

Improving the Overall Performance of the Warehouse Processes of Temperature-Sensitive Goods

within the Warehouses of KLM Cargo at the Schiphol Hub

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by

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Preface

This report represents my graduation research and is written as part of the master degree Transport Engineering and Logistics at Delft University of Technology. During my graduation, I have been given the chance to execute my research at KLM Cargo for which I am very grateful. The graduation research has been an amazing experience full of challenges, new topics and interesting insights. The aim of this research was to improve the overall handling processes of temperature-sensitive cargo within the warehouse of KLM Cargo at the Schiphol hub.

First of all, I would like to thank KLM Cargo for giving me the the opportunity to conduct my research at the Business and Process Improvement office. Especially Paul Crombach and Marja van Cleef, who supervised and challenged me the past couple of months. Their knowledge, feedback and questions helped me to improve my research and create a better storyline.

Furthermore, I would like to thank my graduation committee for guiding and supervising me during the process. Prof. dr. R.R. Negenborn, thank you for all the critical questions and feedback during our meetings. This helped me to structure this research and learnt me how to substantiate every decision logically. Dr. W.W.A. Beelaerts van Blokland, my daily supervisor and expert in the aviation industry, thank you for all your help, expertise and guidance during my research. Our meetings resulted in new insights and out of the box solutions due to your extensive knowledge of the aviation industry.

Finally, I would like to thank my friends and family for their support, encouragement and understanding during all phases of my studies. Without them, I would not be in the privileged position I am today.

Enjoy reading,

David Hensens
Delft, September 2019

Abstract

A significant part of the revenue generated by KLM Cargo comes from transporting temperature-sensitive goods. Currently, KLM Cargo faces quality issues in the handling processes of these goods which may lead to significant loss in revenue, and the risk of not generating new revenue.

This research focuses on the improvement of the performance of the handling processes of temperature-sensitive goods at the warehouses of KLM Cargo. The main research question answered in this research is:

'How can the overall performance of the handling processes of temperature-sensitive goods in the KLM Cargo warehouses be improved?'

The current state of the handling processes of temperature-sensitive pharmaceutical and perishable goods is analysed by using the Delft Systems Approach and the principles of lean manufacturing. The current state analysis shows that the temperature-sensitive goods are out of refrigerated storage for long periods of time or are stored in the wrong refrigerated storage area (perishables and pharmaceuticals are not to be stored together). This is mainly due to insufficient capacity of processes and facilities, the erratic arrival pattern of air cargo and the presence of non-value added process steps.

It is concluded that KLM Cargo currently does not use adequate Key Performance Indicators (KPIs) that describe the performance of the handling processes of temperature-sensitive goods. Thus, new KPIs have been proposed. These are the Time Out of Refrigeration (TOR), the number of storage violations and the on-time performance on handling deadlines. The TOR is calculated as the amount of time a shipment is present at the Schiphol hub, but is not stored in a refrigerated area. The number of storage violations represents the number of times a cool storage area has insufficient capacity and the on-time performance shows the percentage of shipments that are delivered on-time according to the handling deadlines set up by KLM Cargo.

The overall performance of the handling processes of temperature-sensitive goods can be improved by decreasing the TOR while the amount of storage violations and the on-time performance do not deteriorate. In order to reach the research objective, multiple design options are proposed. The different design options should meet the requirements for the handling of temperature-sensitive goods as well as the procedures laid out in the rules and regulations. Discrete Event Simulation (DES) is used to model the system and test the effects of the different design options. The system performance is measured by the TOR, the number of storage violations and the on-time performance. In the current state the average throughput time of a temperature-sensitive shipment █████ minutes, of which the shipment spends █████ minutes out of a refrigerated area. The number of storage violations is approximately █████ shipments per day, or █████ shipments per year.

There are three design options tested in the DES model, they consist out of the following: 1) the removal of non-value added processes, 2) levelled truck arrivals by optimal supply chain collaboration and 3) an input controller to control the arriving cargo at the Schiphol hub. Input data consisted of a truck and flight arrival schedule based on actual data along with a synthesised dataset which contains the amount of freight per shipment, the type of product, the type of cargo and the departure times. Each design option was run 25 times for a simulated duration of 365 days. The results were averaged and analysed in order to choose the best design option.

The optimal way to improve the overall performance of the handling processes of temperature-sensitive goods is found to be the implementation of an input controller at KLM Cargo. In this design option, an input controller is designed that decides if arriving cargo is accepted for further handling in the KLM Cargo warehouses. If adequate handling can be ensured, the cargo is accepted for further handling within the warehouses of KLM Cargo. If adequate handling cannot be ensured, the cargo is ordered to wait outside of the KLM Cargo premises and is put into a queue with other cargo that cannot enter the warehouse yet. The moment adequate handling can be ensured again, the cargo with the shortest transit time is 'pulled' from the queue and accepted into the warehouse for further handling. Implementing this design option resulted in a [REDACTED] decrease of the TOR, a [REDACTED] decrease in storage violations while the on-time performance did not deteriorate and compliance is adhered to. This design option does however increase the chance of cargo missing their flight, as waiting times are added for shipments that are not directly allowed to enter the warehouse. At the same time, this phenomenon creates an incentive for customers to deliver their cargo on-time.

For future research it is recommended to look further into other potential control strategies that include demand forecasting. In order to address the cost aspect of the performance, it is suggested to investigate the devaluation of temperature-sensitive goods when they are not stored in a refrigerated area. Finally, it is recommended to extend this research on the entire supply chain from shipper to consignee in order to get insights in the performance per lane.

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List of Abbreviations

AAS Amsterdam Airport Schiphol	2
AF AirFrance	2
AF-KL-MP Cargo AirFrance KLM Martinair Cargo	2
CDG Charles de Gaulle	2
CEIV Center of Excellence for Independent Validators	5
COL Cool Goods	4
DAP Delivered as Promised	8
FAP Flown as Planned	8
GDP Good Distribution Practices	2
IATA International Air Transport Association	4
KLM Koninklijke Luchtvaart Maatschappij	2
PCHS Pallet and Container Handling System	27
SHC Special Handling Code	4
ULD Unit Load Device	3

1

Introduction

In this chapter, an introduction to the research is given. First, a general introduction is given in Section 1.1. After the general introduction, the company is introduced in Section 1.2. The problem description is given in Section 1.3. The objective of this research is presented in Section 1.4, after which the main research questions and subquestions are shown in Section 1.5. This chapter is concluded by describing the scope of the research in Section 1.6 and finally discussing the structure of the report in Section 1.7.

1.1. General Introduction

The world is facing a huge population growth. This population growth brings along several challenges, such as a high level of malnutrition and a high need for adequate medicine. It is a major global challenge to ensure both adequate food supply and food quality to over 7.5 billion inhabitants today and nearly 10 billion by 2050. Most solutions tend to meet growing food demand based on the increase of agricultural output, which indeed is vital, but will probably be insufficient without reaching a level that would irreversibly harm the environment. Therefore, a major focus should be the reduction of post-harvest losses [1]. One third of all food grown is spoilt on the way to marketing consumption worldwide. That is enough to feed 870 million people and represents \$990 billion lost annually [2]. One of the UNs goals for sustainable development is to decrease global food waste by 50% by 2030 [3]. In general, food loss is mostly influenced by marketing chains and distribution channels, capacity and internal infrastructure, production choices and pattern, food use practices and consumer behaviour. In order to contribute to the world food problem positively, food losses should be kept to a minimum regardless of the level of economic development of a country [4]. A solution to increase access of food to the consumer could be improving the efficiency and integrity of the food supply chain. Given the huge amount of food losses, investing in the reduction of losses could be profitable or reduce the cost of food.

Next to adequate food supply and food quality, the huge population growth also brings along challenges in providing adequate healthcare worldwide. Access to pharmaceutical products is a big part of adequate health care, and in order to achieve this, an intact cool chain is necessary. The integrity and quality of pharmaceutical products, and ultimately patient safety, increasingly rely on an intact cool chain during storage and transportation. The pharmaceutical landscape is changing and two major trends are reshaping the pharmaceutical industry and its supply chain. The first trend is the dramatic shift in the nature of pharmaceutical products. Drug portfolios are evolving away from small molecule pharmaceuticals toward more structurally complex biotechnology drugs such as biologics and specialty drugs, derived from living cells, used for targeted therapies and employed in customised treatments for rare diseases. Drugs are evolving to contain more high-value active pharmaceutical ingredients that have shorter shelf lives and strict temperature requirements. By 2018, seven of the top 10 best-selling pharmaceutical products in the world will be biotechnology-derived

large molecules, requiring refrigerated storage and handling at 2–8°C. There has also been an increase in demand for body temperature transportation for medications developed by taking the body's own substances, such as cells and blood, modifying them and dispensing the processed substance to the patient. The second trend is the increasing number of regulatory compliance requirements. The industry's migration to these new medicines injects tremendous complexity into the distribution process. Products must be handled within highly specific condition tolerances. Failure to maintain appropriate conditions at any point in the supply chain can impact the efficacy of the drug, resulting in the loss of a shipment and therefore putting patients at risk. Forced by regulations, it is now also requirement that medicines are distributed between 15-25 °C (even generics such as paracetamol). Regulations, EU Good Distribution Practices (GDP) and WHO standards force parties in the supply chain to comply with temperature ranges. A temperature controlled supply chain, or cool chain, is therefore crucial to the pharmaceutical industry and healthcare systems. This is a supply chain management process that involves storage and transportation of temperature-sensitive goods (such as vaccines, serums, biologics, and test samples) from the time they are manufactured until the time they are used, utilising thermal and refrigerated packaging methods to help with transportation and storage, and extensive logistics planning to ensure the integrity of these goods.

Improvement of the air cargo supply chain is also significant on many other levels. The air cargo sector moves only 2% of the global volume of goods but adds up to a huge 35% by value, reserved for the most costly and time-sensitive products. Improving the supply chain will result in multiple advantages for all companies involved. These advantages could be for example the reduction of the process cost and increased reliability on the process for customers. Although many reasons for improving the food supply chain are evident, there is not a lot of ongoing research in the area. Insufficient attention appears to be paid to current global cool chain losses.

1.2. Company Introduction

Koninklijke Luchtvaart Maatschappij (KLM), Royal Dutch Airlines in English, was founded in 1919 by Albert Plesman and is the oldest still existing airline today. KLM has three core businesses:

- **Passenger Business:** The main area for KLM is the passenger business. KLM operates a fleet of over 110 aircraft and flies to over 140 destinations worldwide.
- **Engineering & Maintenance:** At the Engineering & Maintenance department the aircraft are repaired and maintained. KLM does repair and maintenance for different airlines (not only KLM itself) and there are over 200 customers.
- **Cargo:** The cargo department handles all shipments carried out by KLM. There are many different kinds of cargo transported, from live animals to secure goods.

This research is executed at KLM Cargo, the other two core businesses are therefore not discussed in this report.

1.2.1. KLM Cargo

From the foundation onwards, KLM grew rapidly and so did their freight division. Freight had eventually been placed under the pillar of KLM Cargo. In 2004, KLM and AirFrance (AF) merged into the AirFrance KLM group and their freight subsidiary became AirFrance KLM Cargo. The AF KL Cargo operates their network from two hub stations; Amsterdam Airport Schiphol (AAS) and Charles de Gaulle (CDG) in Paris. KLM Cargo added Martinair to the group in 2008 and the freight division is called AirFrance KLM Martinair Cargo (AF-KL-MP Cargo) thereafter. Although the three companies merged, KLM Cargo still operates on its own at the Schiphol hub. Therefore, only KLM Cargo at the Schiphol hub will be focused on in this research.

Within KLM Cargo, four different product groups are distinguished. These different groups are adjusted to specific cargo which have their requirements and priorities. These four groups are graphically represented in Figure 1.1 and each of them is elaborated on below.



Figure 1.1: The four different product groups at KLM Cargo.

Dimension Dimension cargo is for general cargo. Different kinds of cargo are accepted and it is ideal for consolidated shipments. There are fixed drop-off and delivery times at each station, which makes it easy to plan ahead. An extensive range of Unit Load Device (ULD) options is available to suit all types of shipments, such as loose, bulk or custom-built cargo.

Equation Equation cargo is the solution for fast transport. There is a high priority for loading the cargo and the shipment can be accepted just before the departure of the aircraft. For heavy cargo there is a separate choice 'Equation Heavy' for safe transport between two airports.

Cohesion Cohesion cargo is suitable for tailor-made solutions. In this category requirements and wishes of the customer are taken into account. This is communicated to the shipper, the forwarder and the airline.

Variation Variation cargo is the solution for specific commodities. These commodities have its logistical characteristics and special requirements. Within variation these groups are aerospace, art, extremely large or heavy shipments, dangerous goods, perishable goods, live animals, pharmaceuticals, valuable goods and all types of vehicles. Two of these groups will be elaborated on further, namely Variation Fresh and Variation Pharma. These product groups consist of temperature-sensitive products, which will be focused on in this research.

Variation Fresh

The transport of perishables goods is done within the group Variation Fresh. Depending on the specific needs of a perishable product, a type of shipment needs to be chosen. Variation Fresh is divided in three categories; Fresh 1, Fresh 2, and Fresh 3. These categories are specified below:

Fresh 1: Variation Fresh 1 is the product for perishables requiring strict temperature control, such as frozen meat and fish. The shipment is stored and transported in a constant temperature-controlled environment that can be controlled between -20°C and +20°C

Fresh 2: The Variation Fresh 2 category is the greater part of the shipments concerning volume and tonnage. Shipments transported in this category are temperature-sensitive perishables, such as flowers, fresh fish, vegetables and fruits. The commodities transported have a desired temperature range which is between +2°C and +8°C.

Fresh 3: The last category is Variation Fresh 3. In this category, less sensitive perishables are transported. For these shipments the handling procedure protects from extreme temperatures during transportation, like heat or frost. In practice this temperature range is between +2°C and +25°C. Examples are tropical flowers, wine, mangoes, tomatoes, melons, pineapple and chocolate.

Variation Pharma

The transport of pharmaceuticals is done within the group of Variation Pharma. There are two categories of pharmaceutical solutions; 'closed cool chain solutions' and 'controlled cool chain solutions'.

Closed cool chain solutions In the closed cool chain solution several alternative container lease arrangements for transportation of pharmaceuticals are offered, requiring the strictest temperature control throughout the complete transportation chain. Two options are offered:

- Pharma Active container (ACT)
- Pharma Passive container (PCT)

Controlled cool chain solutions Special service designed to transport and to store valuable and temperature-sensitive goods within limited temperature ranges in combination with the customers packaging solution.

- Pharma Control 2-8°C
Air transportation, trucking and warehousing at temperatures between 2°C and 8°C.
- Pharma Control 15-25°C
Air transportation, trucking and warehousing at temperatures between 15°C and 25°C.
- Pharma Control 2-25°C
To be protected against extreme weather conditions between 2°C and 25°C.

KLM Cargo sells the products as described above. These products are handled according to the temperature range the goods should be held between at all times. To make sure these products are handled accordingly, a Special Handling Code (SHC) is used for every product. The different types of product are linked to an SHC in Table 1.1. These handling codes are set up by the International Air Transport Association (IATA) and used by all parties in the supply chain. Within KLM Cargo, also product codes are used for internal use. The product codes for each product can be found in brackets behind the product description in Table 1.1.

Table 1.1: Special Handling Codes with according products.

SHC	Temperature range	Variation Pharma product	Variation Fresh product
ACT	-20°C - +30°C	Active Containers (S52)	Fresh 1 (S26)
PCT	-50°C - +40°C	Passive Containers (S54)	-
COL	+2°C - +8°C	Pharma CTRL 2-8 (S51)	Fresh 2 (S23)
CRT	+15°C - +25°C	Pharma CTRL 15-25 (S53)	-
ERT	+2°C - +25°C	Pharma CTRL 2-25 (S50)	Fresh 3 (S20)

This research will focus mainly on the handling of Cool Goods (COL), which includes the products Pharma CTRL 2-8 (S51) and Fresh 2 (S23). These products are focused on because they have to be stored in a refrigerated storage area within the warehouses of KLM Cargo.

1.2.2. The Cool Chain Program

Both the pharmaceutical and fresh markets are continuously growing. AF KL has the ambition to be the market leader in these segments, however AF KL is facing quality issues while other parties are investing heavily in cool chain processes and facilities. Customers are getting more and more demanding on transparency and want to get insights on the location, temperature and protection of their shipment. As 25% of the AF KL Cargo revenue comes from pharmaceutical and fresh shipments, these are amongst their most important products. KLM Cargo has decided to start the cool chain program in 2018. This program puts more focus on the supply chain of climatized goods and aims for a higher performance of the cool chain.

Pillars of the Program

The cool chain program is structured by six different pillars, which can be seen in Table 1.2. The different pillars of the cool chain program all have their own points of interest, which are summarised below each of the pillars.

Table 1.2: Pillars of the cool chain program.

Infrastructure	Tarmac	Supervision	Processes	Data/IT	Compliance
Cool rooms Climate rooms WH equipment	Thermo covers Cool dollies Canopies	Dedication Monitoring Repair Weather alerts	Process steps Process times Gen./specialised Automation	KPIs Dashboards Automation Digitalisation Tracking	KPIs CEIV DGR ELI/ELM Embargoes

Rules and Regulations

As customers want to be ensured of a certain level of performance, several standards have emerged in the last couple of years. A concentrated effort to improve the level of competency as well as operational and technical preparedness was urgently required to stop the alarming decline of air cargo's market share of global pharmaceutical product transport. The industry identified a need to build a network of certified pharmaceutical trade lanes that meet consistent standards and assure product integrity. As a result, IATA has taken a leading role in supporting the air transport industry to comply with pharmaceutical manufacturers' requirements. Working alongside aviation industry stakeholders and regulators, IATA created the Center of Excellence for Independent Validators (CEIV), to help organisations and the entire air cargo supply chain to get on the right track to achieve pharmaceutical handling excellence. By establishing a common baseline from existing regulations and standards, this certification ensures international and national compliance to safeguard product integrity while addressing specific air cargo needs. Complying with these standards and their rules and regulations is therefore becoming increasingly important for KLM Cargo. CEIV encompasses, or even supersedes, many of the existing pharmaceutical standards and guidelines such as:

- IATA Temperature Control Regulations (TCR)
- European Union Good Distribution Practices (EU GDP)
- World Health Organisation Annex 5
- United States Pharmacopeia Standards

CEIV Pharma addresses industry's need for more safety, security, compliance and efficiency, by the creation of a globally consistent and recognised pharmaceutical product handling certification. CEIV certification for pharmaceuticals already exists, fresh partners are currently exploring the possibility to also have a certification program. The cool chain program is developed to ensure that the CEIV certification is prolonged.

1.2.3. The Schiphol Hub

KLM Cargo operates from the Schiphol hub, where three different freight buildings are located. Goods arrive and depart at the warehouse in two different modes, either by truck or by aircraft. In practice this means that there are four types of possible transport combinations; trucking-flying, flying-trucking, flying-flying and trucking-trucking.

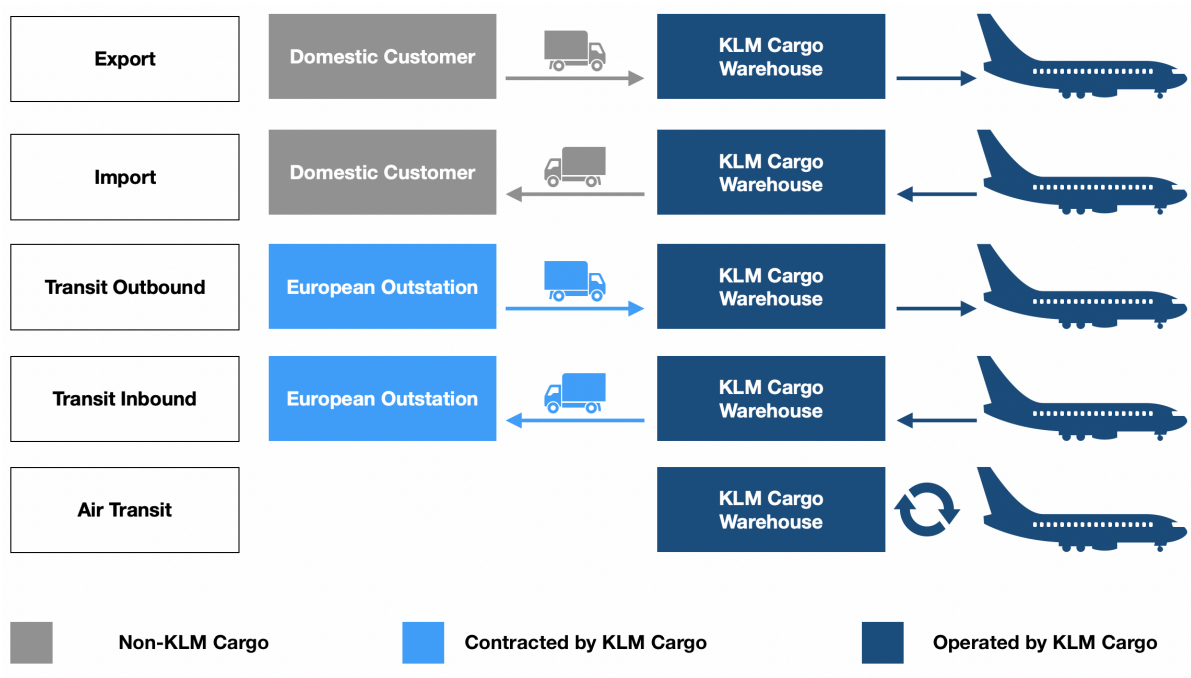


Figure 1.2: Import, Export and Transit flows.

The different modes of transport can be divided into three main flows; import, export and transit. With export, goods that arrive by a non-KLM Cargo truck are meant. Goods that are picked up at the KLM Cargo warehouse by a domestic customer, is categorised as import. Lastly, there are also so-called transit shipments. For these shipments, the arrival and departure at the Schiphol hub is done by KLM Cargo itself, or companies contracted by KLM Cargo.

At the Schiphol hub, there are three different freight buildings. The flows discussed all have their specific path through the warehouse. A schematic overview of the freight buildings and flows can be seen in Figure 1.3.

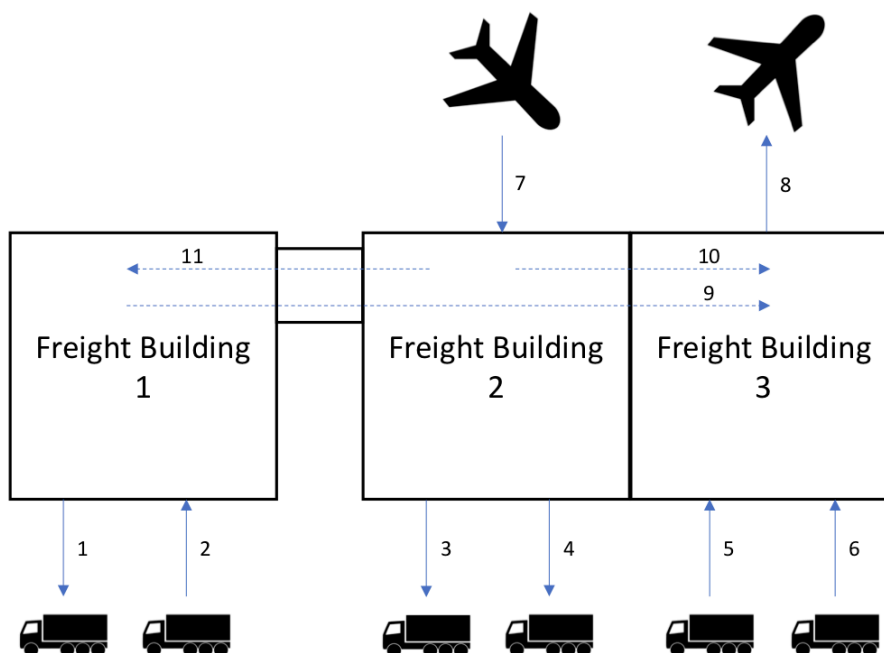


Figure 1.3: Schematic top view of the three freight buildings at the Schiphol hub.

