phones, which allows them to have a more intelligent system with updated information - this way they know what to deliver and where.

What are the next steps for the milkrun?
Originally, cargo handlers build up the pallets and stack/store them in their warehouse. They will pick it for loading when the truck arrives. This part of the process represents a lot of waiting. A study showed that the average truck turnaround time at the handler’s terrain is 54 minutes. Once loaded, the truck takes it to his facility, then to Panalpina for instance. Here, it is stored in the floor and then picked up again by the trucking company, who on their way to the customer, stop again at their own facility. By having the milkrun, one stop is completely eliminated.

The pallets are not stored in the cargo handler’s warehouse but directly stacked at the respective dock. So, if the pallets goes to forwarder A, it goes to Dock #1. Once the truck arrives it is immediately loaded. The truck then brings it directly to the forwarder. From this point on the process continues.

Ideally, the pallets should not have to wait for loading in the truck. So a sort of Cross-Docking would take place at the 1st line facility and the trucks would go immediately to the customer. An example of innovative
thinking is Bos Logistics. They are now offering the service of handling at their own facility. So instead of loosing business because of the reduced amount of movements, they have expanded their business model to include value-added activities. Currently, they are profiting from handling as well. Another possibility would be to have a shared 1st line facility, as in Hong Kong for instance, where several cargo handlers were in charge of airside, a couple did the handling and then the freight forwarders took over the cargo for distribution through their trucking partners.
A.3. Gerard Kervezee- Chief Commercial Officer Dnata- 20th June 2016

How have things changed since the acquisition of Aviapartner by Dnata?

Market share had decreased slightly from a 26% to a 20% last year. We were handling 324,000 tonnes, which was below our ideal target. However, we are back on track handling 420,000 tonnes. This does not include the post business of Dnata, where all e-commerce related packages are handled. So, as you can imagine, we handle a lot more tonnage than officially reported then.

What is the average handling per aircraft type and what is the airside unloading and loading process?

No two aircrafts are the same. Some flights arrive full, others are mixed ones with lower tonnage and there are also code shared flights, in which case a part of the aircraft needs to be left empty for the next airport's loading. 85-90% are 90 tonnes per flight, however the calculated average from your data (65 ton/movement for full freighter and 1.1 tonnes/movement for belly freight) sounds feasible. Of course, that is considering the mix and the above mentioned factors. For instance, approximately 45% of all passenger aircrafts leave empty, which affects directly the average tonnage handling on belly freight.

Since our facility is in front of the Romeo platform we do not use dollies, only transporters. Usually, the unloading of one aircraft is done with 4 transporters, 1 working on the lower deck and 2 to 3 on the main deck. Each transporter can fit 1 pallet, however if it is a 20 foot one, it can fit 2 pallets. The crew working on the airside is highly skilled and trained, and there is no interchangeability between warehouse and airside personnel. Due to this, the unloading time is on average 1 hour.

In terms of loading, the cargo is received and the pallet size optimized based on the carrier's specifications. We also receive the list of shipments to load on the aircraft as: Priority, First Stand-by and Second Stand-by. The planning of the loading and the weight balancing is also done for the carrier.

There are almost no issues on airside, due to the fact that we are dealing with just one organization and one that we control for that matter. Airside is the most important part of our process since we are dealing with highly specialized and expensive equipment. Our goal is to ensure 100% safe and secured execution.

Do you see the share of BUPs increasing or decreasing?

It is currently at 30% and general cargo at 70%. It is not a secret that BUPs and FT are ideal but in the end everything always comes down to price. Agents can only opt for BUPs when they have the right cargo. For the agent it is more ideal to deliver loose cargo and have the cargo handler make the combinations. Cargo handlers either way do the pallet build up, planning and balancing. So, if you end up being stuck with mixed pallets, which cannot go through directly to the distribution since they have to be broken down upon arrival. The FT does not solve that problem.