The flows described in the figure can be described as follows:

- | | |
|--------------------------------------|--------------------------------|
| 1. Import EU special goods. | 7. Intercontinental arrival. |
| 2. Export EU special goods. | 8. Intercontinental departure. |
| 3. Import EU to outstation. | 9. Special goods departure. |
| 4. Import EU pick-up by consignee. | 10. Intercontinental transit. |
| 5. Export EU from outstations. | 11. Special goods arrival. |
| 6. Export EU delivered by forwarder. | |

The process that these shipment go through, is also dependent on their configuration. Different types of cargo are distinguished; T-ULDs, M-ULDs and loose freight. A schematic overview of the difference in process for T-ULDs, M-ULDs and loose freight can be seen in Figure 1.4.

T-ULD or Through-ULD, is a shipment that already has the configuration it is required to have for further shipment. Therefore, no further handling is needed. Some T-ULDs are classified as BB (bijbouwer) within KLM Cargo which means a ULD contains shipments that have the same destination, but there is capacity left on the ULD for additional cargo.

M-ULD or Mixed-ULD, is a shipment that has to be broken down into multiple shipments, and later built up in a different configuration as required for the outgoing shipment. The shipment will be broken down upon arrival and the individual shipments will go into their individual processes. The loose shipments will be built up into ULDs again before departure.

Loose freight is freight that is delivered at the KLM Cargo warehouse and not (yet) built up on a ULD. Loose freight is delivered either in loose packages or on a skid. (wooden pallet)

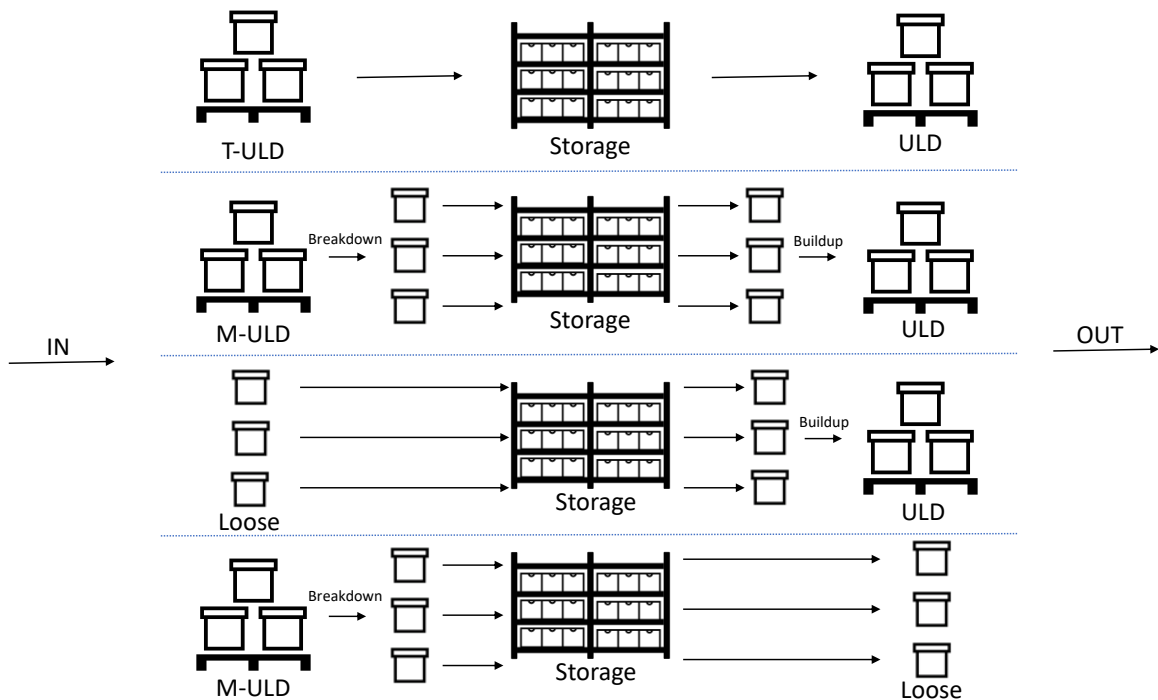


Figure 1.4: Schematic process of T-ULDs, M-ULDs and loose freight.

1.3. Problem Description

At the Schiphol hub, many different products are handled by KLM Cargo. Some of these products require special care, such as perishables and pharmaceuticals. The quality of these products decreases rapidly if they are not cooled along the process and the products can become unsellable. Due to the complexity of the supply chain of climatized goods, or cool chain, it is inevitable that the goods are out of refrigeration in various stages of the process. The time in which the goods are not cooled should be kept to a minimum to ensure that the product integrity remains as high as possible. In fact, over 50% of all temperature excursions occur while products are in the hands of airlines and airports. To ensure a high performance of the cool chain, it is important that the cool chain is constantly monitored so that defects and shortcomings can be found, solved and the cool chain can be optimised.

Currently, the performance at KLM Cargo is mainly measured by two KPIs, Flown as Planned (FAP) and Delivered as Promised (DAP). The FAP states what percentage of the shipments left with the flight is was supposed to leave on. The DAP represents the percentage of shipments that has been delivered according to the arrangement made with customers. These KPIs however, are designed to describe the performance of the general cargo products and are not adequate KPIs to describe the performance of the cool chain products. Without adequate KPIs it is difficult to control the supply chain of refrigerated goods. Thus, new KPIs have to be set up that are designed specially for the handling of temperature-sensitive goods.

Recently, a dashboard is developed that provides more details on the performance of the processes than the KPIs FAP and DAP. However, the developed dashboard is still not accurate on showing the performance, as the performance figures that are shown are determined on the performance of milestone measurements. Milestones are set and the performance is considered good when the set milestones are achieved. Whenever milestones are used as measures, it means not achieving a milestone is equal to failure of the process. While in reality, the performance of the processes is dependent on more than achieving these milestone measurements. The milestone measurements on which the performance is currently based can be seen Figure 1.5.

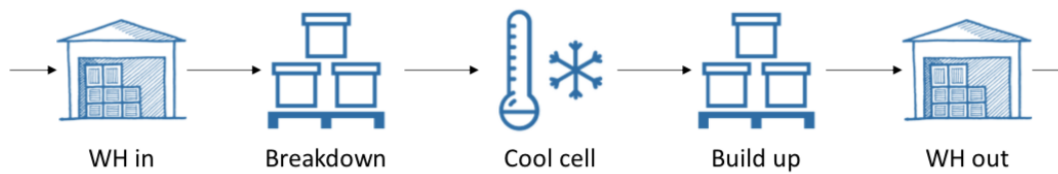


Figure 1.5: Milestone measurement points.

There is a rule for example, that states that COL shipments with a transit time of more than 8 hours should be placed in a cool room. If the transit time is shorter than 8 hours, the shipment is not stored in a refrigerated area. There is no clear reason why this rule is adhered to and why the performance is based upon this rule. Even with the rule of a fixed transit time of 8 hours, the performance of this process is already insufficient. Only 70% of all COL shipments that should be stored in a cool room according to the rule described above, are actually stored in a cool room. Next to that, the cool rooms (KC02 and KC04) are often full during the weekends, when maximum storage capacity is reached. More shipments are stored in the cool rooms than there is capacity as can be seen in figure 1.6. The same storage positions are logged multiple times and shipments are put on fake locations close-by. Cargo is put on floor of the cool room as there is no more space available. As a consequence, shipments get lost resulting in non quality and temperature excursions may occur.

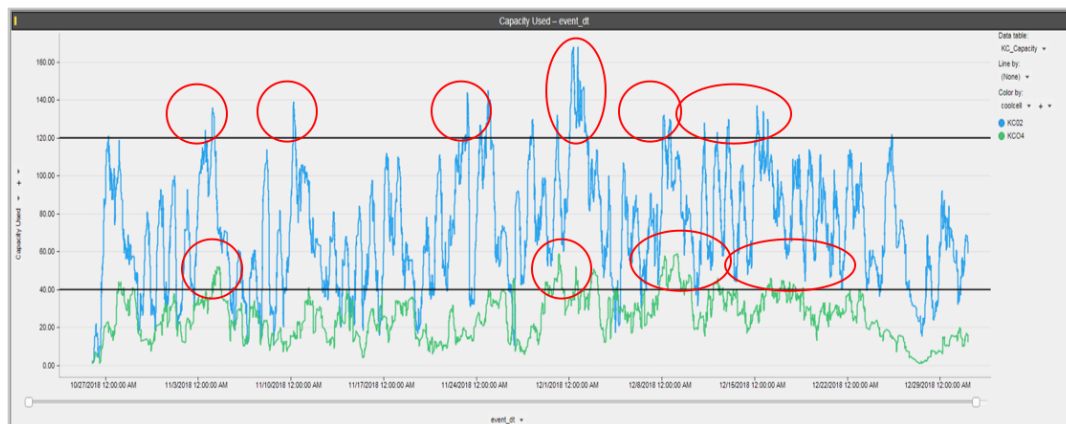


Figure 1.6: Storage utilisation of the cool rooms exceeded.

The problem definition can be summarised as follows:

- The current KPIs that are used to describe the performance of the cool chain are inadequate and therefore the supply chain is difficult to control.
- Milestone measurement points that are used do not define the performance of the handling of temperature-sensitive goods adequately.
- The capacity of multiple processes and the different cool rooms is insufficient which may lead to temperature excursions.

1.4. Research Objective

The objective of this research is to improve the overall performance and integrity of the cool chain at KLM Cargo, focusing on the processes within the warehouse at the Schiphol hub.

In order to evaluate the current cool chain, a thorough analysis is to be executed on the current processes. New KPIs have to be set up to adequately measure the performance of the handling of climatized goods and the current state will be measured as a benchmark. To improve the performance of the handling processes, multiple design options will be discussed and the impact of the improved scenarios will be assessed.

1.5. Research Questions

In order to achieve the research objective, several research questions are to be answered. A main research question is formulated with accompanying subquestions:

'How can the overall performance of the handling processes of temperature-sensitive goods in the KLM Cargo warehouses be improved?'

- (a) What is the current state of the handling processes of temperature-sensitive goods in the warehouses of KLM Cargo?
- (b) How is the performance of the handling processes currently measured and monitored in terms of maintaining temperature integrity? (What KPIs are used and what data is available?)
- (c) What relevant KPIs can be used to express the performance of the handling processes?
- (d) What alternative scenarios can be used to improve the performance of the handling processes?
- (e) How can the alternative scenarios be assessed using simulation?
- (f) How do the redesigned scenarios improve the performance of the handling processes?

1.6. Research Scope

This research will be executed at KLM Cargo and will specifically focus on the processes that take place within the KLM Cargo warehouses at the Schiphol hub. This means starting point of the processes that are looked into is the moment a shipment enters the warehouse. The ending point is when a shipment leaves the warehouse for further transport. This research will focus mainly on the handling of COL goods as these goods are the only goods that have to be kept between 2 °C and 8 °C and should therefore be stored in a refrigerated storage area within the warehouses of KLM Cargo. The COL goods include the products Pharma CTRL 2-8 (S51) and Fresh 2 (S23). The flow that will be looked into is the transit flow of ULDs that require further handling such as breakdown or build up (M-ULDs and loose freight).

1.7. Report Structure

In order to give an answer to the main research questions and related subquestions, a structure has been set up that describes the methodology followed. The structure of the report can be seen in figure 1.7.

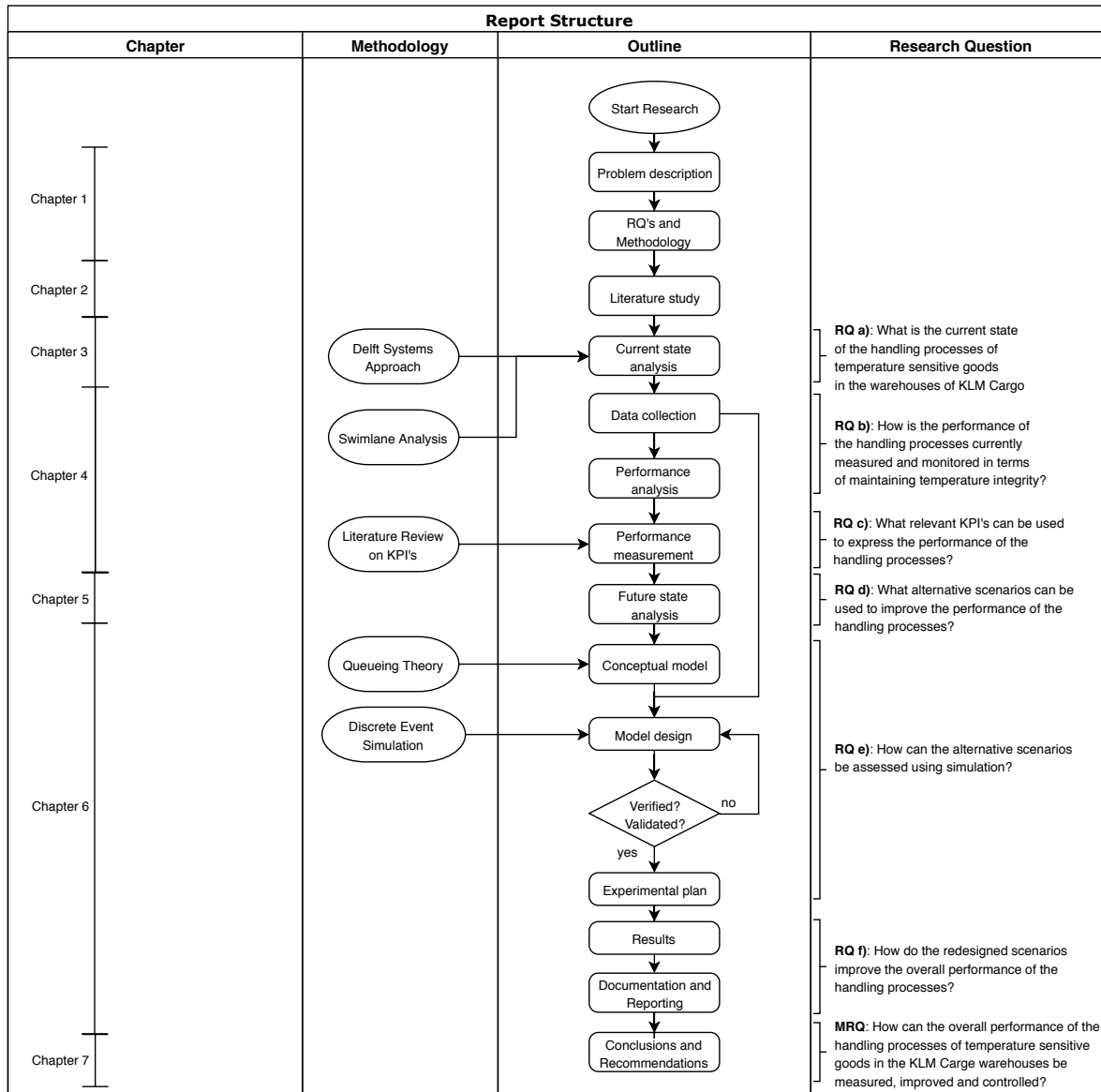


Figure 1.7: Report structure and outline.

2

Literature and Methodology

In this chapter the relevant literature and methodologies used in this research are discussed. First, the cargo handling standards and guidelines that are important for KLM Cargo are discussed in section 2.1. Next, the on-time performance is elaborated on in section 2.2 after which an introduction is given to the Delft System Approach in section 2.3 which will be used later in this report to analyse the handling processes. Queueing theory will be explained in section 2.5 followed by a brief summary of different simulation methods in section 2.6. This chapter is concluded by elaborating on lean manufacturing and controlling cargo handling demand in 2.7 and 2.8, respectively.

2.1. Cargo Handling Standards and Guidelines

As described in Section 1.2.2, it is of high importance to KLM Cargo that certain handling standards and guidelines are adhered to. The handling standards and guidelines that are most important are the following WHO Good Distribution Practices, the EU Good Distribution Practices, the IATA Temperature Control Regulations, the IATA CEIV and the AF KL Cargo Handling Manual which is set up by KLM Cargo itself. Of these standards, the IATA CEIV is of the highest importance. IATA CEIV Pharma encompasses, or even supersedes, many of the existing standards and guidelines, therefore this standard will be elaborated on. Since 2016, the AF KL group has been IATA Pharma Certified. This means the regulations set by the authorities and the pharmaceutical industry, such as Good Distribution Practice (GDP) and IATA-TCR (Temperature Control Regulations) are strictly adhered to. Those regulations are created by the authorities and the pharmaceutical industry because it is important for patients that the quality of the medication is maintained during transport. For perishables there is no such standard yet but this will soon become available. The handling standards mentioned above are discussed in more detail in Appendix B. As discussed, the CEIV certification is of high value for KLM Cargo and the most important elements of the certification for this research are therefore summarised below:

- The loading and unloading bays should be protected from different environmental conditions.
- The vehicles and equipment used for the handling of pharmaceutical shipments should be dedicated. If this is not the case, a risk assessment and procedure should be in place to minimise risks to the process.
- Sufficient capacity of equipment, vehicles and facilities.
- Performance monitoring should be based according to risk assessments.
- Dedicated temperature controlled vehicles, otherwise it should be included in a risk assessment.

- The area where ULDs are built up or broken down should be temperature controlled. If this is not the case, a risk assessment on the process is necessary.

2.2. On Time Performance

In the airline industry, the turn around time (TAT) and on-time performance (OTP) of an aircraft are important indicators, used to increase the operational performance of the aircraft. "A short TAT has a positive effect on the utilisation rate of the aircraft as a fixed asset and as such turnover and profit" [5]. Airline turnaround time is defined as the time required to unload an aircraft after its arrival at the gate and to prepare it for departure again [6].

De Jong and Beelaerts van Blokland studied lean implementation for airline maintenance, repair and overhaul (MRO) companies [5]. They used the TAT as indicator regarding the efficient use of fixed assets, and the OTP as indicator regarding the effective use of fixed assets in the MRO service industry. In this context, the TAT indicates the time between the moment the component comes in at the MRO service company and the moment it has been serviced and is shipped back.

Analogous to the airline MRO service, ground handling of air cargo can also be considered a service in the airline industry. The TAT of a ULD could then be defined as the time required to unload the ULD from the aircraft after its arrival at the gate and prepare it for departure again. In this context, the warehouse process is one of the processes that has to be completed during the TAT of a ULD. Improving this process, contributes to a shorter TAT of the ULD. The on-time start (OTS) of each activity in the handling process is important to guarantee on-time delivery (OTD) of the ULD for the next activity in the process. The three most important KPIs to assess the performance of the processes are the On Time Start (OTS), On Time Delivery (OTD), and On Time Performance (OTP) which are described by Beelaerts van Blokland.

- **On Time Start (OTS)**

The OTS is defined as the earliest time a task can start. If a process starts later, the OTS is not met.

- **On Time Performance (OTP)**

The OTP is the time that is necessary to perform a task. This time is calculated by keeping in mind all parameters which can influence the length of a task. If a task takes longer than the predetermined time, the OTP is not met.

- **On Time Delivery (OTD)**

The OTD is the latest time a task can be finished before it will cause delays, making it an important KPI.

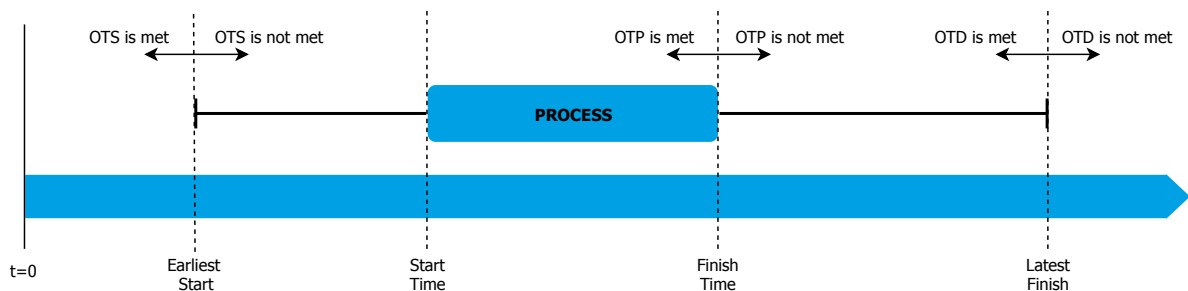


Figure 2.1: OTS, OTP and OTD graphically illustrated in a timeline.

2.3. The Delft System Approach

The warehouse processes can be conceptualised as a very simple input-output system. ULDs enter the system and after handling of the ULDs leave the system again. In this research, the Delft Systems Approach (DSA) is used to describe and analyse the warehouse system. DSA was found to be the most appropriate tool to graphically structure the process, because it follows a systems approach and it is very suitable to use as a basis for simulations. It provides a disciplined methodology to determine the structure of systems, based on describing systems in terms of functions and control. For every task in the process its contribution to the system performance is quantified. Out of process requirements, quantitative standards are derived. The extent to which these standards (and thus requirements) are met, is quantitatively measured in process performance.

Similar tools, such as IDEF-0 and Value Stream Mapping (VSM) were found to be less suitable. Just like DSA, IDEF-0 follows a systems approach. However, IDEF-0 is a more qualitative approach to structure and visualise the system. An IDEF-0 diagram gives information on the sequence of process steps, and the information needed to control the process [7] [8]. In contradiction to the DSA, IDEF-0 is not explicitly focused on the identification of quantitative standards, to be used for process control. This identification of standards is, in the context of this study, a great advantage of the DSA, since it allows to quantitatively measure the process performance in a simple manner, by measuring the extent to which the standards are met. Therefore, IDEF-0 was found to be less suitable.

VSM provides a more quantitative approach, identifying the value added at each process step [9]. However, VSM follows a process approach; it is more suitable for analysing a larger and more complex chain of production steps, where in each step value is added to the product. Therefore, VSM was found to be less suitable for this study.

The Delft Systems Approach (DSA) is an instrument to decompose complex systems in a simplified overview. The PROcess-PERformance (PROPER) model is introduced as a tool for the description of a system and analyse all aspects of the system and its interrelations. The Proper model is based on the principle of "zooming". A system is considered as a black box. From there, the system black box is opened and aggregation layers can be reached by selecting subsystems and functions of interest to zoom into. A system always consists of subsystems where, zoomed out, two subsystems can be distinguished. These two subsystems consist of a control system and an operational system, which can be seen in figure 2.2.

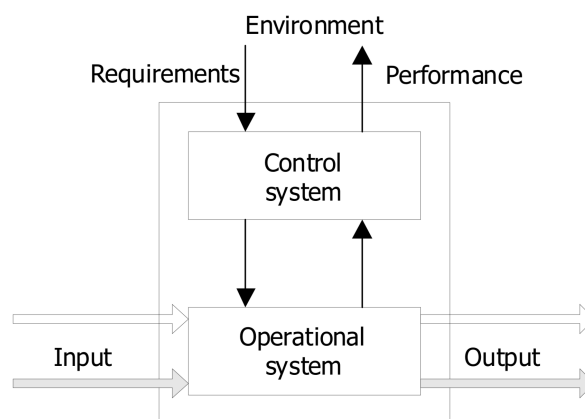


Figure 2.2: PROPER model of a system.

It is described by Veeke et al. [10] as: "An industrial system is a subsystem of the organisation as a whole; it contains a subset of the elements, but includes all of the relations. We now approach industrial systems from the viewpoint of the primary function, and at least three aspects are included in the conceptual model:

1. The 'product' as a result of a transformation.
2. The 'flow of orders'; without customer orders no products will flow. In this flow, orders are transformed into handled orders.
3. The 'resources' (people and means) required to make the product. To make use of them, they must enter the system, and they will leave the system and they will leave the system as used resources. The results of the transformations are delivered products, handled orders and used resources.

Figure 2.3 shows the conceptual model of the PROPER model. The model can be used to define subsystems in a total system that need further investigation. This is achieved using aggregations layers, where each aggregation layer is based on the results of decision making in the preceding aggregation layers, thereby defining standards and efforts and dividing functions into a structure of sub functions.

The control function coordinates all transformation functions by generating executable tasks from orders and by assigning resources. The task and assignment flows help to get insight in the factors that influence the performance of the operation. Bad performance can be the result of long task lead times, a shortage in assigned equipment, or misunderstandings between different components. By doing an in-depth analysis on these processes, a good understanding of the system is given.