It is better to then combine services so that one facility can offer several types of handling (pharmaceuticals, perishables, general cargo) so that pallets can be build up in an optimal way. An initiative by Schiphol to have a Centralized Pharmaceuticals Center did not work because shippers and carriers want to consolidate. So in one pallet the full capacity needs to be used, which means that in the same pallets a cargo handler will build up pharmaceuticals and clothing for instance. Centralization works only if you can build up optimal pallets in your facility.

The developing of e-commerce in the last 10 years is unpredictable and no one can state with certainty if the BUP amount will increase or decrease. There are a lot of opportunities and threats and it could all be over in one second. Dnata is trying to stay on top of the developments without making any investments on it. Other parties in the industry, like PostNL, are also staying clear of making big investments. Originally, this used to be the integrators business, however it is now being handled as AirMail by PostNL. This means that all items are normally shipped as loose cargo in receptacles, which need to be broken down or build up by the cargo handler. So, there might be 50 items received from airside and 2000 released to the trucking company. It is for this reason that all post items are scanned as IPS (International Postal System) and the tonnage does not count as handled tonnes. These items are counted separately.

What are the current throughput times?

The average transit time, as stated by IATA, is at 6 days. So for example, a flight from Shanghai is 11.5 hours. As it lands, we proceed to unload it and break it down. 90% of the cargo is handled in 7 to 8 hours. That means the last shipment is released after 8 hours, but there are continuous releases being made as the cargo is broken down and prepared. For BUPs our goal is 2 hours, although it is hardly picked up when ready. Since the system works real time, the agent is timely informed. There are delays with the pick up usually and once it is picked up it stays at the agent's warehouse for 1 to 2 days.

All information is transparent on the system, however there is some information that is not shared all along the chain. This allows other parties (freight forwarders and carriers) to optimize the shipping even though it might represent longer times. It is important though for these companies to be able to gain from
economies of scale.

**Which productivity improvement measures has Dnata taken?**

Dnata currently holds 5 FTs, 3 for export and 2 for import. We can say that an 80% of the cargo is handled in less than 12 hours.

e also try to keep the morale of the employees high. Due to the type of work it is understandable that not all employees are highly motivated or committed. And the ones that are, also get tired after a work’s day. It is not the same to handle a flight in which everything is on skids and one where it is all loose cargo. So, employees are rotated so that their work load is relatively balanced throughout the week, as much as possible.

**What are some of the truck scheduling and dock allocation issues that Dnata faces?**

It is important to understand this within the context that we work with more than 130 trucking companies, which complicates the coordination process. Yet, one of the main problems lies at the route planning in the trucking company. The reason behind this is that the carrier sends the information when it is definite, which usually means, once the aircraft has departed. So, trucking companies are faced with basically no information at the beginning of the day, and as it starts arriving, it begins its planning. The initial plan, which is communicated to the cargo handler, is hardly met since at the time of planning the trucking company might not even know if it has enough trucks or drivers. The change in plans is not communicated to the cargo handler either. Less than half of all the trucks are on time, and the ones that are late can even be a couple of hours delayed. Dnata does manage the transport for some airlines, in which case they organize directly the pickup/drop off time with the trucking company. In this cases, the coordination problems are considerably reduced.

The problematic is particularly troublesome for transit (i.e. RFN) transportation. In the case of Amsterdam transport, Dnata has block times assigned. 50 minutes before truck arrival it pre-stages by the dock door. If the truck arrives at the assigned time, it can take normally 45 minutes to load a truck and then it can leave. But, if it arrives late, it may have to wait for 2 to 3 hours until a dock door is free. This also represents a problem for the internal warehouse operations since the dock door is non-utilized or if there is another truck that can take that position, the pre-staging is not done yet.

Block times have been tried for the transit flows as well, but it has failed so far. It is quite difficult since they do not have any loading flexibility, so the truck driver needs to follow a defined route with no possibility of skipping a cargo handler that is late and then coming back for instance.

**How is the dock allocation performed?**

It is done based on the smallest distance at the warehouse. In the case of Amsterdam transport, there are 6 dock doors for block time trucks and 4 free dock doors that serve as a buffer.

**What do you think about pre-emption?**

I do not think it would work. If you start loading a truck, you finish it. Otherwise you lose control, especially with transit trucks. Since RFN shipments go under the AWB, customs needs to seal the truck upon loading completion. If there would be pre-emption, the process would not be under control and the customs check could be jeopardized.

In the case of shipments in the Amsterdam Area it might work, although it does not seem to matter when you have enough dock capacity. Might be interesting if they represent a capacity constraint.

**What is your opinion of the Milkrun and why has Dnata decided to not participate?**

Dnata is not interested in participating since the gains are not clear. This is not a particularly new concept but it was done on a small scale with small agents. For Dnata, their core business is handling, not transportation. The optimization of the transportation can be done by the trucking company since they have all the necessary information in the system. But with the current milkrun configuration the cargo handler becomes responsible for the transportation between their warehouse and the agent’s facility. So, there is an additional risk that may not yield benefits. Another point is the fact that the system (ICT platform) is not fully liberalized and is owned by ACN. Finally, the use of just one trucking company for the milkrun (Bos Logistics) does not benefit the whole trucking industry, so that could be improved. If these things are resolved, Dnata would have no problem in participating in it.

**What are your thoughts on the expected capacity constraint on the 1st line?**

I disagree partly with that statement since there is enough are if we were to use more than 1 level. At the moment, all facilities have 1 level, which is ridiculous. Of course, due to the ground and height restrictions, we might not be able to build a 7 levels warehouse, but we could at least double it. An ETV system can easily be used to store the pallets. The ground floor could be used for heavier goods, which in the case of Schiphol, correspond to export. The second level, could be used for import shelves, which are usually lighter. This is due to the type of goods exported and imported: From Asia usually electronics, whereas on the export side it
is normally heavy machines or odd sized goods.

You have to think about what makes Schiphol attractive as a cargo hub. It is cheap, flexible, high quality due to a high competition among cargo handlers. So whatever solution you propose cannot be at the expense of any of those factors. A shared FT for instance, would diminish flexibility since all peak times are the same. Monday, Weekend and Wednesday are quite important, with slower traffic on Tuesday and Thursday. It would also cause additional costs due to the increased distances.

What collaboration initiatives has Dnata taken on?

Dnata has focused on value added logistics, which allows the carrier to offer extra services to their customers. So, Dnata has a perishable center, an animal center and a Pharma lane. This is quite unique since only KLM has an animal center, and most of the perishables go to Freshport. In addition to this, it also handles all the mail and e-commerce shipments through its partnership with PostNL. Finally, it offers an offline handling network with more than 120 partners all across the European Union so that carriers can extend the offer of their destinations and handling facilities.

A.4. Gerard Kervezee- Chief Commercial Officer Dnata- 14th July 2016

During this meeting, a shorter interview and a tour of the Dnata warehouses was conducted. In this section, the most relevant points for this research are mentioned.

At what point is Dnata informed of cargo that needs to be checked by customs?

Dnata receives the pre-information 1 to 2 hours before ETA. The Flight-Information department works with their team in order to plan and organize all necessary resources for the handling of the aircraft upon arrival. Then the Ramp team, lead by their Ramp Supervisor, ensures that there are sufficient lanes with dollies for the destinations (i.e. customs, 1st line facility from a freight forwarder). So, upon arrival and unloading, the cargo begins to be split into these lanes. Once the dollies are full or that assigned cargo is completed, it is taken to the next destination. From the aircraft the cargo is taken directly to the Joint Inspection Centre (JIC) for the customs check and then back to the handler’s facility. The same principle is applied with BUPs for 1st line forwarders. Basically, by taking the cargo directly where it needs to go, there is a saving of 2 handling movements (i.e. unload to handler’s facility and load on dollies on airside once cargo has been split). These are non-value added activities, which is why they are eliminated when possible.