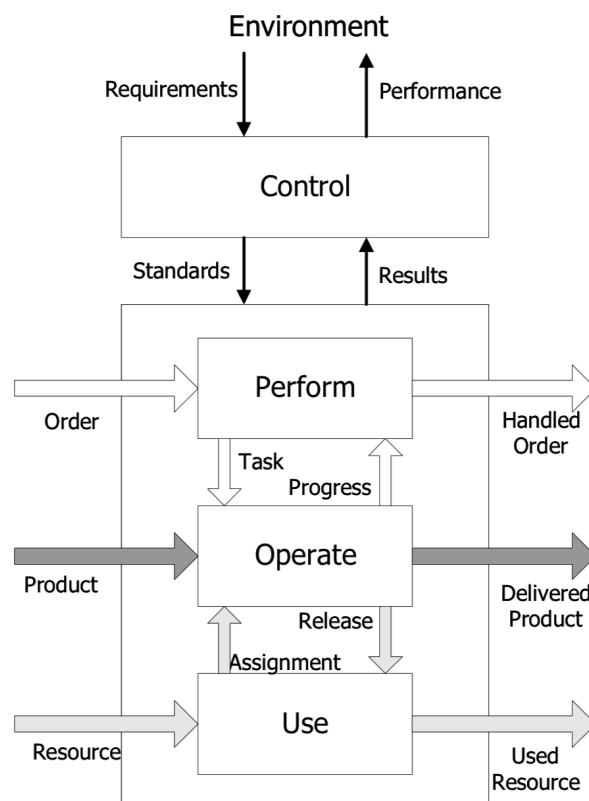


Figure 2.3: PROPER model as described by Veeke et al.

2.4. KPI Development

Key Performance Indicators (KPIs) are quantifiable metrics that are used to measure the performance of processes. The process can be steered in order to ensure that goals are met in an effective and efficient manner. To do so, the performance of the process needs to be measured. Performance is measured by so called performance indicators, which should point out what to do to increase the performance of the process. In this section, the need for KPI selection and the methodology used in this study to select appropriate KPIs is described. In the current situation, a very limited set of KPIs is used to measure the performance of the handling processes of climatized goods. Despite the fact that a lot of warehouse data is automatically and continuously collected, these data are only used to a very limited degree for managerial purposes. A logical reason for this is the limited extent of data processing. As long as the big sets of collected data are only translated into a few main performance indicators, the management will only use these indicators to steer the process. The goal of this research is improve the handling processes of climatized goods that have to be kept between 2 and 8 degrees celsius. In this study, multiple improvement scenarios are tested by simulation. In order to decide what scenario results in the most optimal process, more detailed indicators are needed to measure the process performance. Moreover, KLM is advised to use these KPIs in addition to their current set of KPIs in order to improve operational performance management. Rezaei et al. summarised the core principles for a KPI [11]:

1. The PI must be specific, realistic and representative, so that the gathered information reflects reality.
2. The measurements must be performed, defined, and quantified consistently.
3. The PI must be measurable in physical and financial units.
4. The PI must reflect the responsibilities of the involved departments/managers.
5. The set of PIs must make the costs elements transparent.
6. The PI must be aligned with overall organisational goals, when used by a particular department.

These principles are very generic, and therefore merely used as a strategic list that should be kept in mind when selecting KPIs. It is not intended that every KPI meets all of these principles, but the list is used to measure the correctness and usability of a KPI. It will be carefully considered during the KPI selection process.

2.5. Queueing Theory

A method is needed to conceptualise the processes and translate it into a model. Queueing theory is the mathematical study of waiting lines, or queues. It is very suitable for the design of stocking systems in terms of capacities and control [12]. An often used example to explain a queueing system is the example of a post office with waiting customers and multiple desks. Customers arrive at the post office, get in line and as soon as a service desk is free, the longest waiting customer is serviced. The basic elements of a queueing system are depicted in Figure 2.4.

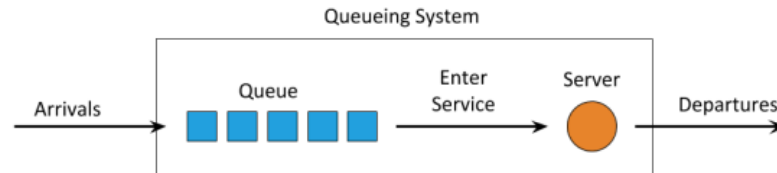


Figure 2.4: Basis elements of a queue system.

In this study, the 'customers' are ULDs delivered at the warehouse. This delivery of a ULD is an arrival event, marking the timestamp at which the ULD enters the queueing system.

A queueing system is characterised by three components:

1. The *arrival process*, describing how customers arrive to the system:

- Interarrival time: A_i
- Mean interarrival time: $E(A)$
- Arrival rate: $\lambda = 1/E(A)$

The interarrival time is the time (in minutes) between two sequential arrival events. For inbound ULDs, the system interarrival times are derived from historical warehouse arrival data.

2. The *service mechanism*, specifying the number of servers and the probability distribution of service times:

- Service time: S_i
- Mean service time: $E(S)$
- Service rate: $\mu = 1/E(S)$
- Number of servers: c

The service times are the times (in minutes) required for the different handling steps of the ULD. The determination of the service times will be discussed in Section .

3. The *queue discipline*, referring to the rule that a server uses to choose the next customer from a queue:

- FIFO: First In First Out
- LIFO: Last In First Out
- Priority

A combination of both the *FIFO* and *priority* queue discipline will be used.

2.6. Simulation Methods

There are several methods to evaluate the performance of a system, often divided in three categories; analytic methods, simulation or emulation and physical experiments [13]. Most systems are too complex for the use analytic methods, and physical experiments are too expensive to use on a large scale. "Simulation is the imitation of the operation of a real-world process or system" [14]. It provides a cost-efficient method to analyse complex systems, and it is sometimes required that a model is developed which represents the key characteristics of the system, functions and behaviours of the selected system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time [15]. The warehouse processes at KLM Cargo are subject to multiple uncertainties that have a great impact on the performance of the total system. To cope with these uncertainties and the dynamic behaviour of the system, a simulation tool will be used as a tool for evaluating different ways to control the processes.

2.6.1. Continuous and Discrete Simulations

There are different simulation methods which can be categorised into two main categories:

1. Continuous Simulation
2. Discrete Event Simulation (DES)

The most common known continuous simulating method is System Dynamics (SD), which is an approach to understanding the nonlinear behaviour of complex systems over time using stocks, flows, internal feedback loops, table functions and time delays [16]. In this category the state of an object varies continuously resulting in many unnecessary calculations. In DES the state of an object varies at discrete events in time. Each event occurs at a particular instant in time and marks a change of state in the system [17]. Because recalculations of the system are only performed when events occur less computation power is needed, resulting in shorter simulation runs.

2.6.2. Software

The selection of the right simulation tool is essential to achieve the objective of the research. For complex dynamic and stochastic systems there are many options for a simulation tool which can be categorised in:

Spreadsheet Software

Spreadsheet packages such as Microsoft Excel and Apple Numbers are suitable for modelling static systems and deterministic operations. Although the random number generator function of spreadsheet packages does enable simulation application, these packages are less suitable for modelling complex dynamic systems. In this study, Microsoft Excel in combination with Matlab was used for data analysis and calculation of service times. Dynamic simulation was needed to get a more detailed idea of the needed capacity under different circumstances.

Simulation Languages

Simulation languages can be continuous and discrete and allow much detail and accuracy when modelling. Some discrete languages are Delphi, Tomcat, Matlab or Python, which all allow tailor made solutions but can take much time to develop from scratch.

Simulator Packages

Simulator packages, such as Simio, Arena or Anylogic can also be used when modelling stochastic and dynamic systems. These packages are object-oriented and have built in blocks which can be edited to the modellers preference. This allows for faster model development but less freedom compared to the simulation languages.

2.7. Lean Manufacturing

In the 1970s, Toyota Motor Corporation developed a management system in order to deal with the unfavourable economic conditions at the time. The core of this management system, the Toyota Production System, is the elimination of waste within the processes of a company. By decreasing waste and its related costs, the productivity and therefore profit can be increased. The lean manufacturing theories work from the philosophy: 'minimise waste while maximising customer value'. The lean theory has five main principles that support this philosophy [18]:

1. **Specify Value** - focus on steps that create value for customer.
2. **Map the Value Stream** - identify all the steps in the process.
3. **Create Flow** - remove the identified wastes in the value stream.
4. **Create Pull** - ideally created by customer demand.
5. **Pursue Perfection** - there is no end to the process of reducing waste.

To realise the principles listed above, the waste has to be minimised. In lean theory there are seven types of wastes identified as non-value adding to customer value and these are often presented as the acronym TIMWOOD [19]:

- **Transport:** while transport is necessary in many cases, unnecessary movement of people, products and information is wasteful since it takes up time and resources and increases the risk of damage;
- **Inventory:** goods that are not being used or sold have storage costs associated while they do not generate income;
- **Motion:** where transport refers to the transportation of goods, motion refers to the movement of equipment and employees. Time lost by employees looking for products/tools is wasteful as this time can be eliminated if the necessary products/tools are available;
- **Waiting:** products that have to wait in between process steps cost money while no value is being added during the waiting time;
- **Overproduction:** when more products are produced than ordered, time and resources have been spent on the production of a good or service;
- **Overprocessing:** this occurs when more work is done than required by the customer. As the customer did not pay for this work, it may be eliminated;
- **Defects:** defects cause the work put into the product to be useless. Elimination the number of defects directly reduces waste.

Value Added and Non-Value Added

In lean manufacturing it must be defined what adds value. While the wastes described above are non-value-adding, it takes more information to get into the step-by-step process to determine what is adding value and what isn't. Lean manufacturing provides straightforward guidelines. For something to be add value, three things must happen:

1. The step must change the form or function of the product or service.
2. The customer must be willing to pay for the change.
3. The step must be performed correctly the first time.

Anything that does not comply to this is considered a waste, or non-value added. There is however one extra type of activity that is used in lean manufacturing: necessary non-value added. This is an activity that must be done but does not necessarily add value for internal or external customers. The most common necessary non value added activities are related to compliance with rules and regulations. In this research the TIMWOOD wastes will be used, however for the purpose of this research the storage in a refrigerated area will not be considered as waste.

Push-Pull Systems

The terms 'push' and 'pull' originate in logistics and supply chain management and are an element of lean. Push and pull are manufacturing principles which determine when goods are produced in a supply chain. In a push system, the demand for the product is forecasted and the product is produced according to a predefined schedule [20]. This system works well if the forecasting is accurate, which is typically the case for products with a stable demand pattern as they are easier to forecast and push based supply chains are suited to meet this demand. The current process of air cargo being transported to the breakdown process is an example of a push system, since cargo is sent to the breakdown as soon as it arrives in the warehouse.

When the demand pattern is more volatile or unpredictable, a pull system may be more suitable. A pull system is a demand-driven system in which goods are produced when an order for a specific amount is placed further down the supply chain. In other words, a production job is triggered by the completion of another job [21]. If the lead time of a process is known, the order could be placed such that the product is delivered just in time (JIT) when current stocks run out, thereby minimising inventory. However, when this lead time is long, reacting to the change in demand may not happen fast enough. A hybrid system, called a push-pull system, aims to combine the benefits of both systems by operating the initial parts of the supply chain with a push system, and later stages have a pull system in place [22]. This way lead times can be reduced by having stock further down the supply chain, but still in a central place [23]. However, this approach can be argued not be considered lean, since there is waste to be found in the form of inventory/waiting.

2.8. Controlling Cargo Handling Demand

Within the supply chain of air cargo, information sharing is crucial. Currently, this is in a developing phase and not yet in an optimal state. Due to this, it is hard for the different parties involved to arrange their own part of the supply chain in such a way that no waste occurs.

2.8.1. Pattern Classification

The demand pattern for cargo handling influences the processes at KLM Cargo and unpredictability of the cargo arrival pattern is highly unfavourable. It is important to determine the categorisation of demand in order to apply the correct measures to smooth the demand. To distinguish between overall variability and demand peaks which are followed by periods of zero or low demands, a categorisation scheme is proposed by Syntetos et al. [24]. The categorisation is based on the average inter-demand interval (ADI) and the squared coefficient of variation (CV^2) and four categories are used:

- *Smooth demand*: low variation and demand in each time period.
 $ADI \leq 1.32$, $CV^2 \leq 0.49$
- *Erratic demand*: high variation, characterised by unpredictability. The variation in the time period is low.
 $ADI \leq 1.32$, $CV^2 > 0.49$
- *Intermittent demand*: low variation and with several time periods of zero demand.
 $ADI > 1.32$, $CV^2 \leq 0.49$

- *Lumpy demand*: random demand with zero demand in several time periods.
 $ADI > 1.32$, $CV^2 > 0.49$

When calculating the squared coefficient of variation, only the non-zero demand periods are taken into account.

2.8.2. Control Strategies

Controlling the supply chain is essential in improving the performance. In literature, several controlling strategies can be found that are suitable to control the cargo arrivals at KLM Cargo such as reactive, active and predictive control.

Currently, reactive control is being used at KLM Cargo. Reactive control focusses on constantly dealing with immediate problems. The problems consume all time and attention of decision makers results in only ad-hoc and short-term solutions. The reactive control is also known as 'firefighting'. In reactive control, the separate parts of the supply chain act independently and have separate responsibilities.

Another control strategy is active control. For the purpose of this research, an active controller is used to control the input of cargo arrivals at KLM Cargo. This control strategy actively manages and controls one specific part of the supply chain.

2.8.3. Neutral Control Tower

At Schiphol, a platform is currently being created to increase the collaboration within the supply chain. the platform is called the Smart Cargo Mainport Program (SCMP). SCMP has three pillars; smart data processes, smart landside processes and smart innovations. The main developer for this platform is Schiphol Airport. All the cargo companies that are active in the airport area, including KLM Cargo, are however involved in the development. Initially, the project is focused on solving short-term problems, but the long-term goal is to establish a Neutral Control Tower. A Neutral Control Tower will ensure optimal planning of trips, higher load factors of trucks, faster turnaround at the handling agent, and will provide a transparent chain for increased reliability and efficiency. The added value of a Neutral Control Tower will be the introduction of transparency in the landside process at Amsterdam Airport Schiphol, which will ensure reliability through operational agreements.

3

Current State

In this chapter, the cargo handling process is described. A system analysis is performed and current state of the system is discussed. This chapter will provide the answer to the first sub question:

- (a) *What is the current state of the handling processes of temperature-sensitive goods in the warehouses of KLM Cargo?*

3.1. Warehouse System Design

The general introduction explained that KLM Cargo operates in three buildings: freight building 1, 2 and 3. This section will zoom in on the terminal design and processes of the freight buildings. The Delft Systems Approach (DSA) is used in order to structure the analysis of the freight buildings. The DSA will be used to gain understanding of the cargo handling process within the freight buildings. The goal is to emphasise the interconnections between resources and physical processes, and the measurement of performance of the processes more explicitly.

3.1.1. System Identification - Delft Systems Approach

The Delft Systems Approach is characterised by describing system elements by their functions and the emphasis is on *what* is done rather than on *how* it is done. These functions are physically realised by processes that transform input into the desired output. The KLM Cargo system as a whole has the function 'to transport air cargo' and 'to fly cargo'. The main function of the freight buildings is 'to handle cargo'. The Delft Systems Approach starts by illustrating a black box that turns the input (cargo) into the desired output (handled cargo). The black box can be seen in figure 3.1. It furthermore depicts requirements that emanate from the environment and performance that indicates of how well the system functions. Subsequent paragraphs zoom into next levels of aggregation. This setup ensures a holistic approach, taking into account all aspects and interactions.

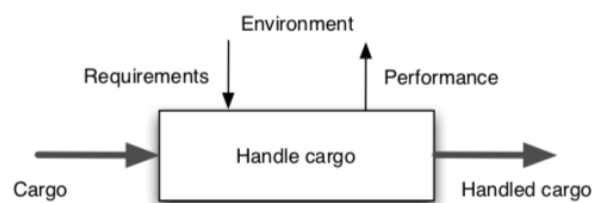


Figure 3.1: DSA - system identification.

3.1.2. PROPER-model

A PROcess PERFORMANCE model (PROPER-model) is designed to illustrate multiple aspect-systems with their interactions. In its standard form a PROPER-model contains an order, a physical and resource flow of a process and is therefore from the perspective of the cargo handling process very suitable for the analysis of this project. The model also illustrates a control mechanism that measures performance by setting standards out of requirements from the environment and registering results. Figure 3.2 shows the PROPER-model for cargo handling at the Schiphol hub in its basic form and shows the interconnections between order, cargo and resources.

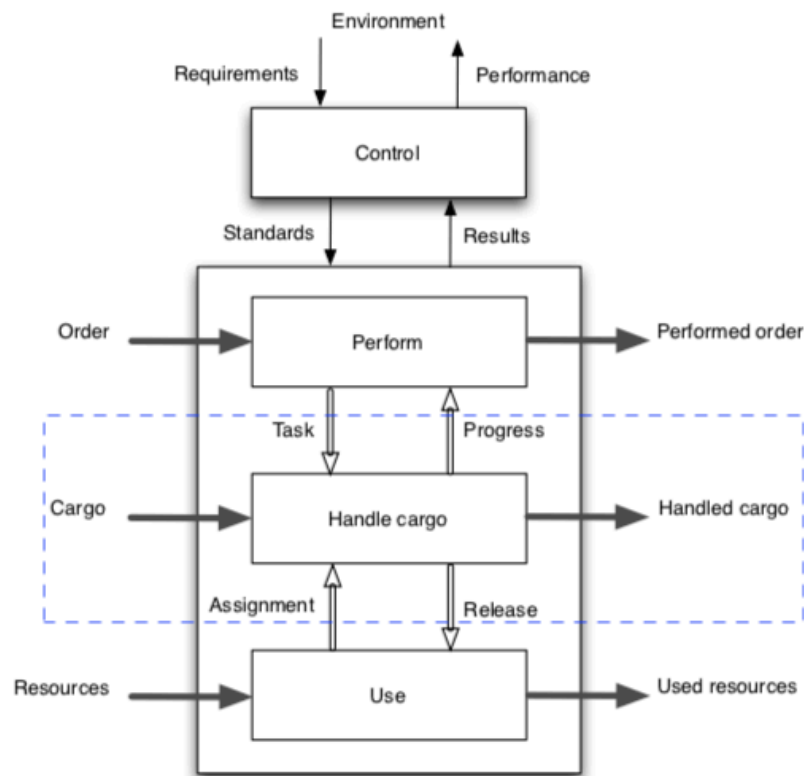


Figure 3.2: DSA - PROPER-model

Order Flow

The order flow comprises of the process of performing an order at the freight buildings. Forwarders place bookings in Cargoal for air transportation. Such a booking automatically includes a request for cargo handling at the terminal. The Cargoal booking system of AF KL is linked to the operational system, which is called 'Chain'. This system coordinates tasks and progress of the cargo in the freight buildings.

Cargo Flow

The cargo flow is controlled by the order flow and processes are executed according to information from the Chain system. Cargo handling transforms arriving cargo at the freight buildings into handled cargo that is put ready for aircraft loading.

Resource Flow

The resource flow contains the resources that are necessary for the processes within the freight buildings. Resources are assigned to tasks and transformed into used resources. They can be used over and over again without leaving the system.

In this research the freight handling process of the system (the cargo flow) will be the most important flow. When zooming in on the flow processes, four types of delivered freight can be distinguished: T-ULD, M-ULD, BB and loose freight/skids. The schematic flow for the different types can be seen in figure 3.3. After unloading, two main processes are performed in the warehouse, the break down of pallets and the build up of ULDs. For a T-ULD, these processes are not necessary as the ULD already has the configuration needed for further transportation. The BBs (bijbouwers) are ULDs that arrive at the warehouse already built up with shipments for a single flight, but still contain enough capacity to add additional freight. The different flows and processes are further elaborated on in the next section.

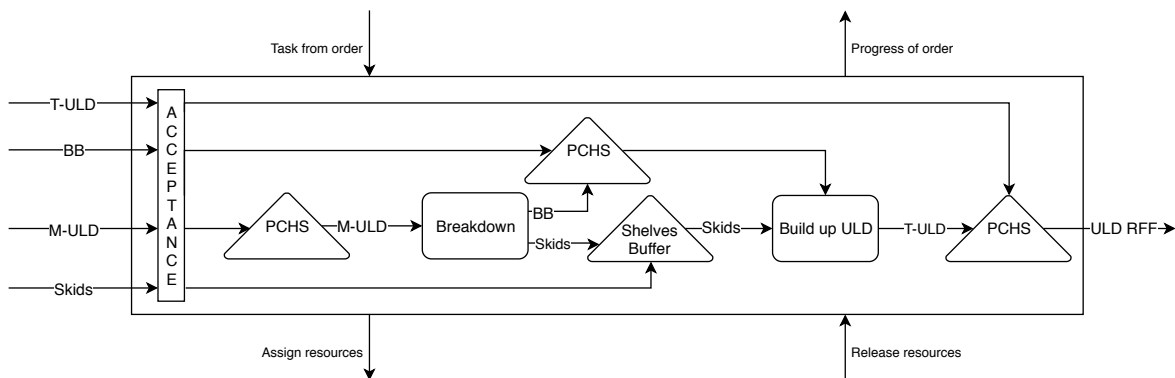


Figure 3.3: DSA - zoomed in on handling process

The inbound flows are subject to a push mechanism from the customers. Freight is pushed into the hub and planning the amount of needed resources to process the freight is done based on historical data. Due to the schedules of departing flight the outbound flow is subject to a pull mechanism [25].

3.2. Warehouse Handling Processes

The different processes that are evaluated in this research all take place within the warehouses of KLM Cargo at the Schiphol hub. The main elements that are relevant for this research can be summarised as follows:

- Pallet & Container Handling System (PCHS)
- Breakdown Areas
- Cool Storage
- Flight Buffers
- Build up Areas

These different elements will be elaborated on in the following sections. Within the warehouse these all have their specific location and purpose. The location of the elements within the freight buildings can be seen on the map in Appendix C. The PCHS is not visible on the map as it is situated above the warehouses. The processes that take place within the warehouses can be mapped to give an overview of the different steps a shipment can go through. Figure 3.4 and 3.5 visualise the logistic chain with all the processes. The location of processes and storage areas are visualised in 3.5. The location of the processes displayed in 3.4 can be retrieved by matching the color of the process/storage with the colours in the map of 3.5.

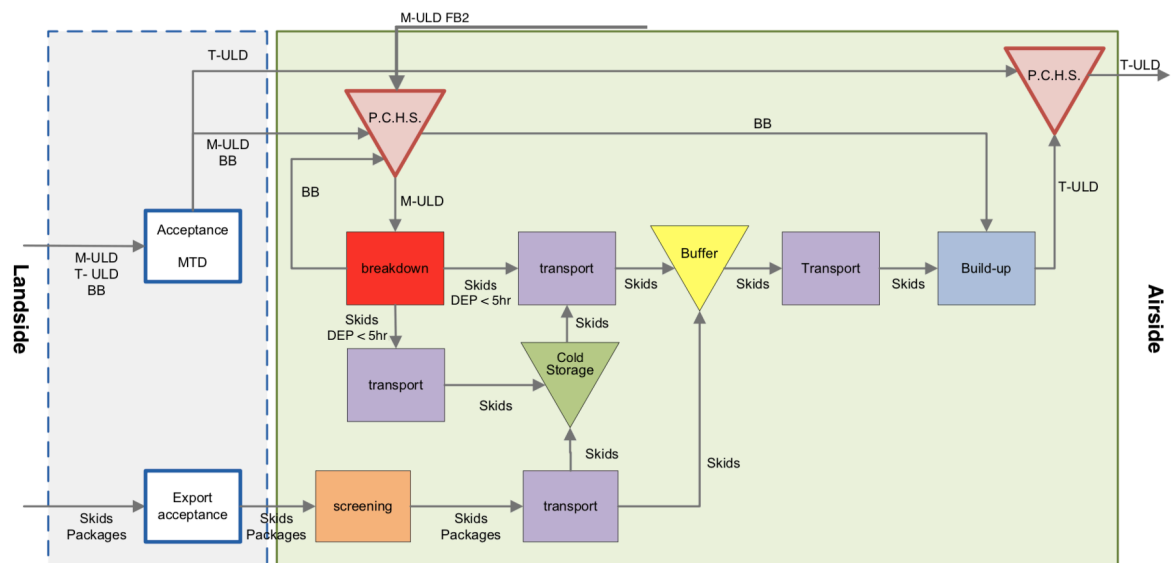


Figure 3.4: Product flow through freight building 3.