In your experience, what is the unloading time of an aircraft?

This depends on whether the aircraft is a full freighter or a passenger aircraft. The type of aircraft will of course also influence on how much cargo you can load and thus on the unloading times. However, we can estimate the times by considering a wide body aircraft (i.e. B777), which is used quite commonly in the industry. For a full freighter: Minimum can be 45 minutes, average 1 hour and maximum 1.5 hours. For belly freight: Minimum of 30 minutes and maximum of 45 minutes. This will of course depend on the type of cargo, since depending on where it is coming from you will get a higher share of loose cargo of ULDs.

What is the loading and unloading time for a truck?

We can load 2 ULDs simultaneously for 20 ft. pallets in 5 minutes. This is of course assuming there are no ULDs out of contour. If they are, then we need to invest extra time in making sure it fits properly. But this only occurs a 4 - 5% of the time. So, when it is normal freight and since one truck can take 4 ULDs, it can take us only 10 minutes to load the truck. If you need to re-do the ULD so that it fits, it can go up to 45 minutes. Unloading on the other hand, is an easy process, which can take 15 minutes.
A.5. Stephan Pieters- Account Manager Jan de Rijk- 1st August 2016

What is the planning and truck scheduling process?
Once the plane departs the flight manifesto is sent to Dnata/Jan de Rijk. The planning is done and then the planning for the freight and the trucks is executed. This is done based on the existing contracts of course so it varies between parties. If they have the information, then they send it to Dnata in the morning (10 am). But this is not the same for all airlines; for instance, in the case of Singapore Airlines Dnata plans the schedule, sends it to Jan de Rijk for approval and receives the confirmation or modification proposal. The reality is that some airlines do not want to combine or share trucks, which hinders the efficiency. There is always the goal of creating FTL but this is not always feasible.

**What are some of the difficulties in terms of cooperation?**
The information flow is not good since there is no shared live platform. Everything is sent by mail. The level of cooperation is also not the same across handlers - with some it is better than with others. There are also no shared performance metrics or penalties. The trucking company and the Cargo Handler cannot really charge each other penalties, except for the case of waiting times. If it is 2 hours or more then they can charge Dnata a share of the cost. There are a lot of grey areas. For instance KLM does review the waiting hours and pay the company back in case of big delays. There is however no agreement on the KPIs of their business relation. There is a new project so that the trucker can check in upon arrival, start loading, finish loading and check out. In this way, the times can be better tracked.

Also, the fact that most work is done at night and the manager structure is not present creates issues. Since the planning will always change due to uncertainties or delays, strict rules cannot apply. But there are no standards procedures for this decision making.

**What are the main RFN destinations? What is the share?**
LON, FRA, CDG, BCN. There are almost no deliveries done to industry hubs. The majority of the destinations are airports. 50% RFN seems like an appropriate estimation for the current destination types.

**What are the main AMS destinations? What is the share?**
Jan de Rijk has very like AMS destinations. However, the business process in that case is not to charge per km but per hour. So a minimum of 2 hours is charged and then from there on, an hourly rate. Considering that now some trucking companies are offering value added logistic services in their own facilities, how do you see the dynamics between cargo handlers, freight forwarders and trucking companies? Jan de Rijk used to have its own warehouse but this is no longer the case. The company now rents a small space only to consolidate but it is a small area since most of the consolidation (99%) occurs somewhere else (i.e. cargo handler or freight forwarder facility). There is indeed a big overlap between cargo handlers and freight forwarders but this does not involve the trucking company specifically.

**What are some of the main problems you experience at landside? How does this contrast with your previous research?**
The influence of the operational personnel is really big and it is a bit arbitrary. The cargo handler has no standard procedure regarding tactical decision. Additionally, the cooperation with the cargo handler is usually low. It is for this reason that Jan de Rijk rents out offices in the Dnata building. In spite of handling around 60-70% of the volume of Dnata and having offices in the same building, cooperation is still low. It even results in Jan de Rijk creating its own waiting line since all trucks go to pick up the cargo in the same time slots.

Another issue is the working schedules of the truck drivers. In order to maximize the actual driving time, the company has pre-loaders. The trucks are left in a secured parking but what happens is that pre-loading is performed even for LTL, which does not make sense or help in improving the efficiencies. The current schedules are based on travelling at night so that the trucks can arrive for opening times. In addition, it reduces travel times since there is less congestion. But if the truck driver has fulfilled his hours, he needs to stop, take this mandatory rest hours and only then can he continue on route. It even happens while waiting in the queue at the cargo handlers. Then the truck has to drive out of the queue and when he can continue working, drive back in queue at the end of the line. Even though Jan de Rijk has around 950 trucks, the scarce resource is the driver not the truck itself.

**What trend do you see on the share of BUPs?**
Current experts state it at 5% per flight but I think that might be higher for the AMS share. The problem with BUPs is that they are always on a PMC plate and this has to go back to the network of the airline. So it only works when the destination can also serve as a BUP station.

**What is dock allocation process?**
There is no particular dock allocation but the truck gets assigned whichever dock is empty first. Then they can start with the picking and the loading. Some big shipments are already in one single place but it also happens
that they are spread all across the warehouse. There is no pre-stacking done but as far as I am concerned it

What are the associated duration to loading BUPs?
If it is a FTL of BUPs, then it can be 30 minutes. However, if the cargo is loose on wooden pallets, then it could
be up to 1.5 hours.

Could you elaborate on how the slot assignment work?
These are assigned only to RFN shipments but these are delayed (i.e. +/- 15 minutes) around 15% of the time.

Could you elaborate on the Milkrun pilot and the involvement of Bos Logistics?
We would have liked to be involved of course but it is still a pilot and only Bos Logistics was considered for it
on this first stage.
B.1. Discrete Event Modelling with Simio

Simulation is a way to assess and imitate real-life systems that change over time. As such, it can be used for analysing, experimenting and deciding on different scenarios and how these might affect the system. There are several types of simulation: static, continuous, discrete event and hybrid (Corman and Duinkerken, 2015). For this research, the discrete event simulation is used since its applicability is particularly successful in the areas of manufacturing, material handling and general queuing systems (Schriber and Brunner, 2000).

Each simulation language attempts to represent the world in its own "words". Discrete simulation interrelates it with the concept of "locality" and through the occurrence of events defines where the entity is and what its state is (Verbraeck, 2015b). This "transaction-flow world view" as Schriber and Brunner (2000) mentions visualizes a system as "discrete units of traffic that move (flow) from point to point in the system while competing with each other for the use of the scarce (capacity-constrained) resources. These units of traffic are called entities and are the ones that initiate and respond to events. There are however two types of entities (i.e. external and internal). The external ones are those created and manipulated by the modeller. The internal ones in contrast are used by the simulation software itself for its background processes, not all known by the modeller. Entities will have different states as they move through the model. Even though there are differences among simulation languages, most of them will have the the same basic states (Schriber and Brunner, 2000): Active, Ready, Time-delayed, Condition-delayed and Dormant.

In the case of Simio, the language is object-oriented and there is a Standard Library from which objects can be directly used. Some of the most common objects are: Entities, Resources, Servers, Sources, Sinks, Nodes and Connectors. There are also additional objects that provide specific processes like Separators, Combiners and Workstations. It is important to specify that some of these objects are intelligent ones, which means that they can be seized, released and follow an availability schedule. These intelligent objects are: Agents, Fixed, Nodes and Links. In the case of Agents there is an additional variation since some of these agents can be entities or transporters.