3.2.1. Acceptance

Acceptance is the term used in the air cargo industry for the area in the hub where trucks are unloaded. There are two distinct areas at KLM Cargo where the trucks are unloaded: the Moving Truck Dock (MTD) and the Export Acceptance area. At the MTD, palletised cargo or containers are unloaded onto the Transport Vehicle (TV), which moves the cargo towards the elevator. The elevator is connected to the PCHS where the ULDs are stored. T-ULDs are moved into the storage area at the air side of the hub and wait for the deadline for transportation towards the aircraft. The M-ULDs are stored on a level above the operational floor and wait for a request for breakdown. Loose freight is, placed on a buffer, brought to breakdown areas and stored on shelves or other storage areas (such as cool storage).

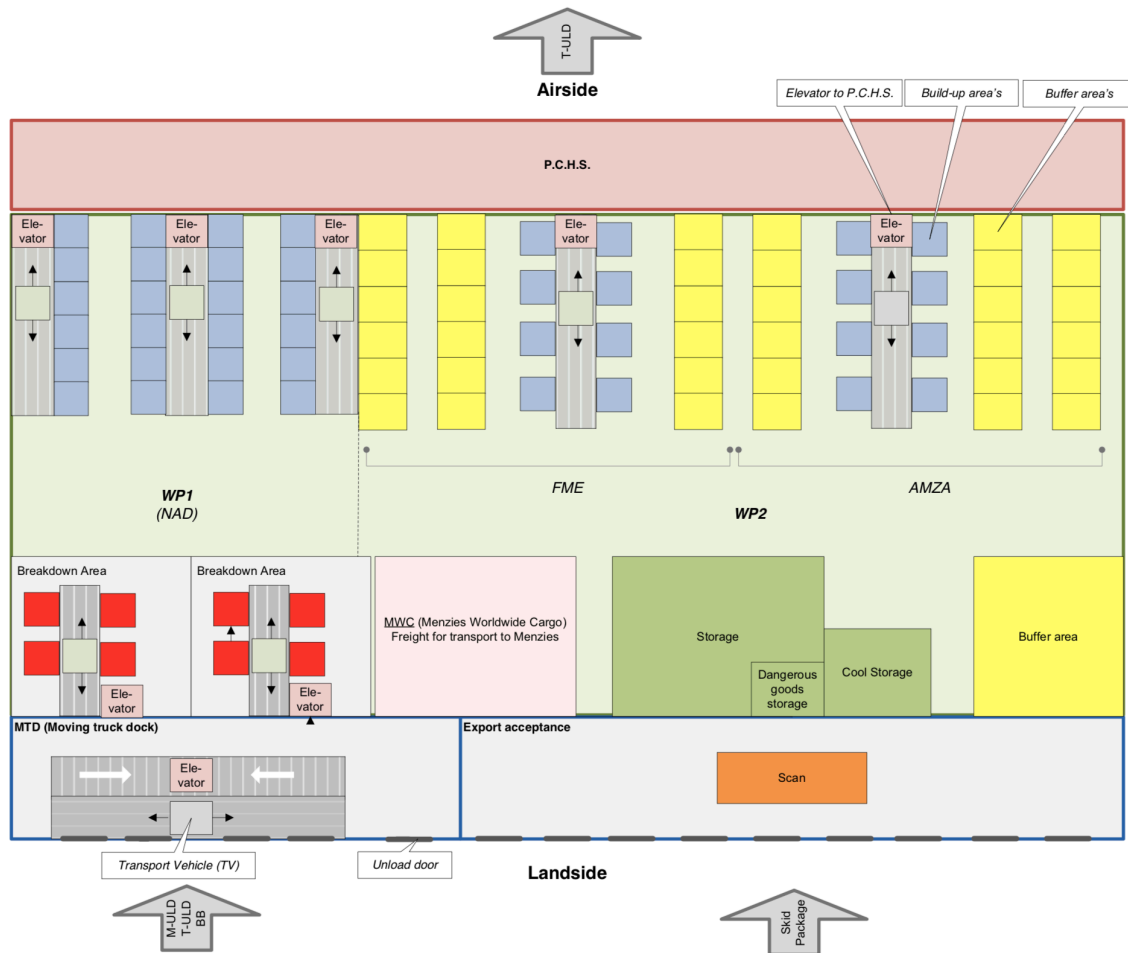


Figure 3.5: Map of freight building 3.

3.2.2. PCHS

The Pallet and Container Handling System (PCHS) is not visible on the maps of the warehouse, as it is situated above the freight buildings 2 and 3. In short, the function of the PCHS is the storage and transloading of ULDs from airside to landside and vice versa. The system consists of multiple elevators, AGVs, turning tables and conveyor belts. It can operate almost fully autonomous when a ULD is in the system and can determine the in- and outbound locations of a ULD as soon as the ULD is identified. In- and outfeed of ULDs is not only limited to airside and landside, but also occurs within the freight buildings themselves. The in- and outfeed of ULDs within the freight buildings mainly consists of M-ULDs, as they have a buildup and breakdown process which is done at the buildup and breakdown areas within the freight buildings.

ULDs enter the warehouses at different locations. From outside of the freight buildings to inside, the transport is accepted at roughly four locations:

- Incoming Area FB2 (IA2)
- Incoming Area FB3 (IA3)
- Moving Truck Dock (MTD)
- Eurotruck Handling System (EHS)

IA2 and IA3 are positioned at the airside. The MTD and the EHS are positioned at the landside. Within the freight buildings, the ULDs enter the PCHS from the build up and breakdown locations.

The outfeed of ULDs to outside of the freight buildings takes place in three locations:

- Outgoing Area FB2 (OA2)
- Outgoing Area FB3 (OA3)
- Eurotruck Handling System (EHS)

OA2 and OA3 are located at the airside, the EHS is located on the landside. Within the freight buildings, the ULDs exit the system from the buildup and breakdown areas.

3.2.3. Breakdown

As the problem description in the introduction briefly described, the M-ULDs require further handling in the hub because these ULDs contain shipments for multiple flights. The first step is the breakdown process. Planners in the hub decide which pallets need to be broken down, at what moment and decide the order in which the pallets go through the breakdown process. Planners base this schedule on the connection times of shipments on the M-ULDs, characteristics of the shipments, the destination and the type of shipments (for example, highly paid freight has a higher priority over other shipments).

M-ULDs are lowered by an elevator onto the breakdown area where a breakdown team will decompose a pallet, split the shipments according to their destination, sticker them with shipment information and move these shipments to either the flight buffer area or (refrigerated) storage areas depending on the time left until the departing flight.

3.2.4. Cool Storage

As the transit times of freight arriving at the Schiphol hub often exceed the time needed to handle the freight, storage is inevitable. For temperature-sensitive goods it is important that the temperature is maintained and therefore there are multiple cooled storage areas within the different freight buildings:

- **KC01**

KC01 is located in freight building 1 and is used for palletised COL shipments (T-ULDs). As T-ULDs are outside of the scope of this research, KC01 is not discussed in further detail.

- **KC02**

KC02 is located in freight building 2 and is used for perishables. KC02 has a capacity of 117 skids.

- **KC04**

KC04 is in FB3 and is used for pharmaceutical products. KC04 has a capacity of 40 skids.

Due to rules and regulations, pharmaceuticals and fresh products are not to be stored in the same cold storage, as they have different characteristics. However, in the situation where one of the storage locations is full the other cold storage can be used as alternative.

3.2.5. Flight Buffer

Shipments are collected on flight buffers before they are placed on a pallet. A flight buffer is an area on the operational floor that is reserved to collect shipments for a specific flight. The flight buffers and build-up areas are spread out over the floor, based on the geographical location of the destination of the flight. For example, all flights with a destination in North-America (NAD) are located in World Port 1 (WP1). Next to WP1, World Port 2 (WP2) is located and is host to the flight buffers and build-up sites for flights with destinations in the Far-Middel-East (FME) and Africa-Middle-South-America (AMZA). A flight buffer opens 24 hours before departure of a flight and from that moment freight can be moved from the breakdown area and storage facilities to the flight buffers with forklifts.

3.2.6. Build Up

Build up workers (they work in couples) are assigned to put shipments from the buffers onto empty ULDs on the build up sites. The build up plan is made by flight planners. These flight planners prioritise freight and thus decide which shipments are rebooked to a next flight if the available capacity proves to be too small. This happens occasionally because a wide variety of package dimensions causes a sub-optimal utilisation of the capacity of ULDs. For instance, it can occur that only 80% of the freight capacity of a flight is utilised on paper but that all pallets are fully loaded. A complete pallet is covered with plastics and a net. After some safety checks the pallet is finalised and provided with the status Ready For Flight (RFF). This process should be completed at least two hours before flight departure. Finally, the ULD is moved into the PCHS, which delivers the ULD at a PU lane on the air side where it awaits transport to the aircraft.

3.2.7. Transport

Transportation within the warehouses is either automated due the PCHS or performed by workers on a forklift on the operational floor. The forklifts are used to move skids (wooden pallets) and empty ULDs through the hub.

3.3. Flow within the Warehouse

The processes that are described above individually, can be drawn schematically in a flow chart to show the paths the different products follow within the warehouses. The flows within the warehouse can be seen in figure 3.6 and 3.7. The entrance differs due to cargo arriving by aircraft or truck. For aircraft arrival, extra transportation time is needed for the freight as it has to be transported from the tarmac to the warehouse. There is also a difference in palletised or loose freight arrival, as palletised freight can be stored in the PCHS. For climatized goods it is also relevant what type of product the cargo consists of, as there are separate cool storages for different types of product.

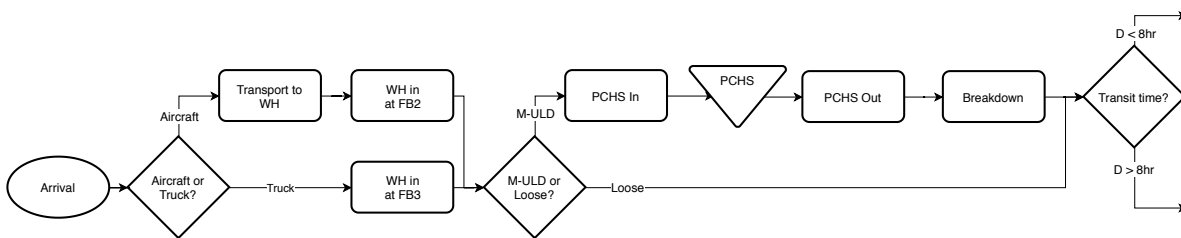


Figure 3.6: Flowchart of the different types of shipments.

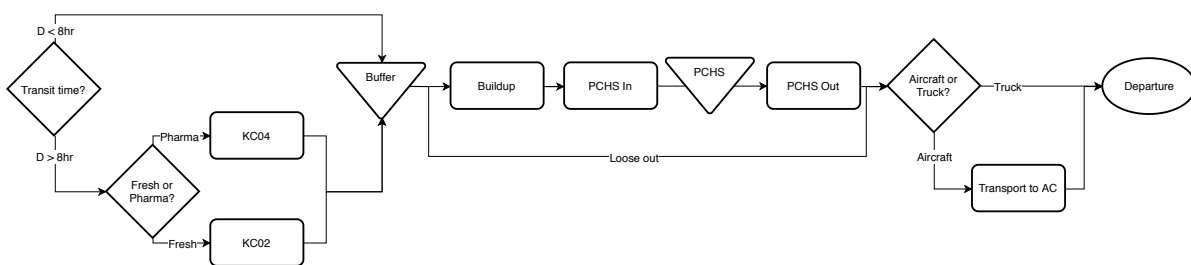


Figure 3.7: Flowchart of the different types of shipments.

The duration of each of the processes can vary significantly, due to several characteristics and circumstances. Not every pallet or freight is the same and can be compared, but also experience of the employee plays a significant role. Measurements are done for the process times, out of these measurements standard process times are generated based on characteristics of the ULDs or freight.

3.3.1. Breakdown

The process time of breaking down a ULD is based on the number of packages, total weight and total volume which generates a standard process time. This standard process time is on average 21 minutes, with a minimum process time of 8 minutes and a maximum of 40 minutes. The M-ULD will be broken down in a particular sequence, which depends on the shortest deadline for a certain piece on a pallet. So the departure time of the packages on an M-ULD determines when the process of that pallet will start. As a rule, the process of breaking down should be done five hours before departure. Nevertheless, the employees keep on breaking down during their shift, also if there are no short deadlines at that moment. Besides this, it is logical that the workload is higher if there are more short deadlines.

3.3.2. Build Up

The duration of the build-up process depends on the activity that should be performed. A distinction can be made between five different ULDs: one container and four pallets with different dimensions. The characteristics and standard process times of those ULDs can be seen in table 3.1.

ULD type	Description	Dimensions [cm]	Build up time [min]
AKE	Half-size Lower Deck Container	200 x 151 x 162	25
PLB	60.4-inch Lower Deck Pallet	318 x 153 x 160	30
MDP	Main Deck Pallet	318 x 224 x 224	55
LDP	Lower Deck Pallet	318 x 224 x 224	40
PRA	16 ft Main Deck Pallet	498 x 244 x 244	110

Table 3.1: ULD characteristics.

The build-up process has deadlines. As a rule this process should be done two hours before departure. In that way the ULD can be picked up by the Transportation department to be directed on time to the aircraft.

3.3.3. Resources

The breakdown and build up processes are performed in operational teams. A team for breaking down pallets consists of seven people; four of them are physically breaking down the pallets, one person is responsible for placing the stickers on every skid and the remaining two take care of the transportation of the skids to the storage area or the flight buffer. Building up ULDs is performed in a team of two people; one is placing the freight on the skids and the other gives directions. Placing some loose freight and covering a pallet with plastic and rope is done by both employees. The unload processes by forklifts and the MTD is performed by one employee per ULD or skid, because a forklift and the MTD could be handled by only one person. At the MTD, most of the time the unload process is supported by the truck driver. The small freight transportation with forklifts is also performed by one employee, but this is most of the time someone from the break down or build up team.

3.4. Delivery Deadlines

Due to the many rules and regulations that apply to the handling of climatized goods, KLM Cargo has set up 'Hub rules' for the handling at the Schiphol hub. The following rules are stated for the handling of COL goods:

- **IN + 60**

COL goods should arrive at a cool storage location 60 minutes after breakdown at the latest. This deadline is set up to ensure that the climatized goods are stored in a refrigerated area as soon as possible.

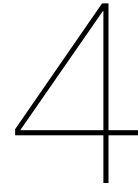
- **DEP - 300**

After storing the goods in a refrigerated storage area, the goods can be built up on a ULD

for further transportation from 5 hours before departure. This rule has to make sure the COL goods are stored in a refrigerated area as long as possible. However, employees in the warehouse tend to start building up ULDs early when there is no other work to be done which may cause temperature excursions of the COL goods.

- **DEP - 120**

Due to regulations ULDs have to be delivered at the VOP at least 80 minutes before the scheduled departure of the aircraft. Research by van Ruggie suggests that it take 15 minutes on average for ULDs to be transported from the PU lane outside of the warehouse to the VOP. The rides to the VOP are planned from the moment when the ULD is present at the PU lane and therefore the deadline of delivering the cargo at the PU lane is 120 minutes before scheduled departure. It is also important that cargo is ready for leaving the warehouse 120 minutes before departure for load control of the aircraft. In this research, this deadline is seen as the 'warehouse out' moment.



Analysis

In this chapter, the KPIs to track the performance of the warehouse handling processes are discussed. The following research questions are answered:

- (b) How is the performance of the handling processes currently measured and monitored in terms of maintaining temperature integrity? (What KPIs are used and what data is available?)*
- (c) What relevant KPIs can be used to express the performance of the handling processes?*

4.1. Key Performance Indicators

In order to assess the performance of KLM Cargo's warehouse processes, a number of key performance indicators are used. Along the processes, a lot of data is logged which is elaborated on in the next section. Analysing this data gives insight into the performance of the system, which can be assessed using a number of Key Performance Indicators (KPIs). In the simulation model, future performance can be predicted using these KPIs, allowing for a direct comparison of the performance of various cargo handling alternatives. In the problem statement of this research it is explained that the KPIs that are currently used to define the performance of the processes within the warehouses are inadequate. In order to describe the performance more adequately, new KPIs are described in this section. In Chapter 2.4 the method for KPI selection was described. The core principles of a KPI as described by Rezaei et al. can be summarised as follows [26]:

- 1. The PI must be specific, realistic and representative, so that the gathered information reflects reality.**
All KPIs are measured directly from the handling process. By staying close to the process, transparency is achieved: the KPIs are easy to understand, for everyone involved in the process.
- 2. The measurements must be performed, defined, and quantified consistently.**
For all KPIs, an unambiguous explanation is given on exactly how the KPI is measured, in order to guarantee consistency.
- 3. The PI must be measurable in physical and financial units.**
All KPIs are measurable in physical units. However, not all KPIs can be measured in financial units. Reason for this is that there is no straight forward way to ascribe costs to some of the KPIs. For example, when cargo is not stored in the correct cool cell, this does not directly implicate costs. When a deadline is exceeded, this cargo is at risk of not being delivered on time to the next step in the process. However, for every incident, the (financial) consequences deviate.

4. **The PI must reflect the responsibilities of the involved departments/managers.**
Although the different departments have different responsibilities, they all share the same goal: the on time delivery of cargo in an adequate manner. As the KPIs are set up to achieve this goal, they reflect these responsibilities.
5. **The set of PIs must make the costs elements transparent.**
As already mentioned above, the financial consequences of the behaviour of the process are difficult to quantify.
6. **The PI must be aligned with overall organisational goals, when used by a particular department.**
The main objective of an air cargo handling terminal could be described as: to handle cargo correctly and on time. In order to handle cargo correctly, product specific standards need to be respected. In this case, the product specific standard means maintaining temperature integrity. The KPIs are therefore aimed at meeting both the product specific standards and the process deadlines.

Keeping these core principles and the requirements of the handling processes in mind, multiple KPIs were identified which can be seen in table 4.1.

KPI	Magnitude	Unit
1. Time out of Refrigeration (TOR)	Time	[min]
2. Overcapacity cool storage	Violations	[#]
3. On Time Performance (OTP)	Fraction	[%]

Table 4.1: Key Performance Indicators

1. **Time out of Refrigeration [min]**
Time out of refrigeration (TOR) is the amount of time that a product is outside of its specified temperature range. Deviations from the specified temperature range can occur during the warehouse processes. In this research, the TOR is calculated by subtracting the time a shipment is stored in cool storage from the total time a shipment is present in the KLM Cargo warehouses. The KPI is expressed in minutes, as an absolute value is the best measure to depict the performance. If the TOR would be calculated as the percentage of time a shipment is out of refrigeration, shipments with a long transit time are most likely to show a lower TOR percentage as the handling processes should take a fixed amount of time. In this way the handling processes stay the same while the cool storage increases, which would show a lower TOR percentage.
2. **Overcapacity cool storage [#]**
As discussed in the problem description, one of the current bottlenecks of the process is the capacity of the cool storage. Whenever the capacity is insufficient, devaluation of cargo may occur which in its turn may result in loss of revenue. Therefore, it is important to keep track of the capacity of the cool storage. Whenever a skid is ready to be stored in one of the refrigerated areas, but the cool storage has insufficient capacity, it is recorded in this KPI. This performance indicator is a measure to show up to what extent the capacity of the cool storage is sufficient. It should be noted however, that whenever one of the cool storage locations is full, the shipment is often stored in the other cool storage and therefore no temperature excursions occur. Storage in the other cool storage is recorded in this KPI as a violation however, as it is not the intended use of the cool cells due to the segregation principle.
3. **On Time Performance, [%]**
The On Time Performance (OTP) of the handling processes will be evaluated at different moments in the process. The IN + 60, DEP - 300 and DEP - 120 deadlines will be used to evaluate the OTP.

4.2. Data Collection

For the analysis of the warehouse handling processes, all relevant data has to be collected. Historical data is gathered from the warehouse management system CHAIN (Cargo Hub Advanced Information Network) and is evaluated at skid level. Most of the data is put into CHAIN automatically, but adjustments can be made manually by employees if the data is not correct. The data is provided by the department of Performance Management and consists of shipments handled by KLM Cargo between January 1, 2018 and January 1, 2019. The dataset contains all transit shipments that arrive in the form of an M-ULD or as loose freight and which consists of pharmaceutical or fresh goods that need to be kept between 2°C and 8°C, which is 36,784 skids in total. Each row of data in the dataset contained the parameters that are summarised in table 4.2.

Data Label	Description	Example
<i>Flight_In</i>	Flight number of incoming flight.	KL1348
<i>Actual_In</i>	Actual arrival time of incoming flight.	2018/01/01 08:43:05
<i>PI_lane</i>	Time ULD arrives at a 'Pallet Inslag' lane	2018/01/01 08:43:05
<i>PCHS_In</i>	Time ULD enters the PCHS.	2018/01/01 08:43:05
<i>AWB</i>	Airway Bill number of the shipment.	7412779384
<i>Breakdown_DT</i>	Time ULD arrives at breakdown area.	2018/01/01 08:43:05
<i>AWB_Destination</i>	Destination of the shipment.	YVR
<i>ULD_In</i>	ULD number of the incoming ULD.	PMC23714
<i>Skid</i>	Number of skids on incoming ULD.	4
<i>Units</i>	Number of colli on skid.	22
<i>Product_Code</i>	Type of product.	S23
<i>Cool_Loc</i>	Location code of storage rack in cool cell.	C2H1
<i>Cool_In</i>	Time shipment arrives at cool cell.	2018/01/01 08:43:05
<i>Buffer_Loc</i>	Location code of buffer area.	W176
<i>Buffer_DT</i>	Time shipment arrives at buffer location.	2018/01/01 08:43:05
<i>Buildup_DT</i>	Time shipment arrives at buildup area.	2018/01/01 08:43:05
<i>Flight_Out</i>	Flight number of outgoing flight.	KL0743
<i>ULD_Out</i>	ULD number of the outgoing ULD.	PMC25001
<i>PCHS_Out</i>	Time ULD leaves the PCHS.	2018/01/01 08:43:05
<i>PU_lane</i>	Time ULD arrives at a 'Pallet Uitslag' lane	2018/01/01 08:43:05
<i>Actual_Out</i>	Actual departure time of outgoing flight.	2018/01/01 08:43:05
<i>Sched_Out</i>	Scheduled departure time of outgoing flight.	2018/01/01 08:43:05

Table 4.2: Description of dataset.

Within the warehouses there are different points in the process where a timestamp is given to a shipment, an overview of the timestamps that are measured can be seen in figure 4.1. The delivery deadlines are also shown below the figure, as well as the 'warehouse in' moment used in this research. The DEP-120 deadline is assumed to be the 'warehouse out' moment for all shipments. The timestamps are depicted with a red dot. Only the start times of the processes are measured within the warehouses, not end times. This means the transportation time necessary between the different process steps is already incorporated in the total process times.

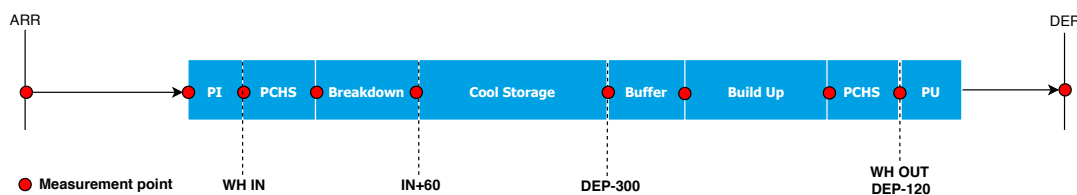


Figure 4.1: Process times and measurement points.

4.3. Data Processing

Data filtering and processing is an important step. When the model structure used is valid, the results of the simulation can still be misleading due to inaccurately collected input data. Several characteristics of the freight are registered, however not all characteristics are relevant for this research. The characteristics that are not relevant for this research are removed from the dataset. Not all data in CHAIN is fully reliable, mainly due to manual adjustments. Therefore, it is possible that some errors are present mainly with adjustments on time. In order to eliminate these errors, several data processing steps have been executed. Which can be summarised as follows:

1. Double values are removed. Due to manual data input, occasionally a skid is doubled, the duplicate is removed so that only unique skids remain.
2. Skids that have negative duration times for events that take place in a chronological order are double checked and removed if unsolvable.
3. The timestamps necessary to calculate the performance are not recorded for all skids. Therefore, the empty process times for these skids are determined by adding the average time for the same process step for a shipment with the same characteristics.

4.4. Data Synthesis

After processing the data a total of 35,645 unique skids remain. As stated earlier, the analysis is done from the moment a shipment enters the warehouse until a shipment leaves the warehouse. However, timestamps of the warehouse arrival and warehouse departure are not readily available and are therefore derived from the data that is available.

Truck: The moment a truck arrives at the gate of KLM Cargo and passes the documentation, a timestamp 'actual_in' is recorded. From historical data the transportation times that are available are fitted with a distribution fitter [27]. This resulted in the distribution which can be seen in figure 4.2. As a result, the assumption is made that the transportation time between truck arrival and warehouse arrival follows a lognormal distribution with parameters $\mu = 3.714$ and $\sigma = 0.692$. The moment a shipment arriving by truck enters the KLM Cargo warehouse is determined by generating a random number from the distribution and adding it to the truck arrival time.

Aircraft: For airside arrivals, the timestamp when a shipment arrives at the PI lane (pallet in-slag) is used when available. Whenever the timestamp is missing, the warehouse in moment is calculated based on the available data. The moment an aircraft arrives at Schiphol airport, a timestamp 'actual_in' is recorded. From historical data the total time it takes for a ULD to be transported from the aircraft to the PI lane is retrieved and a histogram is made of all of the available values after which the histogram is fitted with a distribution fitter. As a result, the assumption is made that the transportation time between truck arrival and warehouse arrival follows a negative binomial distribution with parameters $R = 4.3589$ and $P = 0.0559$. The missing warehouse in timestamps are now calculated by generating a random number from the fitted distribution and adding it to the aircraft arrival time. The distributions where the transportation times are drawn from can be seen in figure 4.3.

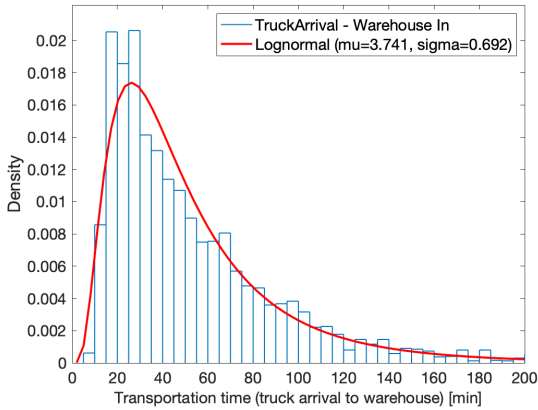


Figure 4.2: Histogram of the transportation times from truck arrival until arrival at the warehouse.

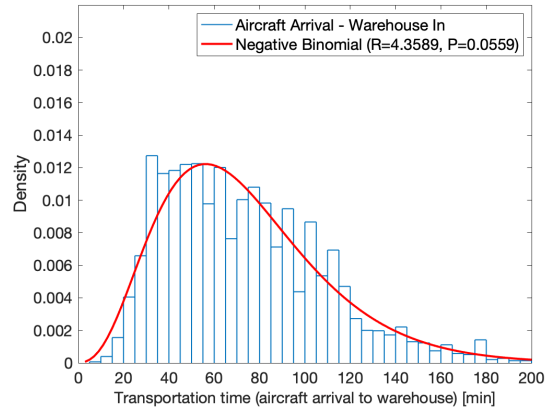


Figure 4.3: Histogram of the transportation times from aircraft arrival until arrival at the warehouse.

4.5. Data Analysis

The processed dataset contains 35,645 skids in total that are handled within the KLM Cargo warehouses in 2018. The cargo does not arrive at KLM Cargo evenly distributed, as can be seen in figure 4.4. The arrival pattern of cargo can be classified as erratic. Due to the erratic pattern, it is hard to align the warehouse processes with the availability of cargo.

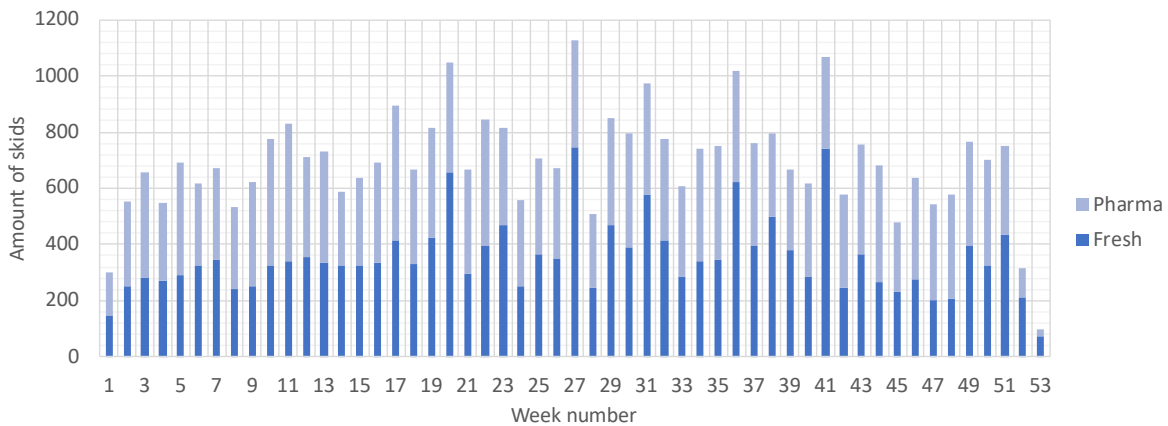


Figure 4.4: Average number of skids arriving per week (2018).

The cargo supply is does not only show fluctuations on a weekly level; on a daily level these fluctuations are even larger. The pattern, that can be seen in figure 4.5, is known as the 'weekend effect'. This effect can be explained by the fact that forwarders send out their shipments just before or after the weekend, as they are usually not operating in weekends. The cargo transported just before the weekend arrives at KLM Cargo on Saturday and Sunday, and the cargo transported after the weekend arrives on Tuesday. Due to the volatility in cargo arrival patterns, it is very hard for KLM Cargo to plan resources adequately. Therefore, solutions for a more even distribution of cargo arrivals are desirable.

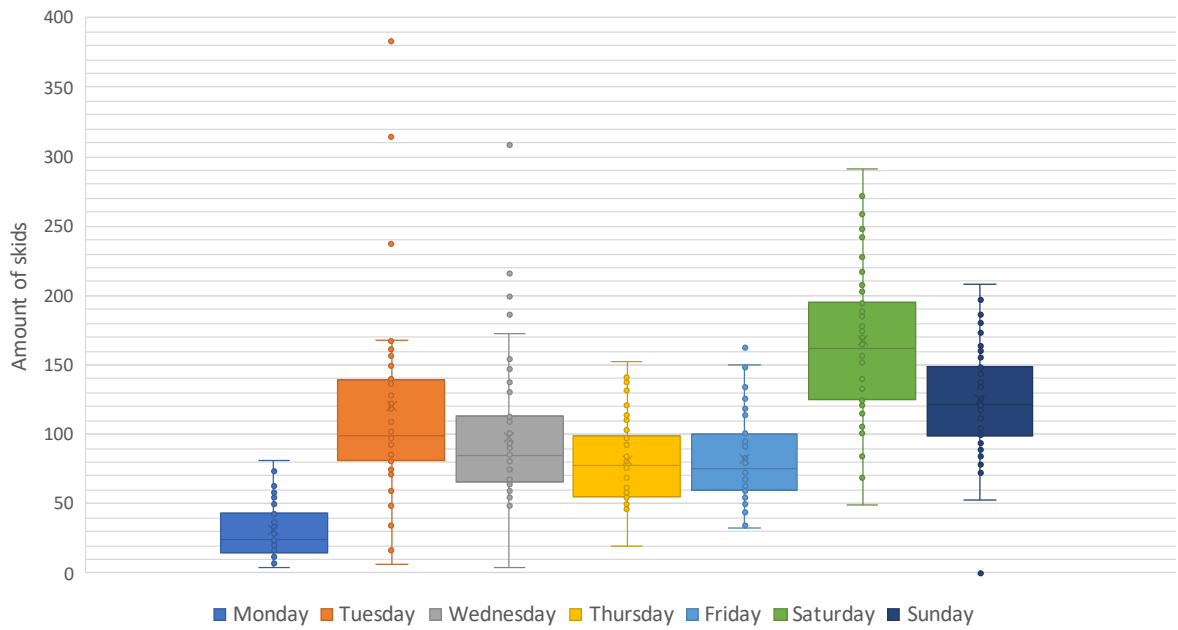


Figure 4.5: Average number of skids arriving per day (2018).

The cargo supply also shows a large deviation on hourly arrivals. Most of the trucks for example, arrive between 23:00 and 4:00 which seems beneficial as there are no aircraft that arrive between these hours. However, the amount of freight arriving by truck is large enough to still be the cause of the peak hour value for the entire day. The cargo arrival of trucks should be spread out more evenly to ensure more efficient handling at the hub.

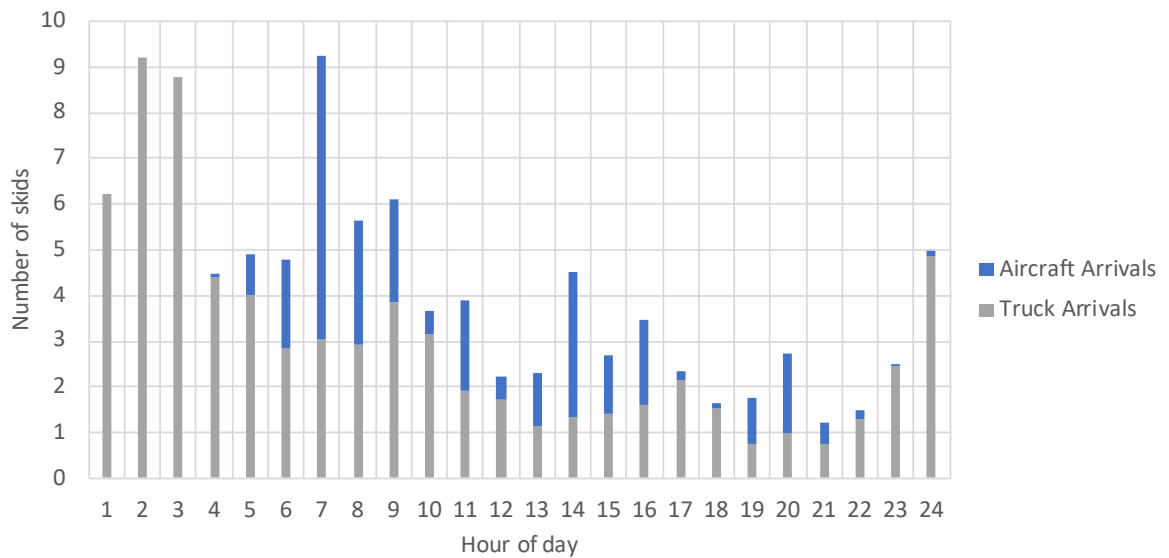


Figure 4.6: Average number of skids arriving per hour of day (2018).

The data analysis above is done on skid level. However, most freight does not arrive and depart the warehouse on skids. The skids are merely used to handle the cargo within the warehouse, as they can be transported easily by forklifts. Within the warehouse, there are different product flows that are important to distinguish. The dataset, which is on skid level, can be split up into different types based upon characteristics that are important to the process. The following distinctions can be made:

- Type of freight.

A shipment can arrive as ULD or as loose freight. When a shipment arrives as ULD, it is taken into the warehouses by the Pallet and Container Handling System (PCHS). As the name states, this system can only handle containers and therefore loose freight does not enter the PCHS but is placed in a buffer zone instead.

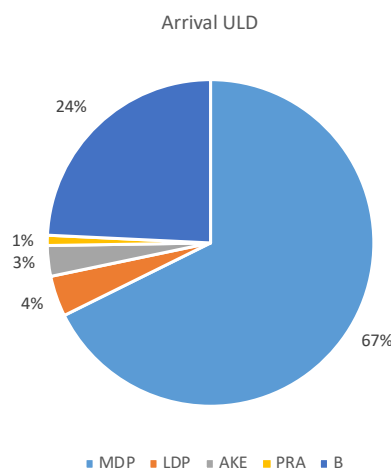


Figure 4.7: Arrival ULD split.

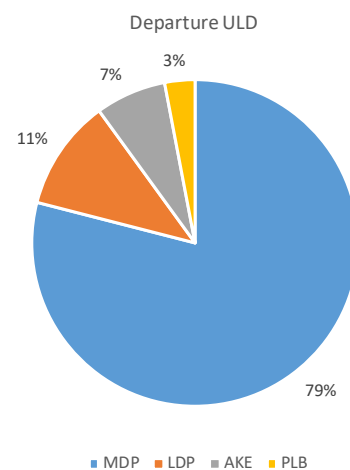


Figure 4.8: Departure ULD split.

- Arrival mode.

A shipment can arrive at the warehouse by aircraft or by truck, this has influence on the process. As in general, freight arriving by truck is handled significantly faster than freight arriving by aircraft. This is mainly due to the fact that the unloading of an aircraft and transportation to the warehouses takes longer than the unloading of a truck, as a truck is docked directly at one of the warehouses and an aircraft arrives at a runway.

- Type of product.

It is relevant to make a distinction between the two different products, fresh and pharma, as they both have their own separate storage areas. The type of product is therefore of influence on the process the shipment goes through.

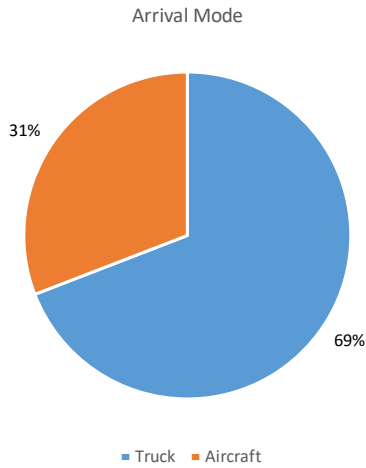


Figure 4.9: Arrival mode split.

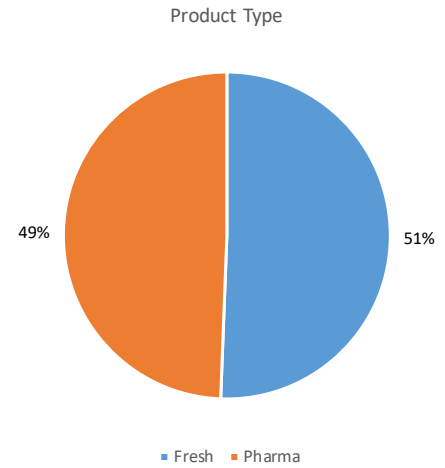


Figure 4.10: Product type split.

As can be seen in figure 4.9, approximately 69% of the transit shipments arrive by truck and the remaining 31% arrives by aircraft. For transit M-ULDs, 51% of the freight that arrives at KLM Cargo consists of 'Fresh' products. This is remarkable as the percentage of 'Fresh' shipments in the other flows (export and import) is significantly higher, which is also the reason that the cool storage facility for perishable products has more capacity than the cool storage facility for pharmaceutical products.

In figure 4.11, the average process times are given for the warehouse handling processes within the warehouse of KLM Cargo to give an idea of the duration of all the steps. As stated in the introduction, the only process steps considered as value adding are the breakdown, build up and refrigerated storage. This means that a lot of time spent at the hub, for example the waiting times in the PCHS, are non value added and should be removed from the process if possible.

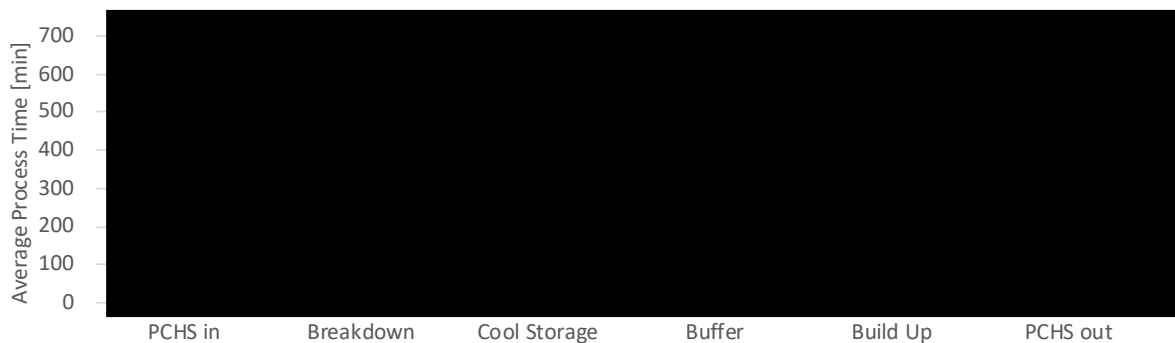


Figure 4.11: Average process times of all process steps.

The data is split up into eight flows to show the differences in performance between the different arrival modes, cargo types and product types. The 'IN+60' values determine the percentage of shipments that went into a refrigerated storage facility within 60 minutes after the start of breaking down a ULD. These values are calculated for shipments that entered the cool cell, as the values of shipments that did not enter the cool cell will have a value of 0%.

Next to the different deadlines that are used to measure the on-time performance of the shipments, also other KPIs have been introduced and are evaluated in the current state analysis. In table 4.4, the TOR is shown for all the different product flows. The throughput time (TPT) is the total time a shipment spends at the Schiphol hub, the duration of buildup and breakdown are given by the abbreviation 'BU+BD'.

			Skids	TPT [min]	TOR [min]	BU+BD [min]
Truck	Loose	Pharma				
Truck	Loose	Fresh				
Truck	ULD	Pharma				
Truck	ULD	Fresh				
AC	Loose	Pharma				
AC	Loose	Fresh				
AC	ULD	Pharma				
AC	ULD	Fresh				

Table 4.4: 2018 transit COL shipment performance on KPIs.

During data analysis it has become clear that the quality of the data is not optimal which might have an influence on the performance measured. As can be seen in the performance measurement tables, the loose cargo arriving by truck containing pharmaceutical shipments has the worst performance. The reason for this could be the data quality, as this type of shipments is only 2% of the total a deviation in the data can have a large influence on the average.

The last KPI used in this research, the number of storage violations, is difficult to analyse for the different flows in the current state as they are not recorded and there are more reasons for shipments not be stored in a refrigerated area. For all flows combined, approximately 16 storage violations occurred per day in 2018.

4.5.2. Conclusion on Current State

Through data and process analysis it has become clear the current state is not optimal. The arrival pattern of cargo is found to be highly unpredictable and irregular. This is very likely to be one of the causes of the non-performance of the current state cargo handling. Due to peaks in cargo arrival, the refrigerated storage areas are not always capable of storing all goods necessary which leads to waiting times and cargo that is not processed on time and adequately. In the next chapter, design options will be given that can ensure a smoother demand pattern or better control of cargo arrivals.

There are also several steps in the process where waste occurs, especially unnecessary waiting time when the cargo is stored in the PCHS. When the cargo is stored in the PCHS, it is not refrigerated and waiting times occur due to the planning of cargo handling by the IT system CHAIN. These parts of the process should be eliminated for a better warehouse handling process. The elimination of these steps will also be evaluated in the next chapter.

5

Future State

In this chapter, the future state of the cargo process will be explored. First, an ideal state will be discussed and the objective will be elaborated on, followed by the requirements and constraints. From the objective, requirements and constraints different design options are provided that can possibly improve the handling processes of cargo within the hub. These alternatives are tested using the DES model to assess the potential improvement. In this chapter, the answer is given to the following research question:

(d) What alternative scenarios can be used to improve the performance of the handling processes?

5.1. Ideal State

The ideal state for the handling of temperature-sensitive goods would be a lean concept in which information is digitally shared throughout all parties involved in the supply chain. In an ideal state, temperature-sensitive cargo is always delivered by the customer to KLM Cargo on time. The cargo deliveries are divided over time in such a way that peaks in cargo arrivals that lead to insufficient capacity of refrigerated storage area are prevented. There is always sufficient capacity for the handling of the goods within the warehouses so temperature excursions due to lack of capacity do not take place. The on time delivery of cargo is ensured by digital information sharing between all parties involved in the supply chain which results in transparency throughout the total supply chain. Unnecessary steps, or waste, are eliminated and the cargo only goes through necessary steps for the handling. If waiting times should occur, KLM Cargo has to make sure the waiting goods are in a refrigerated storage area at all times. In this way, safe and reliable handling can be ensured.

5.2. Objective

After evaluation the current state and setting up new KPIs for measuring the performance of the handling of temperature-sensitive goods, the objective of this research can be updated. The objective of this research is:

'Improve the overall performance of the handling of temperature-sensitive goods by decreasing the TOR, while storage violations and OTP do not deteriorate and compliance is adhered to.'

In order to reach this objective, multiple design solutions can be thought of. However, some solutions may not be realistic or are achievable, or they are out of the scope of this research. The requirements and constraints that are applicable to this research will set the boundaries for a design and determine which solutions are feasible and realistic.

As stated, the objective is to ensure that the temperature-sensitive goods are stored in a refrigerated area as long as possible at the hub. In other words, the goal is to minimise the TOR. This objective can be categorised in an objective tree, which is shown in figure 5.1. In the objective tree, different ways of reaching the objective are shown in a structured way.

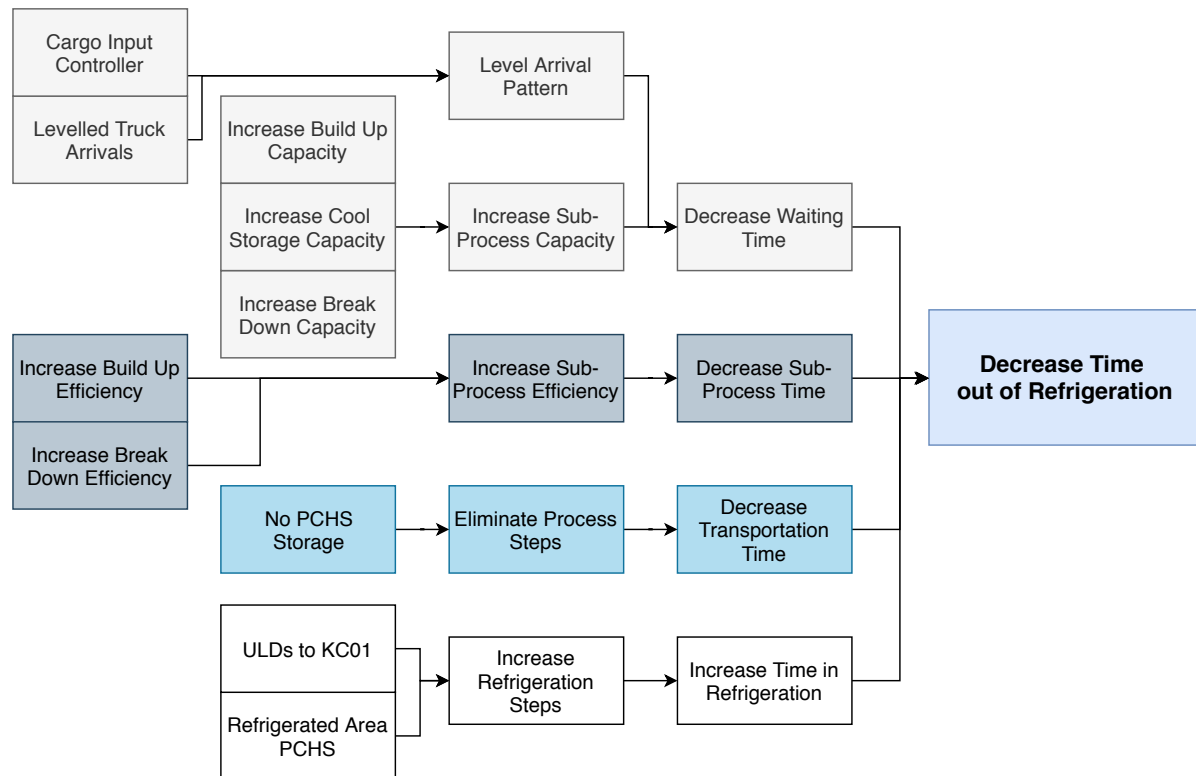


Figure 5.1: Objective tree

Decreasing the TOR can be done in several ways; by increasing the time in refrigerated areas, by decreasing the waiting time, decreasing the transportation time or decreasing the time of the sub-processes of the cargo at the hub.