Even though most users will rely only on these, the option exists to change these objects and customize their behavior. This is done through Add-On-Processes executed by Tokens or by Sub-classing existing objects. These Tokens are a particularity of Simio and the fact that there can be multiple tokens executing different steps or processes for the same individual object improves the flexibility of the modeling (Schriber and Brunner, 2000). They have have several user-defined states, reference an associated object like an entity or even the parent object that is being visited. According to the Reference Manual of Simio LLC. (2012): "A token lives inside of a process- it is created at the beginning of a process and it is destroyed at the end of that same process".

B.2. Model Specification

In this section the model will be elaborated upon and the details provided in sections 7.1.5 and 7.2 expanded. In addition to this, a short overview of the existing Simio modules will be presented.
B.2.1. Modules
In this section a summary of the key modules and components of Simio is explained. The detail of process steps, elements

**Process Steps**
As mentioned in the introduction of this appendix, Simio has the capability of using pre-defined objects from its Standard Library or customizing these through the use of processes. The most common process steps in Simio are shown in table B.1

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assign</td>
<td>Assigns a new value to a state variable</td>
</tr>
<tr>
<td>Decide</td>
<td>Determines the flow of a token through process logic.</td>
</tr>
<tr>
<td>Delay</td>
<td>Delays the arriving token in the step for the specified time duration.</td>
</tr>
<tr>
<td>Interrupt</td>
<td>Interrupts either an existing delay or an on-going process.</td>
</tr>
<tr>
<td>Execute</td>
<td>Executes a specified process.</td>
</tr>
<tr>
<td>Search</td>
<td>Searches a collection of objects based on provided matching conditions.</td>
</tr>
<tr>
<td>SetNode</td>
<td>Sets the destination node of any entity object.</td>
</tr>
<tr>
<td>Tally</td>
<td>Tallies an observation for each token arriving to this step.</td>
</tr>
<tr>
<td>Create</td>
<td>Generates objects into the system.</td>
</tr>
<tr>
<td>Destroy</td>
<td>Destroys either the parent object or the executing token's associated object.</td>
</tr>
<tr>
<td>Fire</td>
<td>Fires an object event.</td>
</tr>
<tr>
<td>Wait</td>
<td>Used to hold the arriving token in the step until a specified event occurs.</td>
</tr>
<tr>
<td>Seize</td>
<td>Seizes capacity on behalf of the parent object or the associated object.</td>
</tr>
<tr>
<td>Move</td>
<td>Requests a move from one or more moveable resources that have been seized.</td>
</tr>
<tr>
<td>Release</td>
<td>Releases capacity on behalf of the parent object or the associated object.</td>
</tr>
<tr>
<td>Transfer</td>
<td>Transfers the entity object associated with the executing token between objects.</td>
</tr>
<tr>
<td>EndTransfer</td>
<td>Used to indicate that the executing token has completed transfer into an object or station.</td>
</tr>
</tbody>
</table>

**Elements**
Simio also has a Definitions section where properties, states and events can be controlled. They are either inherited or added to the model by the modeller. They constitute a key part in the customization and serve as input and decision variables in the elaboration of the processes. According to Simio LLC. (2012) these are:

- **Elements**: Represent things in a process that change state over time.
- **Properties**: Model input parameters that do not change during the simulation run. The definition is thus fixed although the return value might change based on the expression.
- **States**: Dynamically changing values which serve as output responses and change throughout the execution of the object logic.
- **Events**: Logic triggers used through the processes (i.e. Fire or Wait step).
- **Functions**: Queries of calculated values that can be called by another object.
- **Lists**: Define a collection of strings, objects, nodes or transporters.
- **Tokens**: Execute the steps in a process flow within the Processes window.