One way to decrease waiting time is to prevent that queues are formed. This can be done by levelling the levelling the cargo arrival to level the peaks in cargo arrivals. Currently, the arrival patterns shows an erratic demand pattern which results in a queue at busy moments. If the cargo would arrive at more regular intervals, queues could be avoided and therefore the TOR can be decreased. Levelling the arrivals of cargo can also be achieved by using an input controller, which decides whether KLM Cargo is capable of handling the cargo in an adequate way with the current capacity.

Another way to decrease the TOR is to decrease the time per sub-process. This can be done by increasing the capacity of one of the sub-processes and in that way reduce the overall TOR. Combinations of multiple increased capacities could reduce the waiting times even more.

To decrease transportation time within the system, steps that do not add value to the process can be removed. Steps that do not add value are considered as waste according to the lean methodology, and should therefore be eliminated. In the warehouse handling processes at KLM Cargo, the cargo passes through the PCHS, which is a storage location that does not add value to the cargo supply chain and therefore it should be eliminated.

5.3. Requirements and Constraints

The solution for the handling processes of cargo is bound by certain constraints, functional and non-functional requirements. These requirements define the space in which a feasible solution is to be found.

Functional Requirements

- Arriving cargo must go through a breakdown and build up process.
- All handling processes should comply with the IATA CEIV.
- The design option should not add extra steps to the process, thus not increase complexity.

Non-functional Requirements

- The on-time performance of the handling processes may not deteriorate.
- The throughput time of cargo should not increase.

Constraints

- The size and layout of the freight buildings may not be changed.
- Cost of implementing the design solution may not be too prohibitive.

5.4. Design Options

There are multiple design options considered for the future state of the handling of climatized goods at the warehouses of KLM Cargo which are shown in the objective tree. Increasing the efficiency and capacity of breakdown and build up will not be elaborated on further, as this is out of the scope of this research. All design options that are considered for further evaluation are summarised below:

1. Increase the capacity of the cool cells

As the current state has shown, the warehouse handling processes sometimes have insufficient capacity. The lack of capacity leads to unnecessary waste and non performance and thus an improvement scenario would be to increase the capacity of cool storage areas. In this way, the climatized goods will have sufficient capacity in most of the cases.

2. Refrigerated area PCHS

The system at the Schiphol hub is designed in such a way, that storage in the PCHS is an obligatory step in the process. The PCHS storage takes up a significant amount of process time, and together with the storage at the buffer it is waiting time that should be avoided. In the case of climatized goods however, waiting time in a refrigerated area is less harmful to the products and therefore a refrigerated area of the PCHS is considered.

3. ULDs to KC01

Within the warehouse there are three different cool storage locations. KC02 and KC04 are the ones currently used for the storage of skids that come from the M-ULDs that are broken down. The third cool storage however, is used for the storage of built up ULDs (T-ULDs). An improvement scenario could be to start the process building up ULDs earlier and store the built up ULDs in the cool storage that can handle ULDs.

4. Eliminate process steps

By removing process steps that do not add value to the process, the outcome of the cargo handling remains the same but transportation time of the cargo will decrease. For example, PCHS storage is currently part of the process of all ULDs due to the way the system is built up, but the PCHS storage itself is of no further value to the cargo and therefore removal of this step would be beneficial for reaching the objective.

5. Level cargo arrival pattern

One of the causes of the problematic current state of the handling of cargo at the Schiphol hub is the irregular and unpredictable arrival pattern of cargo at the hub. Data sharing amongst all stakeholders can improve the collaboration and agreements can be made on cargo delivery times in order to ensure a more equal arrival pattern.

6. Input Controller KLM Cargo

Another option to level the cargo arrival pattern is to apply an input controller at the gate of KLM Cargo. The input controller will predict if KLM Cargo can ensure that the freight is handled in an adequate way. If this is not the case, the cargo is rejected or rebooked as devaluation of the cargo might take place. This solution does not rely on the collaboration with other stakeholders as described in design option 5.

Evaluating the Design Options

From the aforementioned design options, a selection is made based on the constraints and requirements that will be tested and evaluated on their performance on the KPIs that were set up.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Functional 1	√	√	√	√	√	√
Functional 2	√	√	√	√	√	√
Functional 3	√			√	√	√
Non-functional 1	√			√	√	√
Non-functional 2	√			√	√	√
Constraint 1			√	√	√	√
Constraint 2	√		√	√	√	√

Table 5.1: Design options evaluated on different requirements and constraints.

There are three design options that are elaborated on further; option 4, option 5 and option 6 which resemble the elimination of process steps, the levelling of the cargo arrival pattern and the use of an input controller respectively. The chosen design options will be further elaborated on below.

5.4.1. Design Option 4: Eliminate Process Steps

The first step in removing waste, or non-value-added processes, is identifying where waste exists. In the handling process of cargo there are actually only two main processes that add value, these processes are the breaking down and the building up of the cargo. In lean methodology every form of waiting or inventory is considered as waste. In this research however, the refrigerated storage of goods is not considered as waste, as waiting times are unavoidable, but when the goods remain refrigerated it does not lead devaluation of the product immediately. In the design option where the non-value added processes are removed, there is one major change in comparison with the current state. Currently, all cargo that enters or leaves the warehouse goes through the PCHS. The PCHS is a storage system which is controlled by the IT architecture CHAIN. This IT architecture calculates the deadlines for cargo in the PCHS. For COL goods however, these deadlines are different and the PCHS storage is therefore considered as waste. In this design option, the cargo entering and leaving the warehouse do not enter the PCHS, which might allow for faster warehouse handling and thus a decrease in TOR.

5.4.2. Design Option 5: Level Truck Arrivals

The second design option to enhance the performance of the handling processes from both a company and supply chain perspective can be found in increased collaboration between parties within the supply chain. As discussed in the data analysis, cargo is currently delivered at random moments in time. A pattern can be found in cargo arrivals, which shows a peak in cargo deliveries on Friday and Saturday. However, KLM Cargo currently does not know when cargo arrives at the hub exactly. This can be classified as both silo mentality, in which the information on arrival times is not shared, as well as a lack of supply chain visibility, in which the focus of both parties is on their own goals instead of thinking and handling to reach the most efficient overarching supply chain. The collaboration with supply chain partners could, in particular, be of added value concerning the arrival pattern of the cargo. The processes of the warehouse handling are strongly influenced by the random arrival pattern, therefore a collaboration between stakeholders should be set up, in which information is shared. This research is not focusing on the best way to establish such a collaboration, but into the potential impact of a successful collaboration. This assumes that optimal arrangements between both parties are possible. In practice, it will not always be easy to achieve this. But the goal of this study is to demonstrate what the possible improvements can be, which could be of great value in consideration to enter into collaboration and information sharing.

5.4.3. Design Option 6: Input Controller KLM Cargo

As stated, one of the main causes of the low performance of the warehouse handling processes of climatized goods at KLM Cargo is the irregular arrival pattern of cargo. In order to prevent defects within the processes at KLM Cargo, an input controller can be used. The input controller decides whether climatized goods are accepted by KLM Cargo or the decision is made to reject the cargo. Whenever KLM Cargo has insufficient capacity, the integrity of the processes can not be guaranteed and therefore devaluation of the product may occur. On the long term, forwarder might not send their shipments with KLM Cargo as they have a high possibility of defects.

In this design option, an input controller decides what happens to the cargo arriving at the warehouse. When COL goods arrive at the KLM Cargo warehouse, the input controller predicts if the warehouse handling processes have sufficient capacity to handle the freight in an adequate manner. It does so by calculating the time left in each step of the handling processes for the freight that is present at the warehouse at that moment. In this way, a prediction can be made on the possibility of having sufficient capacity for additional COL goods. If the controller decides there will be enough capacity, the cargo may enter the warehouse. If this is not the case, a waiting time is given to the truck which resembles the amount of time before the cargo can be accepted. As the trucks are refrigerated, the COL goods are not stored out of refrigeration.

Simulation and Results

In this chapter, the discrete event model of the current warehouse handling processes at the Schiphol hub of KLM Cargo is discussed. It is important to notice that from this point in the research, the real life situation is translated into a model and the following results and conclusions are based on the outcome of the simulation model. To give insight into the process of developing the model the different steps taken are discussed in this chapter. First the purpose of the model is and the model properties are discussed. The model design is elaborated on after, which is followed by the assumptions made and the verification and validation. This chapter will provide the answer to the following research question:

(e) *How can the alternative scenarios be assessed using simulation?*

(f) *How do the redesigned scenarios improve the performance of the handling processes?*

6.1. Model Properties

Anylogic is used to create a discrete event simulation model of the warehouse processes of COL goods. The model's purpose is to use the inputs and controls shown in figure 6.1 to determine the effects of these controls on the model's output, which includes the determined KPI values. The input data is collected and synthesised from the data as described in the previous chapter. The delivery deadlines are as follows:

- IN + 60
- DEP - 300
- DEP - 120

These values are found in the handling manual of KLM Cargo [28].

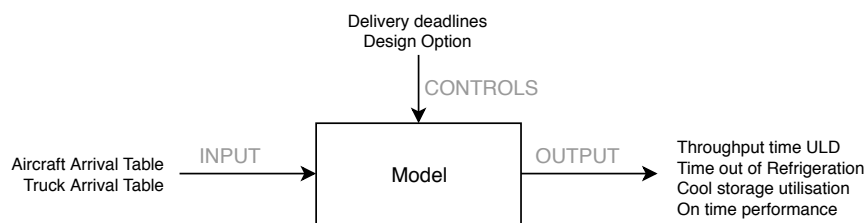


Figure 6.1: Input and output of the simulation model.

The conceptual model, which is shown in figure 6.2, is used to model the process logic of the simulation model. In the current situation, cargo arrives at the warehouse by aircraft or truck. After arrival at the warehouse, the cargo is put onto a buffer zone and waits to be picked up for breakdown by warehouse employees. The cargo is 'pushed' to the breakdown area, as the freight is supposed to be broken down as soon as possible. After the cargo has been broken down, it is checked whether the flight the cargo is scheduled on, departs within 8 hours. If this is the case, the freight is not stored in a refrigerated storage area but is brought directly to the flight buffer to await the process of building up. If the freight has a transit time of more than 8 hours after breakdown, the freight is transported to a refrigerated storage area where it is stored until approximately 300 minutes before departure. The cargo is picked from the refrigerated storage area by warehouse employees and it is taken to a flight buffer, where it awaits build up. When a build up pit and its employees are available, they will start building up the freight onto ULDs. When this process is done, the ULD is transported to a PU lane through the PCHS and is ready to be picked up by the Transport department for further transport to the aircraft.

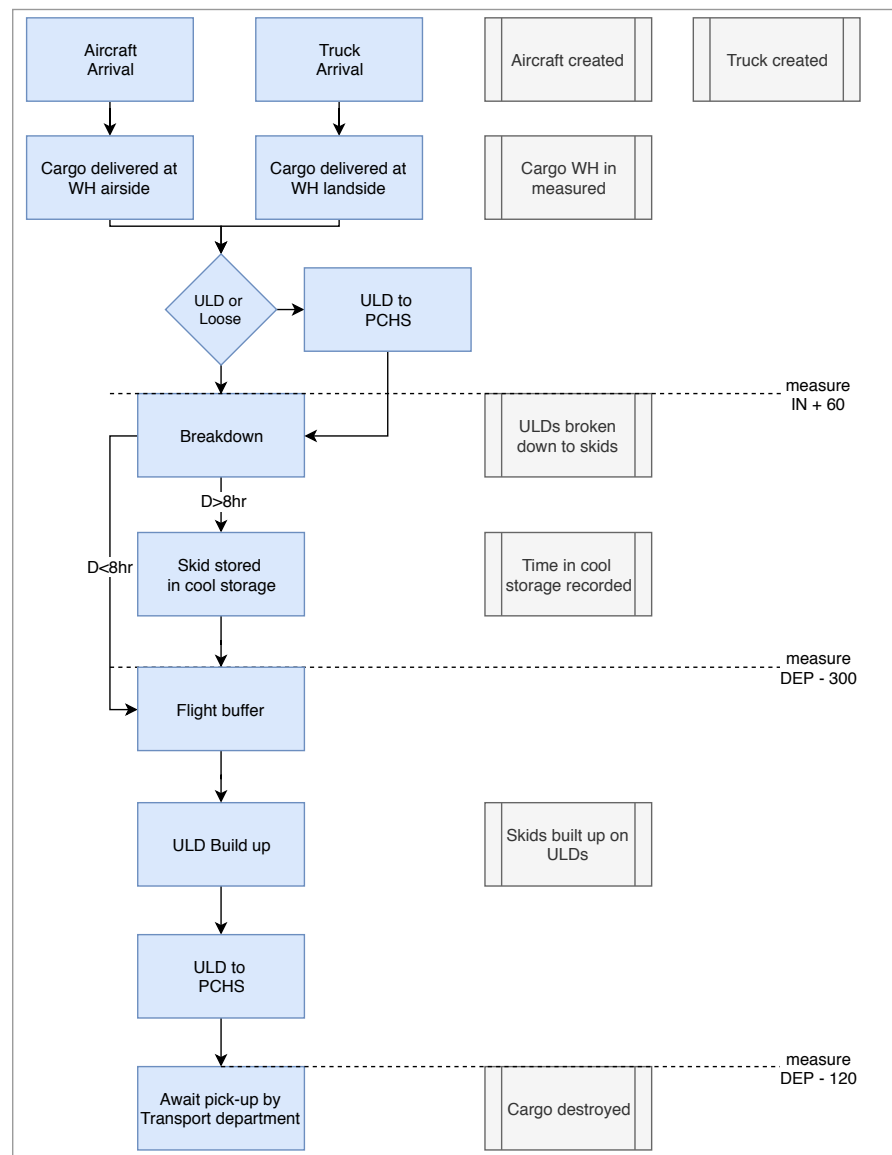


Figure 6.2: Conceptual model of the current state.

6.2. Model Design

The warehouse processes are modelled in Anylogic, using 3.6 and 3.7 as a blueprint. The model consists of a network of nodes and links. Cargo entities are generated by a source at the cargo warehouse according to the arrival tables synthesised in Excel and Matlab. Each cargo entity is assigned its properties at the time of generation. The entities enter the warehouse after generation and wait in queues to get picked up by resources for further handling. The first handling process is the breakdown process. Here ULDs are broken down into several skids, according to a distribution derived from historical data. The ULD entities are destroyed and at the same time multiple new entities are generated which represent the skids the ULD is broken down into. The skid entities go into (cooled) storage to await to be picked up by resources for the build up process. At the build up process, several skids with the same destination are assigned and the ULD is given a process time depending on the type of ULD it is built up on. After the skids are built up on a ULD, the skid entities are batched onto a single entity. When all handling procedures are completed, the cargo leaves the warehouse and the entities are destroyed.

6.3. Model Assumptions

In order to model the current situation of warehouse handling for COL goods, a number of simplifying assumptions are made:

1. All skids that have a transit time of less than 480 minutes after the start of breakdown, do not go into cool storage.
2. As build up and breakdown employees are not dedicated to COL products, waiting times are added to COL shipments to imitate warehouse employees that are busy with building up other ULDs. The amount of employees is the same for all design options.
3. To compensate for the import and export flows that also have skids that enter the cool storage, the cool storage capacities are decreased by 20%. This is done as the transit flow consists of 80% of all the COL goods that enter the warehouse.
4. Transportation between different processes times are incorporated in the process times.
5. The number of available breakdown and build up pits are not modelled separately, as they are directly related to the number of employees that is available. It is assumed that employees work in teams of 6 and 2 employees, and represent a breakdown or build up pit as a whole.
6. If one of the cool storage facilities has insufficient capacity, it is allowed for cargo to be stored in the other cool storage facility. It is however seen as a violation, due to the regulations set by CEIV, and therefore it is tracked in the KPI 'overcapacity cool storage'.
7. The transit time, or the time the freight is delivered at the warehouse before the scheduled departure time, is drawn from a distribution fitted on empirical data. The latest acceptance time is assumed to be 300 minutes and the earliest acceptance as 3 days prior to scheduled departure.
8. The number of empty skids and ULDs is assumed to be infinite.

6.4. Verification and Validation

The model must be verified and validated to ensure that this model has been built according to the specifications of the conceptual model, that the model behaves as expected and that is an accurate representation of the real system [29]. The model will be verified first, after which the model's representation of the real process will be validated.

Verification

Verification is used to determine whether the model has been built correctly, i.e. give answer to the question *"Is the model right?"*. In the verification it is tested whether the model follows the logic described in the conceptual model. Throughout the modelling, test runs were executed to make sure that all entities behaved the way that they are intended. The conceptual model has also been verified by employees of KLM Cargo.

The model's behaviour to changes in the input is also measured by setting up various scenarios where an input parameter is altered in order to determine whether the model's response is as can be expected. Each scenario is run 25 times and the average KPI values are shown in the table 6.1.

Scenario	TPT [min]	Time in KC [min]	TOR [min]
Baseline			
Cargo arrivals +25%			
Cargo arrivals -25%			

Table 6.1: Results of verification of the model.

Another verification strategy is done by making use of the entity tracing. By running the model and tracing single entities, it can be made sure that no entities follow impossible paths or had processing times that are off limit. As a last verification, it is checked whether the amount of entities created is equal to the amount of entities destroyed (or still in the system) at the end of the run.

Validation

Validation is the step in which the quality of the model is assessed and it is investigated if the model portrays reality sufficient. In other words, *"Is it the right model?"*. In order to test the model's validity, the output of the model is directly compared to the KPI values calculated from the empirical dataset. The values are put side by side in table 6.2 together with the simulation model's performance and deviation of the empirical dataset.

Output parameter	Empirical data	Simulated value	Difference
Throughput time [min]			
TOR [min]			
IN+60 [%]			
DEP-300 [%]			
DEP-120 [%]			

Table 6.2: Results of validation of the model.

A model that is 100% valid does not exist, except for the real system itself. A simulation model can however imitate the real system accurately. As can be seen in table 6.2, there are slight differences between the outcome of the model and the real life situation. However, the model is deemed valid due to the small differences between the model and actual situation.

6.5. Model Design Options

The DES described above represents the warehouse handling processes at Schiphol hub. In order to simulate the effects of the design options, they have to be implemented in the model. The different design options are implemented in the model as follows:

Design Option 4: Eliminate Process Steps

In this design option, the non-value added processes are removed. There is one major change in comparison with the current state. Currently, all cargo that enters or leaves the warehouse goes through the PCHS. In this design option, ULDs entering and leaving the warehouse do not enter the PCHS, which might allow for faster warehouse handling and thus a decrease in TOR.

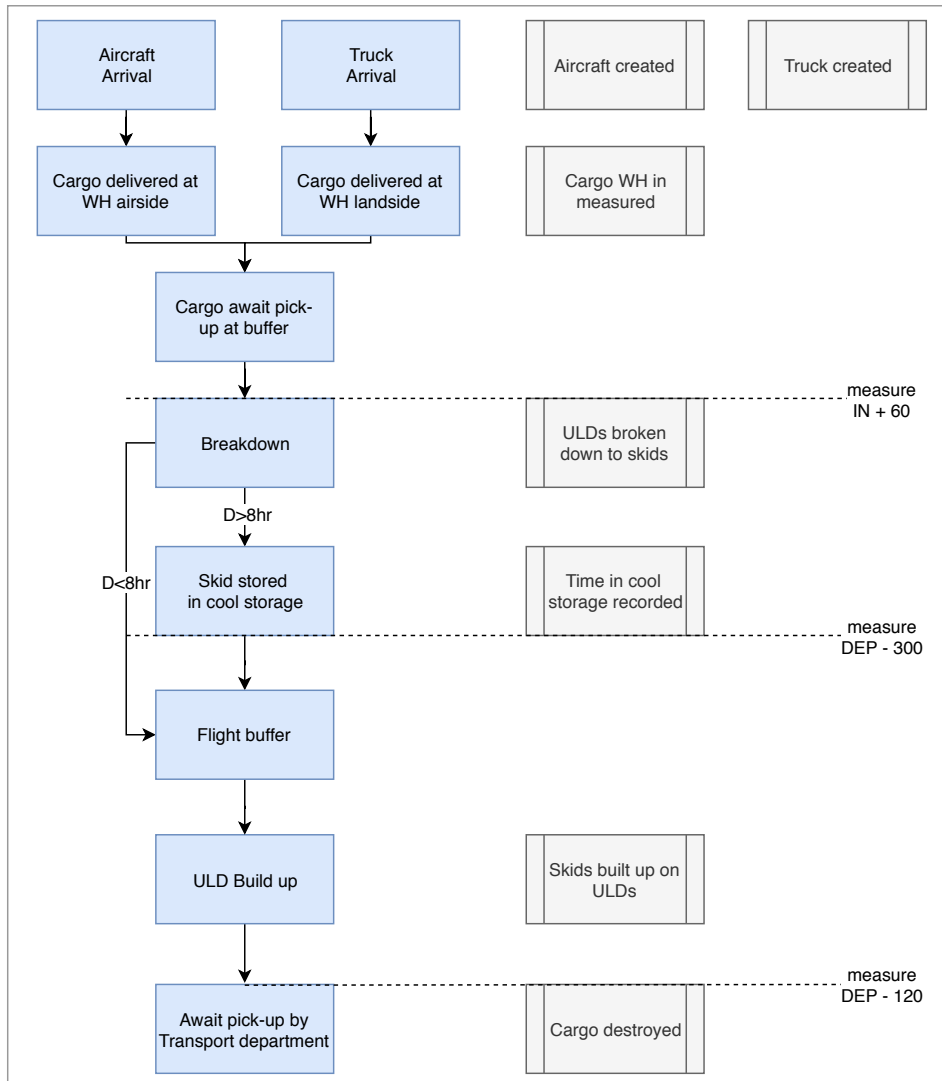


Figure 6.3: Conceptual model of design option 4: Elimination of process steps.

Design Option 5: Levelled Truck Arrivals

In design option 2, it is assumed that the Neutral Control Tower is in place and all information is shared between the parties involved in the supply chain and is thus also available to KLM Cargo. Due to the centralised control tower it is possible for KLM Cargo ensure the trucks arrive exactly when they want to. This is implemented in the model by dividing the arriving trucks into slots in a way that the freight arrives at the warehouse in equal time intervals, this means a truck will arrive at the warehouse every 51 minutes. Altering of the aircraft arrival pattern is not deemed possible in this design option, as they are bound to time-slots in which they can arrive at Schiphol airport. Therefore, the arrival pattern of cargo arriving by aircraft is not altered. Next to that, cargo is mainly transported on passenger flights where the passengers have priority. Therefore, it is not possible for KLM Cargo to alter these flights.

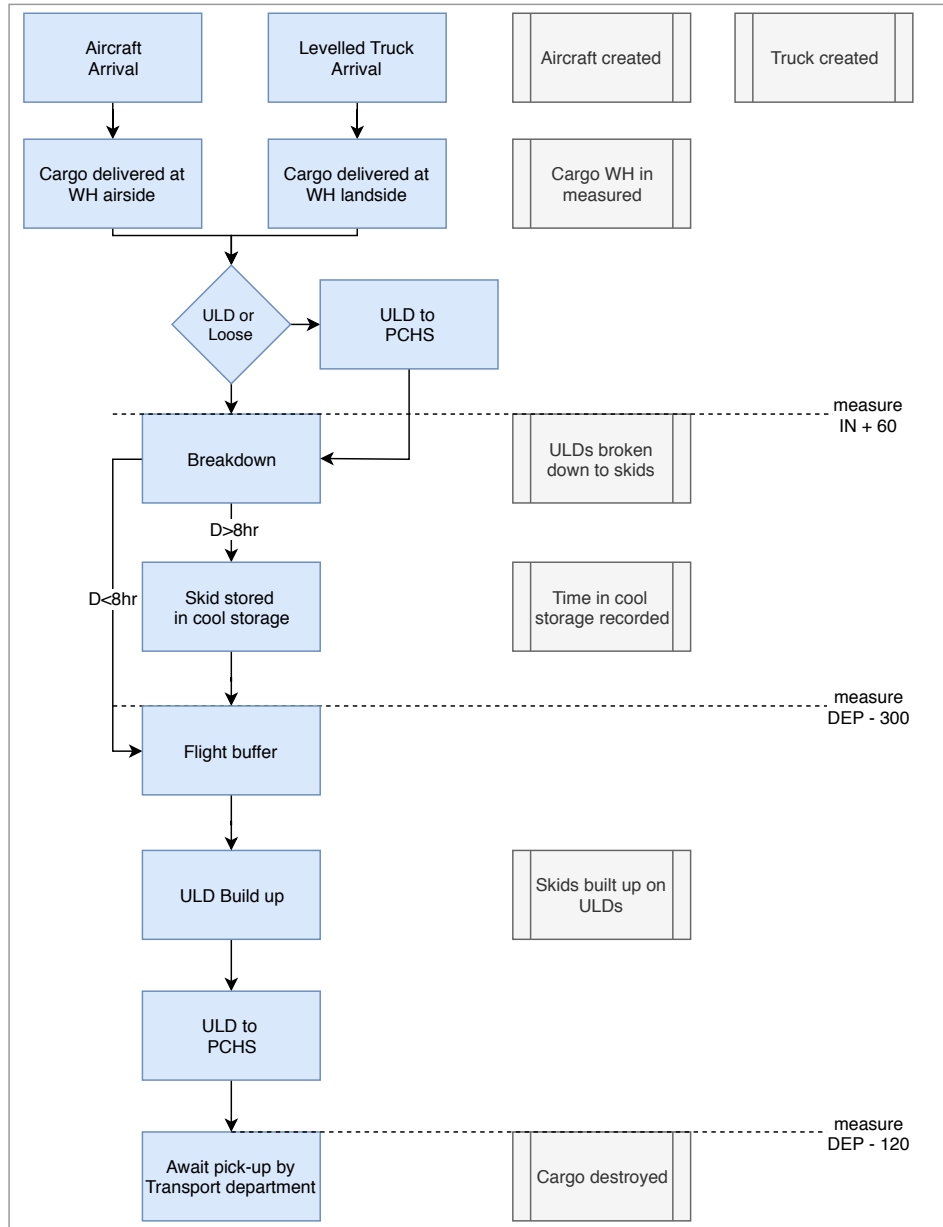


Figure 6.4: Conceptual model of design option 5: Levelled truck arrivals.

Design Option 6: Input Controller KLM Cargo

In this scenario, centralised control is not yet in place and KLM Cargo will therefore control the arrivals of cargo based on their own information. An input controller decides whether cargo is accepted on the premises of KLM Cargo to unload their freight or not. Whenever cargo arrives at the hub, it is considered whether the cargo can be handled on time and in an adequate manner according to the rules and regulations. If this is not the case, the cargo is given a waiting time until the moment there is sufficient capacity available and the freight can be unloaded at the warehouse.

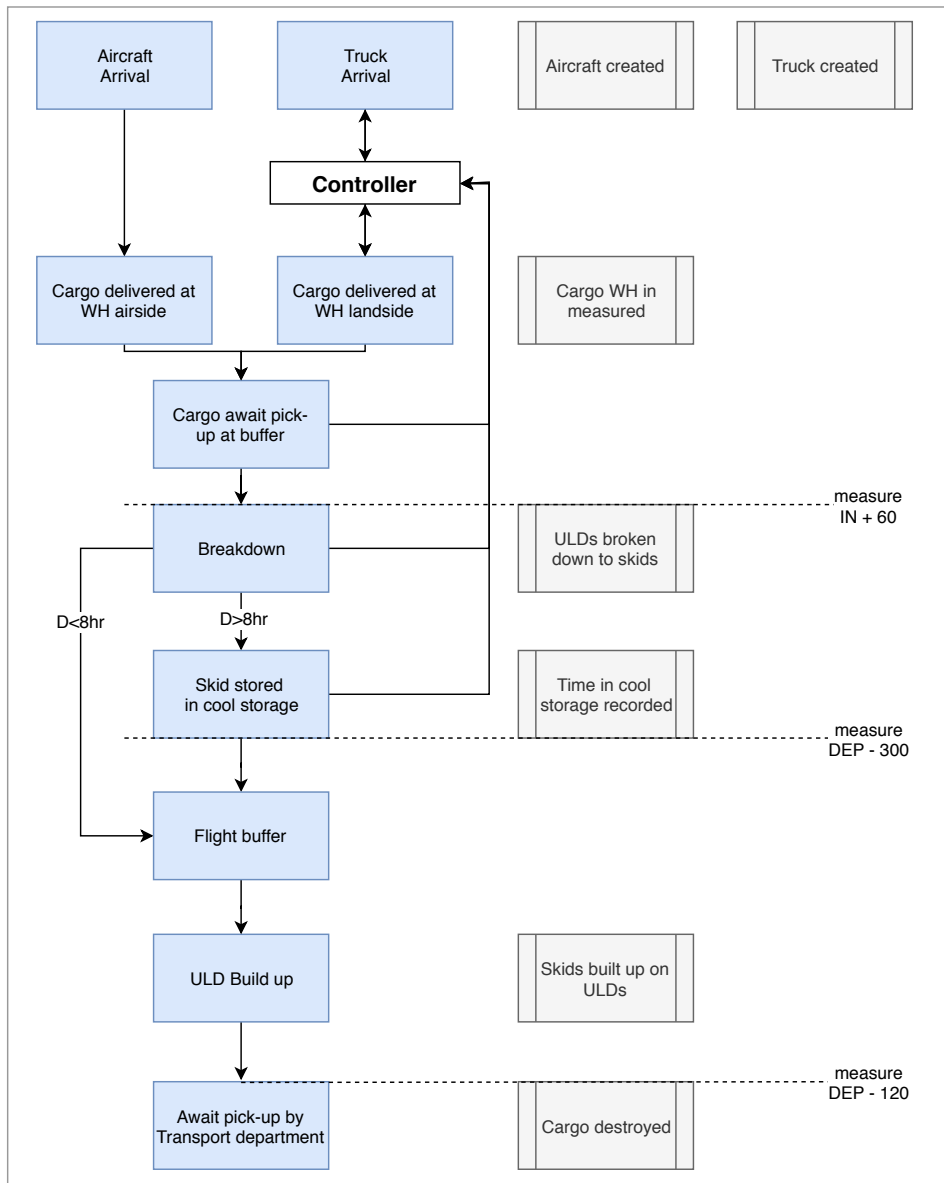


Figure 6.5: Conceptual model of design option 6: Input Controller KLM Cargo

6.6. Results

In order to predict the effect of the design options, the different design options were tested in the DES model. The design options were implemented in the model as described in the paragraph above and the results of each of the design options can be seen in table 7.1.

Design Option	TOR [min]	Storage Violations [#]	IN+60 [%]	DEP-300 [%]	DEP-120 [%]
Baseline					
Option 4					
Option 5					
Option 6					

Table 6.3: Simulation results of different design options.

Baseline

The performance of the current state, which was also shown in the verification and validation, shows that the average TOR of a shipment is █████ minutes, or approximately █████ hours. Keeping in mind that the average transit time of a shipment is █████ minutes, COL goods are out of refrigeration at the Schiphol hub for about █████ of the time. Next to that, the arrival pattern of cargo is not levelled as discussed which results in cool storage violations. On average, there are █████ skids per year that can't go into the (correct) refrigerated storage area. This is approximately █████ skids per day.

Design Option 4

Significantly more cool storage violations can be seen in design option 4, where non-value added processes are eliminated, compared to the baseline scenario. This can be explained by the fact that shipments arrive at breakdown earlier, and are therefore also done at breakdown earlier than in the current situation. As the remaining transit time is evaluated at this point to decide whether a shipment goes into refrigerated storage or not, there is more cargo that has more than 8 hours transit time left. This means that there will be more cargo that needs to be stored in a refrigerated area. With the same capacity in refrigerated area, this results in more cool storage violations. The two refrigerated area's combined have sufficient space however, which means the cargo will be stored in the other refrigerated area (the 'wrong' one). The fact that the cargo does go into refrigerated storage and that the time it takes for a shipment to reach the refrigerated storage area declines, results in a lower TOR.

Design Option 5

For design option 5, the arrival pattern of cargo arriving by truck is levelled due to collaboration within the supply chain. Due to a more levelled arrival, the peaks that usually occur are levelled and less storage violations take place. The TOR does not decrease as much as with design option 4, which implies that waste still occurs at several steps in the process and the influence of levelled cargo arrival is less significant on the TOR than the removal of the non value added processes.

Design Option 6

In design option 6, there will be no storage violations if the controller is designed perfectly. As can be seen however, 1,010 storage violations still occur per year which is due to imperfect predictions by the controller. The TOR does decrease significantly which can be explained by the fact that rejected there is sufficient capacity in the refrigerated areas at (almost) all times, and the fact that rejected cargo will have a shorter time at the hub due to the added waiting time in the refrigerated trucks.

6.6.1. Chosen Design Option

The most important KPI the design option will be chosen on, is the TOR, as was stated in the objective of this research. Design option 4 significantly decreases the TOR, but performs the worst on storage violations, and it is therefore not chosen. Design options 5 and 6 have a better overall performance on the KPIs and therefore one out of these two design options will be chosen.

Design option 5 shows to be a good option for the improvement of the handling processes. However, due to the dependence on other parties in the chain, this design option is not realistic for KLM Cargo to be implemented on the short term. It is advised to KLM Cargo to proactively look for participation in sharing data with other departments and actors within the chain in order to make design option 5 a feasible solution for in the future.

It is suggested to KLM Cargo to implement design option 6, as this option is relatively easy to implement and shows a big improvement on the performance. The design option might also create an incentive for truck arrivals to level out, as they will have an added waiting time if they keep arriving in the current pattern. The higher chance of missing a flight is rather small and should therefore not be a reason for not implementing design option 6.

7

Conclusion

In this chapter conclusions will be drawn from the case study at KLM Cargo and the simulation model used. The answers that are given to the subquestions in the previous chapters will be discussed, followed by the answer to the main research question.

7.1. Conclusions

In order to give answer to the main research question, subquestions have been answered. In this research, the current state of the handling processes of temperature-sensitive goods was looked into in order to answer the following subquestion:

(a) What is the current state of the handling processes of temperature-sensitive goods in the warehouses of KLM Cargo?

Currently, climatized goods arrive at the warehouse in different modes, product types and cargo types. The freight can arrive by truck or aircraft, it can arrive as loose freight or as a ULD, and it can consist of pharmaceutical goods or perishables. Dependent on the type of flow, the cargo is handled in a specific way. The most important steps for COL transit M-ULDs are the breakdown, refrigerated storage area and build up. There are several deadlines set up to ensure the on time handling of freight. The refrigerated cargo should enter one of the cool storage facilities within 60 minutes after breakdown, this is a push system. The warehouse employees 'push' the freight to a cool storage facility whenever they are done to ensure refrigerated storage for as long as possible. A shipment is not stored in a refrigerate area however, when the transit time of a shipment is less than 8 hours after breakdown.

The freight is 'pulled' out of storage by warehouse employees, as a rule this can not be done more than 5 hours prior to departure. However, warehouse employees tend to bring freight to a flight buffer when they have no work in order to lower the workload for busy moments. This results in shipments that are taken out of storage too early and therefore violating the DEP - 300 deadline.

After the freight is 'pulled' out of the storage area, it is built up on a ULD. The time it takes building up a ULD depends on the type of ULD. The ULD should be ready for transport to the aircraft at least 120 before the scheduled departure to allow enough time for transportation and loading the freight into the aircraft. When the workload is too high however, freight can't be built up on time and therefore waits on the flight buffer too long causing a missed DEP - 120 deadline. This does not directly imply a missed flight however, as the transport department is capable of delivering freight that missed the deadline to the aircraft on time. This may lead to delay of aircraft.

After the current state the performance of the current state is discussed and the following subquestions are answered:

(b) How is the performance of the handling processes currently measured and monitored in terms of maintaining temperature integrity? What KPI's are used and what data is available?

(c) What relevant KPI's can be used to express the performance of the handling processes?

The KPIs currently used to measure the performance at KLM Cargo are not suitable for the performance of climatized goods. The performance is measured with the same KPIs used for general freight, which do not include indicators related to the time and temperature-sensitive nature of COL goods. Therefore, the following KPIs have been set up to measure the performance of the handling processes of refrigerated goods:

- Time out of Refrigeration [min]
- Overcapacity cool storage [# of violations]
- On Time Performance [%]

These KPIs have proven to be the most suitable when tracking the performance of the warehouse handling processes. The current performance on these KPIs can be improved. The average TOR is █████ minutes per shipment. As the value added processes take a lot less time than the TOR, waste is found in several parts of the process. The reason for this waste is found to be due a shortage of cool storage space in the correct cool cell, which is in its turn a result of the current arrival pattern of cargo at the KLM Cargo warehouses.

(d) What alternative scenarios can be used to improve the performance of the handling processes?

As the data analysis made clear, there is waste in the process that is to be eliminated. Next to that, the arrival pattern of the freight results in peaks in cargo arrivals which in turn lead to insufficient storage capacity. In order to improve the handling process there are several design options described that are a result of the analysis combined with theory. The design options are evaluated by applying constraints and requirements. The following design options are chosen to be tested:

- Option 4: Elimination of process steps
- Option 5: Levelled truck arrivals
- Option 6: Input controller at KLM Cargo

In order to evaluate whether the design options improve the performance, a model is set and the following subquestion is answered:

(e) How can the alternative scenarios be assessed using simulation?

First, a queueing model is made of the current state. The current state is validated en verified in order to ensure correctness of the model. The model shows to be a good representation of the real system. After the current state was verified and validated, the different design options are implemented in the model tot test their performance on the KPIs. For the first design option, processes have been removed or process times have been altered to simulate the removal of non-value added processes. To simulate the supply chain collaboration, a truck scheduled has been set up in which trucks arrive at levelled time slots. In order to simulate design option 6, a controller has been developed that decides when freight can enter the warehouse upon truck arrival. The results of the different improvement scenarios are shown by answering the next subquestion.

(f) How do the redesigned scenarios improve the performance of the handling processes?

The redesigned scenarios improve the performance significantly. The redesigned scenarios are implemented in the model and their performance is tested with the KPIs that are set up in chapter 4 in order to compare the scenarios with each other and with the baseline, which resembles the current state. The performance of the different scenarios can be seen in figure 7.1.

Design Option	TOR [min]	Storage			
		Violations [#]	IN+60 [%]	DEP-300 [%]	DEP-120 [%]
Baseline					
Option 4					
Option 5					
Option 6					

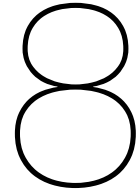
Table 7.1: Simulation results of different design options.

The TOR decreases with all design options. As can be seen in table 7.1, the TOR decreases the most when design option 6 is implemented. The storage violations significantly decrease in options 5 and 6, but increase for design option 4. This can be explained by the fact that shipments arrive at breakdown earlier and therefore the remaining transit time increases. Due to an increased transit time for several shipments, there are more shipments that have to enter the refrigerated area. It is however important to make notice that the performance on the DEP-120 deadline decreases for design option 6, which can be explained by the fact that shipments enter the warehouse later on average and therefore have a higher chance of missing their flight.

All the subquestions are set up to give an answer to the main research question. The main research question to be answered in this research was:

'How can the overall performance of the handling processes of temperature-sensitive goods in the KLM Cargo warehouses be improved?'

The overall performance of the handling processes of temperature-sensitive goods in the KLM Cargo warehouses can be improved by decreasing the TOR, while the amount of storage violations and OTP on the deadlines do not deteriorate. The KPIs that are described in this research have to be implemented so that the performance of the handling processes can be measured, more specifically the performance for climatized goods. The KPIs that are addressed in this research are the time out of refrigeration, the number of storage violations per year and the performance on several deadlines. Different design options can be used to improve the overall performance. Design option 5 shows to be a good option for the improvement of the handling processes. However, due to the dependence on other parties in the chain, this design option is not realistic for KLM Cargo to be implemented on the short term. It is advised to KLM Cargo to proactively look for participation in sharing data with other departments and actors within the chain in order to make design option 5 a feasible solution for in the future. It is suggested to KLM Cargo to implement design option 6, as this option is relatively easy to implement and shows a big improvement on the performance. The design option might also create an incentive for truck arrivals to level out, as they will have an added waiting time if they keep arriving in the current pattern.



Recommendations

In this chapter, first the limitations of this research are discussed after which the recommendations for future research are elaborated on.

8.1. Limitations

This research has a number of limitations. First of all, the model is a simplified display of reality. In reality, the system is very complex and has a lot of different influences from within KLM Cargo as well as external influences. The employees at KLM Cargo have a lot of tacit knowledge, which is very hard to include in the model.

Secondly, the quality of the data provided by the department of Performance Management is deemed not very high. A lot of data is missing or data is found not to be logical which is most likely a result of manual input by warehouse employees. Due to this, data has been synthesised but may therefore not represent the actual system perfectly.

For the purpose of this research, design option 5 was based on an ideal situation where optimal supply chain collaboration was assumed. In practice it is very hard to achieve this ideal situation, and the results of this design option should therefore merely be used to demonstrate the potential benefits of improved supply chain collaboration.

8.2. Future Research

Based on available data and literature, KPIs are set to monitor the performance of the handling processes of COL goods. It is advised to KLM Cargo to implement these KPIs and include performance measurement for the other types of shipment that require special handling due to temperature regulations. In this way, standards can be set for all temperature-sensitive goods and the quality of the handling processes can be monitored more easily.

Another advice to KLM Cargo would be to investigate the needs for future rules and regulations. Currently the focus is on compliance with the IATA CEIV and GDP guidelines. Although the outcome of this research describes a set of KPIs that could be considered to be more than compliant to these guidelines and therefore is ahead on the future tightening of the regulations, it would be wise to have a more specific view of what the future in respect to regulation will bring. Not only to be able to comply in the future, but also to already now distinguish the quality of the services and integrity of the process from the other airlines and ground handlers handling temperature-sensitive freight by setting the standard instead of following the standard.

For future research, it is recommended to look into the performance of the entire cool chain. Thus, extend this research to the entire supply chain of refrigerated goods from shipper to

consignee. It would be of great value to look into the performance of the entire chain on different lanes. In this way, the most vulnerable processes can be determined and improvements can be made on parts of the chain where it is most beneficial. Next to that, a study should be done on the devaluation of cargo that is not stored in a refrigerated area. In this way, defects that occur in the supply chain of temperature-sensitive goods could be translated to costs more easily.

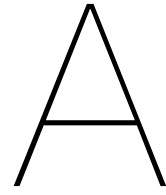
Future research should also investigate the effect of the temperature on the climatized goods. When temperature maps are available, the most optimal storage locations can be determined within the warehouse. Next to that, it should be investigated whether it is more harmful for a shipment to be stored out of a refrigerated area multiple times for a short period of time, or once but for a longer amount of time.

Further research should also be done improving the input controller. When more data becomes available and forecasts can be used, it is possible to control the system more dynamically and based on the expected demand patterns. A fast reconfiguration of the system or a dynamic human resource planning not based on the current shifts are interesting topics for further research as it may increase the performance of the system even more.

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Scientific Research Paper

The following pages contain the research paper written on the research presented in this thesis.

Improving the Overall Performance of the Warehouse Processes of Temperature-Sensitive Goods within the Warehouses of KLM Cargo at the Schiphol Hub

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Abstract - A significant part of the revenue generated by KLM Cargo comes from transporting temperature-sensitive goods. Currently KLM Cargo faces quality issues in the handling processes of these goods. This paper explores the possibilities of improving the overall performance of the warehouse handling processes of these goods in order to overcome these issues. New KPIs have been set up to describe the performance of the handling processes. These KPIs include the TOR (time out of refrigeration), storage violations and on-time performance. Different design options are proposed to improve the performance of the handling processes. The different design options are simulated using a DES model. The resulting KPI values for the different design options are evaluated to determine the most effective improvement. The results of the simulation show that the implementation of an input controller at KLM Cargo leads to the highest increase in performance of the handling processes of temperature-sensitive goods.

Keywords: Cargo Handling, Schiphol, Temperature-Sensitive Goods, Cool Chain, Warehouse Handling Processes, Time out of Refrigeration, OTP, DES.

I. PROBLEM DEFINITION

A. Introduction

The air cargo sector moves only 2% of the global volume of goods, but adds up to a huge 35% by value, reserved for the most costly products [1]. Air transport plays a crucial role in the transportation of pharmaceuticals and perishables. The world is facing a huge population growth which brings along several challenges such as a high level of malnutrition and a high need for medicine [2]. It is a major global challenge to ensure adequate food supply and quality, as well as providing adequate healthcare worldwide [3]. Due to the nature of these

products, a temperature controlled supply chain is crucial [4][5].

KLM Cargo face quality issues with the handling processes of these temperature-sensitive and therefore the cool chain program has been set up. This program aims to address the problems in the supply chain of temperature-sensitive goods. Currently, there is a lack of insight in the performance of the handling processes as no adequate KPIs are used that describe the performance accurately. The unpredictability of demand for cargo handling is also highly unfavourable. Next to that, there is insufficient capacity of refrigerated storage area where the temperature-sensitive goods are stored.

B. Case Study: KLM Cargo

This research problem is addressed in a case study at the warehouses of KLM Cargo located at Amsterdam Airport Schiphol (AAS). Currently the performance of the warehouse handling processes of temperature-sensitive goods is not measured adequately and temperature excursions take place. This research aims to determine how the performance of the warehouse handling processes can be quantified, analysed and improved by answering the main research question:

How can the overall performance of the handling processes of temperature-sensitive goods in the KLM Cargo warehouses be improved?

The scope of this research is limited to transit shipments at the hub that require at least the handling steps of breaking down or building up a shipment. As the research question states, only the processes that occur within the warehouse are looked into from warehouse arrival until warehouse departure.

C. Methodology

In order to analyse the warehouse handling processes in a structured way, the Delft Systems Approach (DSA) is used in this research. DSA is used because it follows a systems approach and is very suitable to use as a basis for simulations. It provides a disciplined methodology to determine the structure of systems, based on describing systems in terms of functions and control. For every task in the process its contribution to the system performance is quantified. Out of process requirements, quantitative standards are derived. The extent to which these standards (and thus requirements) are met, is quantitatively measured in process performance. The PROcess-PERformance (PROPER) model is introduced as a tool for the description of the system and all aspects of the system and its interrelations are analysed [6].

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The demand pattern for cargo handling is evaluated for which a categorisation scheme proposed by Syntetos et al. is used [7]. The categorisation is based on the average inter-demand interval (ADI) and the squared coefficient of variation (CV^2). It is important to determine the categorisation of demand in order to apply the correct measures to smooth the demand.

A discrete event simulation (DES) is used in this research. Experimenting with a physical model or finding an analytical solution is also not feasible due to the complexity of the system. Therefore, a mathematical model in the form of simulation is the best approach [?].

II. CURRENT STATE

The current state of the cargo handling of temperature-sensitive goods at the KLM Cargo warehouses at the Schiphol hub is studied in order to determine the shortcomings and seek for improvement possibilities.

A. Cargo Characteristics

The temperature-sensitive cargo that is handled at KLM Cargo can be classified as either perishables (*fresh*) or pharmaceuticals (*pharma*). This research addresses temperature-sensitive goods that should be kept between 2 °C and 8 °C at all times, these are classified by the special handling code COL (cool goods). The temperature range of these goods is determined by the IATA, as well as the rules and regulations of airport operations which are followed by cargo handlers worldwide [8].

Cargo arrives at the KLM Cargo warehouses in two different transport modes, either by truck or by aircraft. The process that shipments go through, is dependent on their configuration. The freight can arrive in different configurations; as T-ULD, M-ULD or as loose freight. A T-ULD, or through ULD, is palletized shipment that already has the configuration it is required to have for further transportation. As all freight on the ULD has the same destination, no further handling is required at the KLM Cargo premises. Cargo arriving as M-ULD, or mixed ULD, consists of palletized freight with multiple destinations and thus the cargo has to be broken down into individual shipments. Later in the process the loose shipments are built up on a ULD again with shipments that have the same destination and departing flight. Loose freight is freight that is delivered at the KLM Cargo warehouse and not yet built up on a ULD. Loose freight is delivered either in loose packages or on a skid (wooden pallet).

B. Warehouse Handling Processes

The warehouse handling processes consist of multiple steps of which the most important steps will be elaborated on in this section. A schematic overview of all the steps that take place within the warehouse of KLM Cargo from arrival (ARR) to departure (DEP) can be

seen in FIG. 1. The red dots indicate data measurement points and the dashed lines show different deadlines that are used within the warehouse processes, which will be used later in this research.