B.2.2. Model Layout
1. BUP Arrivals
As it can be seen in Figure 7.7, the process begins with the creation of aircraft entities. This is where the input data provided by Schiphol Group (2016d) is used in order to build the rate tables. The aircraft entities enter a Separator, where the BUPs are split from the aircraft according to the stated destination group shares stated in table 7.6. The process of unloading is performed, with distinct durations depending on the type of aircraft. Once unloaded the decision of whether the BUP needs to be checked at Customs or not is made. If the BUP requires a Customs approval, it is directed to the JIC. Here the units are checked and released. The processing capacity is of one at at time (Droste, 2016). There are cases though, where a detailed check needs to be performed. If that is the case then a decision is made. If the dolly contains only one BUP, then it stays
with it waiting for the detailed check to be completed. According to Droste (2016) from the Schiphol Duoane, if there are more BUPs in the dolly train and these have already been cleared, then the dolly train will depart the JIC, drop off the BUPs at the FT and then come back to pick up the remaining one.

If BUPs do not require the Customs check they are loaded and transported towards their destination. It is at this point that the difference between handler configurations becomes apparent. In the case of multiple handlers if the BUP is cleared, it will proceed to be loaded on the dolly and transported to the FT. The transport duration will depend on the ramp at which the aircraft arrived, which is treated as a constant (see table 7.3). But, if the configuration is that of a single handler, the time at airside is increased due to the additional activities and increased distances. As it can be seen in Figure B.2, the BUPs are transported to the airside cargo handler, dropped off, picked up by the single handler, transported to the FT and then unloaded. By contrasting Figure B.1 and Figure B.2 the distinctions between configuration becomes more apparent.

[Figure B.1: Model Layout for Multiple Handlers- BUP Arrivals process and FT Unloading]

[Figure B.2: Model Layout for Single Handler- BUP Arrivals process and FT Unloading]

**2. FT Unloading**

Since this process is relatively small, Figure B.1 will still be used as reference. Once the dolly trains arrive at the
FT, they are unloaded making use of the existing dock doors. Even though there are 10 dock doors depicted, not all of them are available. In the beginning of each run, and based on the value set, some will become "unavailable", reducing thus the effective amount of dock doors.

3. FT Handling

Once the BUP enters the conveyor, it is taken to a Transfer Node. In it, the decision of storing the BUP or waiting is made. If capacity is available it is stored, otherwise the BUP waits for available capacity.

When the BUP is stored in the station, it triggers a check on what type of configuration the system is in (i.e. Push or Pull). Both the station size and the utilization limit are configuration variables. If the utilization of the station is above the desired maximum utilization, then the system will move to a Push logic. Under normal operation, the system should work under Pull, which means that when a BUP searches for its shipment members it does so based on: Time of Arrival for RFN and Destination Group for AMS. In the case of a push system, all entities search based on destination. Additionally, a process is executed in order to push BUPs that have been stored for more than 3 hours out of the FT.

The trucks which were requested at the moment of aircraft landing arrive, after the respective TNT, at a Truck Roaming Node. It is important to add that on top of the TNT, they also have a specific delay depending on the truck type (see table 7.3). This is simply a station where trucks wait for shipment confirmation. Just after the shipment is confirmed as complete, a truck search is executed. Trucks are to be assigned based on entity type (i.e. AMS or RFN). Given the case that a truck is found, assignments are made both to the truck and the BUPs in order to ensure that they become aware of each other and no confusions might occur. By doing so, it is certain that the shipment will be loaded in the truck that was requested and only on that one. After this, the truck is released from the Roaming Node and its destination is set as the Gate In of the FT’s terrain. The shipment will wait until notification of truck docking.

4. Truck Loading

Once the truck has been released, it heads towards the Gate In process, which is simply a check performed at the entrance of the terrain. It is at this point, where the dock allocation is performed. If all docks are busy, the trucks will wait in the Output Buffer of the Gate In. Upon arrival of the truck at the dock a signal is sent to the storage station in order to transfer out the specific BUPs that had called for it. The BUPs exit into the conveyor belt where they are batched and directed towards the dock door where the truck awaits. The loading is performed and when completed, the truck heads to the Gate Out process and exits the FT terrain.
B.3. Input Analysis
In this section the model input data is expanded. The other component of the input analysis, model constants or fixed parameters, is discussed in the main document.

B.3.1. Input Data
As it was mentioned in section 7.1.3, the arrival pattern is based on the data provided by Schiphol Group (2016d) and is based on 4 hour time ranges for a week, which totals 42 data points. The input data for the arrival of freighters can be seen in Figure B.2 and that of passenger aircrafts in Figure B.3.

B.4. Model Results
B.4.1. Statistical Analysis
Statistics are used in diverse industries including scientific settings with the purpose of determining whether experimental results can be generalized. This is called statistical inference and it is when an inference (i.e. conclusion or judgement) is done about the parameters of a population based on random sampling. Once an experiment has been conducted, it is critical to determine if this "treatment" had an effect or not. At this point hypothesis testing is used; the first hypothesis is that there is no effect of treatment, which is why it is referred to as the null hypothesis $H_0$. However, there are specific errors in which the experimenter can incur while making this decision. In the best case, the null hypothesis is rejected when indeed it is false or accepted when it is true. The risk though, is to fall in what are called type I and type II Errors. In the first case, type I Error (i.e. false positive), a true null hypothesis is rejected. Type II Errors (i.e. false negative) consists of accepting a false null hypothesis Lieber (1990).

The p-value relates to type I error and according to Lieber (1990), it is "the probability of committing type I error in a given experiment". Or as Lane (2015) states: "the probability is the probability of an outcome, not the probability of a particular state of the world (i.e. hypothesis). The null hypothesis is rejected or accepted based on the acceptable type I error I defined during the experimental plan. Following this, if an alpha $\alpha$ value of 0.05 is defined, if the results are significant, type I error is committed less than 5% of the time (Lieber, 1990). Type II error can be reduced by improving the statistical power\(^1\) of the experiment. This can be done by increasing the sample size. The probability then of rejecting the null hypothesis when false is 1-\(\beta\).

In order to test if the differences between populations means is significant, several steps will be taken. Variances will also be checked for statistical significance. There are two main approaches or methods to performing these tests. The one proposed by R. Fisher considers the probability value as a reflection of how strong the evidence against the null hypothesis is. So, for instance if $p<0.01$ it is quite clear that $H_0$ should be rejected but if $0.01<p<0.05$, then it is rejected but not as confidently as in the previous case. The second approach, and the one used in this analysis, proposed by Neyman and Pearson, relies on a pre-defined $\alpha$ value and if $p<\alpha$, then $H_0$ is rejected. In this case, the magnitude of the significance is not important (Lane, 2015). In both cases, if the null hypothesis is rejected the alternative hypothesis $H_1$ is accepted. In the following sections, two tests will be performed (i.e. mean comparison and unequal variances). The associated hypothesis will be presented in each sub-section.

---
\(^1\)Statistical power is 1-p
B.4.2. Complementary results

In this section the non-parametric tests part from the main document is expanded to include graphs that were not directly pertinent for the main analysis. This is the case with LT Airside (Figure B.5) due to its perfect correlation with LT and Truck Waiting Time (Figure B.6) with Truck Turnaround Time.

Figure B.5: LT Airside Anova and Mean Comparison

![Figure B.5: LT Airside Anova and Mean Comparison](image)

Figure B.6: Truck Waiting Time Anova and Mean Comparison

![Figure B.6: Truck Waiting Time Anova and Mean Comparison](image)
Table B.2: Arrival table for Freighter Aircrafts. (Schiphol Group, 2016d)

<table>
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<tr>
<th>DayNr</th>
<th>Day</th>
<th>DayWeek</th>
<th>StartTime</th>
<th>EndTime</th>
<th>Flights</th>
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Table B.3: Arrival table for Passenger Aircrafts. (Schiphol Group, 2016d)

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<th>DayNr</th>
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