PI/PU — The 'Pallet Inslag' (PI) and 'Pallet Uitslag' (PU) lanes are the locations where the cargo is transferred from outside to inside the warehouse.

PCHS — Cargo arriving as ULD enters the warehouse through the Pallet and Container Handling System (PCHS). The PCHS is a storage facility situated above the warehouses of KLM Cargo and is used for the storage and transloading of ULDs.

Breakdown — M-ULDs require further handling in the warehouse because they contain shipments for multiple destinations. The ULDs are lowered onto the breakdown area from the PCHS, after which a breakdown team will decompose a pallet and split the shipments according to their destination. After decomposing the pallet, the shipments go to either the flight buffer area or one of the cool storage areas depending on the time left until departure.

Cool Storage — As the transit time of arriving freight often exceeds the time needed for handling, storage is inevitable. For temperature-sensitive goods it is important that the temperature is maintained and therefore there are multiple cooled storage areas within the warehouses. KC02 is a refrigerated storage area that is used for perishables and has capacity for 117 skids, KC04 is a refrigerated storage area used for pharmaceuticals and has capacity for 40 skids.

Buffer — Shipments are collected on flight buffers before they are placed on a pallet. A flight buffer is an area on the operational floor that is reserved to collect shipments for a specific flight. A flight buffer opens 24 hours prior to departure and from that moment freight can be moved from the breakdown area and storage facilities to the flight buffers.

Build Up — Build up workers are assigned to put shipments from the buffers onto empty ULDs on the build up sites. They build up the different shipments on a ULD and cover it with plastics and a net. After some safety checks the pallet is finalised and provided with the status Ready For Flight (RFF), after which the ULD is moved into the PCHS and is delivered at a PU lane where it awaits further transport.

C. Delivery Deadlines

Due to the rules and regulations that apply to the handling of temperature-sensitive goods, KLM Cargo has set up 'Hub rules' for the handling of COL goods. The following rules are stated in the handling manual of KLM Cargo [9]:

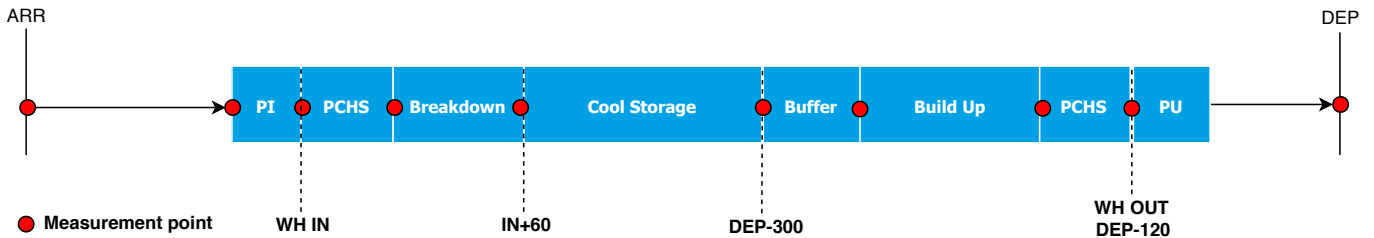


FIG. 1. Schematic overview of warehouse handling processes and delivery deadlines.

IN+60 — COL goods should arrive at a cool storage location 60 minutes after breakdown at the latest. This deadline is set up to ensure that the temperature-sensitive goods are stored in a refrigerated area as soon as possible.

DEP-300 — After storing the goods in a refrigerated storage area, they can be transferred to the flight buffer from 5 hours prior to departure. This rule is set up to make sure the COL goods are stored in the refrigerated storage area as long as possible. Warehouse employees tend to start building up ULDs early when there is no other work to be done which, in the case of COL goods, may cause temperature excursions if started too early.

DEP-120 — Freight has to be delivered at the VOP 80 minutes prior to departure. As the rides to the VOP are planned from the moment the ULD is ready and take approximately 15 minutes on average, the freight has to be present at the PU lane 120 minutes prior to departure. The ULDs also have to be ready for leaving the warehouse 120 minutes before departure for load control in the aircraft.

D. Key Performance Indicators

In order to assess the performance of KLM Cargo's warehouse processes, a number of key performance indicators are used. The KPIs currently used to define the performance of the processes are deemed inadequate and therefore new KPIs have been set up which can be seen in TABLE I.

TABLE I. Key Performance Indicators

KPI	Magnitude	Unit
1. Time out of Refrigeration (TOR)	Time	[min]
2. Overcapacity cool storage	Violations	[#]
3. On Time Performance (OTP)	Fraction	[%]

1. Time out of refrigeration (TOR) is the amount of time that a product is outside of its specified temperature range. In this research, the TOR is calculated by subtracting the time a shipment is stored in refrigerated storage area from the total time a shipment is present in the KLM Cargo warehouses. The KPI is expressed in minutes, as an absolute value is the best measure to depict the performance. 2. Overcapacity cool storage is the number of times there is a lack of capacity in one of the refrigerated storage areas. Whenever the capacity

is insufficient, devaluation of cargo may occur which in its turn may result in loss of revenue. Therefore, it is important to keep track of the capacity of the cool storage. 3. On Time Performance (OTP) of the handling processes will be evaluated at the different delivery deadlines in the process. The IN+60, DEP-300 and DEP-120 deadlines will be used to evaluate the OTP.

E. Data Analysis

The arrival pattern of COL goods is found to be erratic. Due to the erratic pattern, it is hard to align the warehouse processes with the availability of cargo. The arrival pattern shows fluctuations on weekly, daily and hourly levels. On a daily level, the so called 'weekend effect' can be seen (FIGURE 2). This effect can be explained by the fact that forwarders send out their shipments just before or after the weekend, as they are usually not operating in weekends. The cargo transported just before the weekend arrives at KLM Cargo on Saturday and Sunday, and the cargo transported after the weekend arrives on Tuesday.

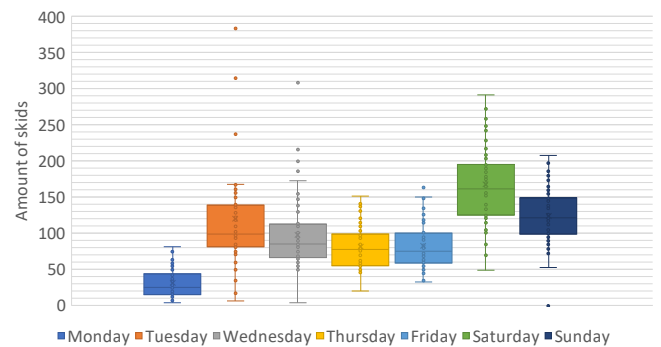


FIG. 2. Average number of skids arriving per day (2018).

The cargo supply also shows a large deviation on hourly arrivals as can be seen in FIGURE 3. Most of the trucks for example, arrive between 23:00 and 4:00 which seems beneficial as there are no aircraft that arrive between these hours. However, the amount of freight arriving by truck at certain hours is still large enough to be the cause of the peak hour value for the entire day. The cargo arrival of trucks should be spread out more evenly to ensure more efficient handling at the hub.

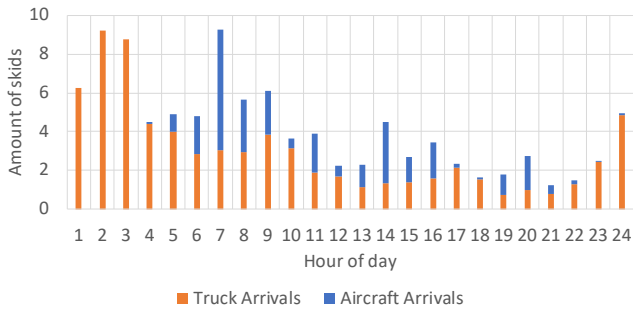


FIG. 3. Average number of skids arriving per hour (2018).

Due to the volatility in cargo arrival patterns, adequate handling is difficult for KLM Cargo. Therefore, solutions for a more even distribution of cargo arrivals are desirable. There are also several steps in the process where waste occurs, especially when the cargo is stored in the PCHS. When the cargo is stored in the PCHS, it is not refrigerated and waiting times occur due to the planning of cargo handling by the IT system that is linked to the PCHS. These parts of the process should be eliminated for an improved warehouse handling process.

III. FUTURE STATE

A. Ideal State Cargo Handling

The ideal state for the handling of temperature-sensitive goods would be a lean concept in which information is digitally shared throughout all parties involved in the supply chain. In an ideal state, temperature-sensitive cargo is always delivered by the customer to KLM Cargo on time. The cargo deliveries are divided over time in such a way that peaks in cargo arrivals that lead to insufficient capacity of refrigerated storage area are prevented. There is always sufficient capacity for the handling of the goods within the warehouses so temperature excursions due to lack of capacity do not take place. The on time delivery of cargo is ensured by digital information sharing between all parties involved in the supply chain which results in transparency throughout the total supply chain. Unnecessary steps, or waste, are eliminated and the cargo only goes through necessary steps for the handling. If waiting times should occur, KLM Cargo has to make sure the waiting goods are in a refrigerated storage area at all times. In this way, safe and reliable handling can be ensured.

B. Design Options

Multiple design options are evaluated in order to improve the performance of the warehouse handling of temperature sensitive goods and get close to the described ideal state. A solution for the handling processes of cargo is however bound by certain constraints, functional and non-functional requirements. These requirements define the space in which a feasible solution is to be found.

Arriving cargo must go through a breakdown and build up process and all handling processes should comply with the rules and regulations. The design option should not add extra steps to the process, thus not increase complexity. The on-time performance and number of storage violations may not deteriorate. The throughput time of cargo should not increase and the size and layout of the freight buildings may not be changed. Lastly, the cost of implementing the design solution may not be too prohibitive. There are three design options that are elaborated on further; the elimination of process steps, the levelling of the cargo arrival pattern and the use of an input controller.

After applying these requirements and constraints there are three design options left to be evaluated, namely the elimination of process steps, the levelling of truck arrivals and the use of an input controller at KLM Cargo.

Design Option 1: Eliminate Process Steps

The first step in removing waste, or non-value-added processes, is identifying where waste exists. In the handling process of cargo there are actually only two main processes that add value, these processes are the breaking down and the building up of the cargo. In lean methodology every form of waiting or inventory is considered as waste. In this research however, the refrigerated storage of goods is not considered as waste, as waiting times are unavoidable, but when the goods remain refrigerated it does not lead devaluation of the product immediately. In this design option the PCHS functions as an intermediary where the cargo is 'pulled' through without waiting time, which might allow for faster warehouse handling and thus a decrease in TOR.

Design Option 2: Levelled Truck Arrivals

The second design option to enhance the performance of the handling processes from both a company and supply chain perspective can be found in increased collaboration between parties within the supply chain. The collaboration with supply chain partners could be of added value concerning the arrival pattern of the cargo. In this design option, optimal supply chain collaboration is assumed and thus truck arrivals are levelled over time to ensure there are no peaks in the demand pattern of cargo handling at the warehouse.

Design Option 3: Input Controller KLM Cargo

In this design option, an input controller decides what happens to the cargo arriving at the warehouse. When COL goods arrive at the KLM Cargo warehouse, the input controller predicts if the warehouse handling processes have sufficient capacity to handle the freight in an adequate manner. It does so by calculating the time left in each step of the handling processes for the freight that is present at the warehouse at that moment. In this way, a prediction can be made on the possibility of having sufficient capacity for additional COL goods. If the controller decides there will be enough capacity, the

cargo may enter the warehouse. If this is not the case, a waiting time is given to the truck which resembles the amount of time before the cargo can be accepted. As the trucks are refrigerated, the COL goods are not stored out of refrigeration.

C. Simulation

Anylogic was used to make a discrete even simulation model of the warehouse processes of COL goods. The model's purpose is to use inputs and controls to determine the effects of these controls on the model's output, which includes the determined KPI values. The input used are truck and aircraft arrival tables based on historical data and the controls are the different design options and delivery deadlines.

The model was verified by measuring its behaviour to changes in the input, trace entities and do an input/output check. Since the model showed predicted behaviour the simulation model was considered to have been programmed correctly. In order to test the model's validity, the output of the model is directly compared to the KPI values calculated from the empirical dataset. As the difference in values between the empirical and simulated data are small, the model is deemed valid.

IV. RESULTS AND EVALUATION

To predict the effect of the design options, the different design options were tested in the DES model. The design options were implemented in the model as described in the paragraph above and the results of each of the design options can be seen in table II.

TABLE II. Simulation results of different design options.

Option	TOR	Storage Violations	IN+60	DEP-300	DEP-120
Baseline					
1					
2					
3					

Baseline

The performance of the current state shows that the average TOR of a shipment is █████ minutes, or approximately █████ hours. Keeping in mind that the average transit time of a shipment is █████ minutes, COL goods are out of refrigeration at the Schiphol hub for about █████ of the time. Next to that, the arrival pattern of cargo is not levelled as discussed which results in cool storage violations. On average, there are █████ skids per year that can't go into the (correct) refrigerated storage area which is approximately █████ skids per day.

Design Option 1

Significantly more cool storage violations can be seen in design option 1, where non value added processes are eliminated, compared to the baseline scenario. This can

be explained by the fact that shipments arrive at breakdown earlier, and are therefore also done at breakdown earlier than in the current situation. As the remaining transit time is evaluated at this point to decide whether a shipment goes into refrigerated storage or not, there is more cargo that has more than 8 hours transit time left. This means that there will be more cargo that needs to be stored in a refrigerated area. With the same capacity in refrigerated area, this results in more cool storage violations. The two refrigerated area's combined have sufficient space however, which means the cargo will be stored in the other refrigerated area (the 'wrong' one). The fact that the cargo does go into refrigerated storage and that the time it takes for a shipment to reach the refrigerated storage area declines, results in a lower TOR.

Design Option 2

For design option 2, the arrival pattern of cargo arriving by truck is levelled due to collaboration within the supply chain. Due to a more levelled arrival, the peaks that usually occur are levelled and less storage violations take place. The TOR does not decrease as much as with design option 1, which implies that waste still occurs at several steps in the process and the influence of levelled cargo arrival is less significant on the TOR than the removal of the non value added processes.

Design Option 3

In design option 3, the amount of storage violations is 1,010 per year which is due to imperfect predictions by the controller. The TOR decreases significantly which can be explained by the fact that rejected there is sufficient capacity in the refrigerated areas at (almost) all times, and the fact that rejected cargo will have a shorter time at the hub due to the added waiting time in the refrigerated trucks.

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The overall performance of the handling processes of temperature-sensitive goods in the KLM Cargo warehouses can be improved by decreasing the TOR, while the amount of storage violations and OTP on the deadlines do not deteriorate. The KPIs that are described in this research have to be implemented so that the performance of the handling processes can be measured, more specifically the performance for climatized goods. The KPIs that are addressed in this research are the time out of refrigeration, the number of storage violations per year and the performance on several deadlines. Different design options can be used to improve the overall performance. Levelling truck arrivals shows to be a good option for the improvement of the handling processes. However, due to the dependence on other parties in the chain, this design option is not realistic for KLM Cargo to be implemented on the short

term. It is advised to KLM Cargo to proactively look for participation in sharing data with other departments and actors within the chain in order to make this design option a feasible solution for in the future. It is suggested to KLM Cargo to implement an input controller, as this option is relatively easy to implement and shows a big improvement on the performance. The design option might also create an incentive for truck arrivals to level out, as they will have an added waiting time if they keep arriving in the current pattern.

B. Limitations of the Research

This research has a number of limitations. First of all, the model is a simplified display of reality. In reality, the system is very complex and has a lot of different influences from within KLM Cargo as well as external influences. The employees at KLM Cargo have a lot of tacit knowledge, which is very hard to include in the model. Secondly, the quality of the data provided by the department of Performance Management is deemed not very high. A lot of data is missing or data is found not to be logical which is most likely a result of manual input by warehouse employees. Due to this, data has been synthesised but may therefore not represent the actual system perfectly. For the purpose of this research, design option 2 was based on an ideal situation where optimal supply chain collaboration was assumed. In practice it is very hard to achieve this ideal situation, and the results of this design option should therefore merely be used to demonstrate the potential benefits of improved supply chain collaboration.

C. Recommendations for KLM Cargo

Based on available data and literature, KPIs are set to monitor the performance of the handling processes of COL goods. It is advised to KLM Cargo to implement these KPIs and include performance measurement for the other types of shipment that require special handling due to temperature regulations. In this way, standards can be set for all temperature-sensitive goods and the quality of the handling processes can be monitored more easily. Another advice to KLM Cargo would be to

investigate the needs for future rules and regulations. Currently the focus is on compliance with the IATA CEIV and GDP guidelines. Although the outcome of this research describes a set of KPIs that could be considered to be more than compliant to these guidelines and therefore is ahead on the future tightening of the regulations, it would be wise to have a more specific view of what the future in respect to regulation will bring. Not only to be able to comply in the future, but also to already now distinguish the quality of the services and integrity of the process from the other airlines and ground handlers handling temperature-sensitive freight by setting the standard instead of following the standard.

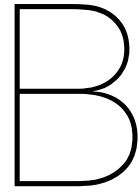
D. Future Research

For future research, it is recommended to look into the performance of the entire cool chain. Thus, extend this research to the entire supply chain of refrigerated goods from shipper to consignee. It would be of great value to look into the performance of the entire chain on different lanes. In this way, the most vulnerable processes can be determined and improvements can be made on parts of the chain where it is most beneficial. Next to that, a study should be done on the devaluation of cargo that is not stored in a refrigerated area. In this way, defects that occur in the supply chain of temperature-sensitive goods could be translated to costs more easily. Future research should also investigate the effect of the temperature on the COL goods. When temperature maps are available, the most optimal storage locations can be determined within the warehouse. Next to that, it should be investigated whether it is more harmful for a shipment to be stored out of a refrigerated area multiple times for a short period of time, or once but for a longer amount of time. Further research should also be done improving the input controller. When more data becomes available and forecasts can be used, it is possible to control the system more dynamically and based on the expected demand patterns. A fast reconfiguration of the system or a dynamic human resource planning not based on the current shifts are interesting topics for further research as it may increase the performance of the system even more.

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Handling Standards

B.1. WHO GDP

The WHO (World Health Organisation) introduced multiple practices for pharmaceutical products, such as; Good Manufacturing Practices (GMP), Good Storage Practices (GSP) and Good Distribution Practices (GDP). The GDP is applicable to the warehouses where the cargo awaits further transportation to its destination, specifically on the processes of an airline in the case of AF KL Cargo. When an airline also conducts other processes, other Practices should be taken into account as well. The GDP for pharmaceutical products is dated from 2010 and has the objective to serve as a guideline in assisting and ensuring the quality and identity of pharmaceutical products during all the aspects of the distribution process. The distribution process includes activities such as procurement, purchasing, storage, distribution, transportation, repackaging, relabelling, documentation and record-keeping practices. This research is focused on operational processes only, of whom its most important restrictions are listed below:

- Standard operating procedures (SOPs) in place have to be in place. An SOP should be a written procedure giving instructions for performing operations in a general nature (e.g. equipment operation, maintenance and cleaning, validation, cleaning of premises and environmental control, sampling and inspection).
- Quality Assurance should be done with the help of; inspections, auditing and certifications. Distributors should from time to time conduct risk assessments to assess potential risks to the quality and integrity of pharmaceutical products and being compliant with a quality system.
- Storage areas: sufficient capacity to allow storage of the various categories of pharmaceutical products offered. Also they should be clean, dry and well maintained within acceptable temperature limits. Pharmaceutical products are not to be stored on the floor.
- Temperature monitoring data should be available for review. Temperature mapping should be done in a storage facility in order to show the uniformity.
- Modalities that facilitate the transportation of goods, should be selected with care, and local conditions should be taken into account, including the climate as any seasonal variations.
- Pharmaceutical products should not be shipped towards their destination if the storage capacity at the destination is exceeded.
- The quality system in place should include self-inspections. These need to be conducted to monitor implementation and compliance according to the principles of GDP and, if necessary, to trigger corrective and preventive measures.

B.2. EU GDP

The European Union (EU) Good Distribution Practices (GDP), takes the rules and guidelines a step further than the WHO and are set in 2013. When achieving compliance with the EU GDP, it will also ensure control of the distribution chain and consequently maintain the quality and the integrity of climatized products. A change control system should be in place. This system should incorporate quality risk management principles, be proportionate and effective, and have the following restrictions in place:

- Deviations from the established procedures should be documented and investigated, and a Corrective action and Preventive action (CAPA) should be followed up after a deviation, in order to correct and prevent them in the future.
- Monitoring and review of the performance should happen on a regular basis, as well as implementation of any required improvements.
- There should be adequate separation between the receipt and dispatch and storage areas. Procedures should be in place to maintain control of inbound/outbound goods.
- Equipment used to control or monitor the environment where the pharmaceutical products are stored should be calibrated on a risk and reliability assessment. Pharmaceutical products should be prioritised above others when handling to ensure their conditions.
- Regardless of the mode of transport, it should be possible to demonstrate that the medicines have not been exposed to conditions that may compromise their quality and integrity. A risk-based approach should be utilised when planning transportation. Risk assessment of delivery routes should be used to determine where temperature controls are required. Equipment used for temperature monitoring during transport within vehicles and/or containers should be maintained and calibrated.
- Selection of a container and packaging should be based on the storage and transportation requirements of the pharmaceutical products; the space required for the amount of products; the anticipated external temperature extremes; the estimated maximum time for transportation including transit storage at customs; the qualification status of the packaging and the validation status of the shipping containers, and should be executed by the shipper.

B.3. IATA CEIV

In this section the guideline of the IATA CEIV will be explained in more depth. This is done by first investigation on IATA CEIV Chapter 17, which explains all about time and temperature related rules.

B.3.1. IATA CEIV Chapter 17 - Air transport logistics for time and temperature-sensitive products

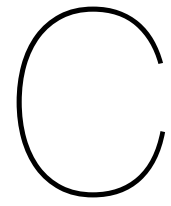
- Refrigerated products have to be maintained at 2 to 8 degrees. Controlled room temperature (CRT) encompasses the usual and customary working environment of 20 to 25 degrees, with some allowances for brief exposure to 15 to 30 during shipping and distribution. WHO defines normal storage conditions as storage in dry well-ventilated premises at temperatures between 15 to 25.
- Attention should be provided to the key risk factors, time- and temperature abuse. Time abuse can be subject to: Excessive loading/unloading times. Delays due to: Missed flights, change in flight plans, landing diversions, weather related delays, wrong destination, security/custom check, weekends/holidays and strikes. Temperature abuse can be subject to: wrong storage temperature. Wrong freight hold temperature, storage near open doors, storage in direct sunlight, extreme temperatures at: Warehouse/truck, Dock/Ramp, Airport apron/tarmac.

- Critical Control Points (CCP) is a point, step or procedure at which controls or checks can be applied to prevent or reduce a hazard or risk to an acceptable level. CCPs in the process are: Monitoring of cool rooms and warehouse temperatures, Availability of batteries and dry ice for active containers, High priority ramp handling, do not load pharmaceuticals near cargo door, Notice to Captain (NOTOC) to maintain recommended cargo hold temperature setting.
- For active containers, dry ice quantity calculations should be organised with the forwarder prior to booking.

B.3.2. How to become IATA CEIV certified

In this section the IATA training guide will be investigated into detail in terms of which topics in the operational processes needs to be risk assessed. Below is a list can be found with the related criteria or questions that a carrier should check if their operations are compliant too.

- em Are the loading and unloading bays protected for different environmental conditions.
- Are vehicles and equipment dedicated in handling of pharmaceutical shipments, if not is there an assessment and procedure in place to minimise risks to the process.
- Sufficient capacity of equipment, vehicles and facilities.
- Perform risk assessments to identify critical lanes.
- Performance monitoring should be based according to risk assessments.
- Dedicated temperature controlled vehicles, otherwise it should be included in a risk assessment.
- Temperature mapping performed by aircraft type.
- Ground transportation done in such a way to minimise the exposure of the shipment to external temperatures and direct sunlight.
- Having a procedure in place to avoid co-loading with general, non temperature controlled cargo.
- The area where ULDs are built up or broken down should be temperature controlled. If this is not the case, a risk assessment on the process is necessary.
- Is tarmac transportation done in such a way to minimise the exposure of the shipments to external temperatures and sunlight? If this is not the case, a risk assessment on the process is necessary.
- Are shipments protected from extreme weather conditions (e.g. thermal blankets, plastic sheets for rain).



Map of the Warehouses

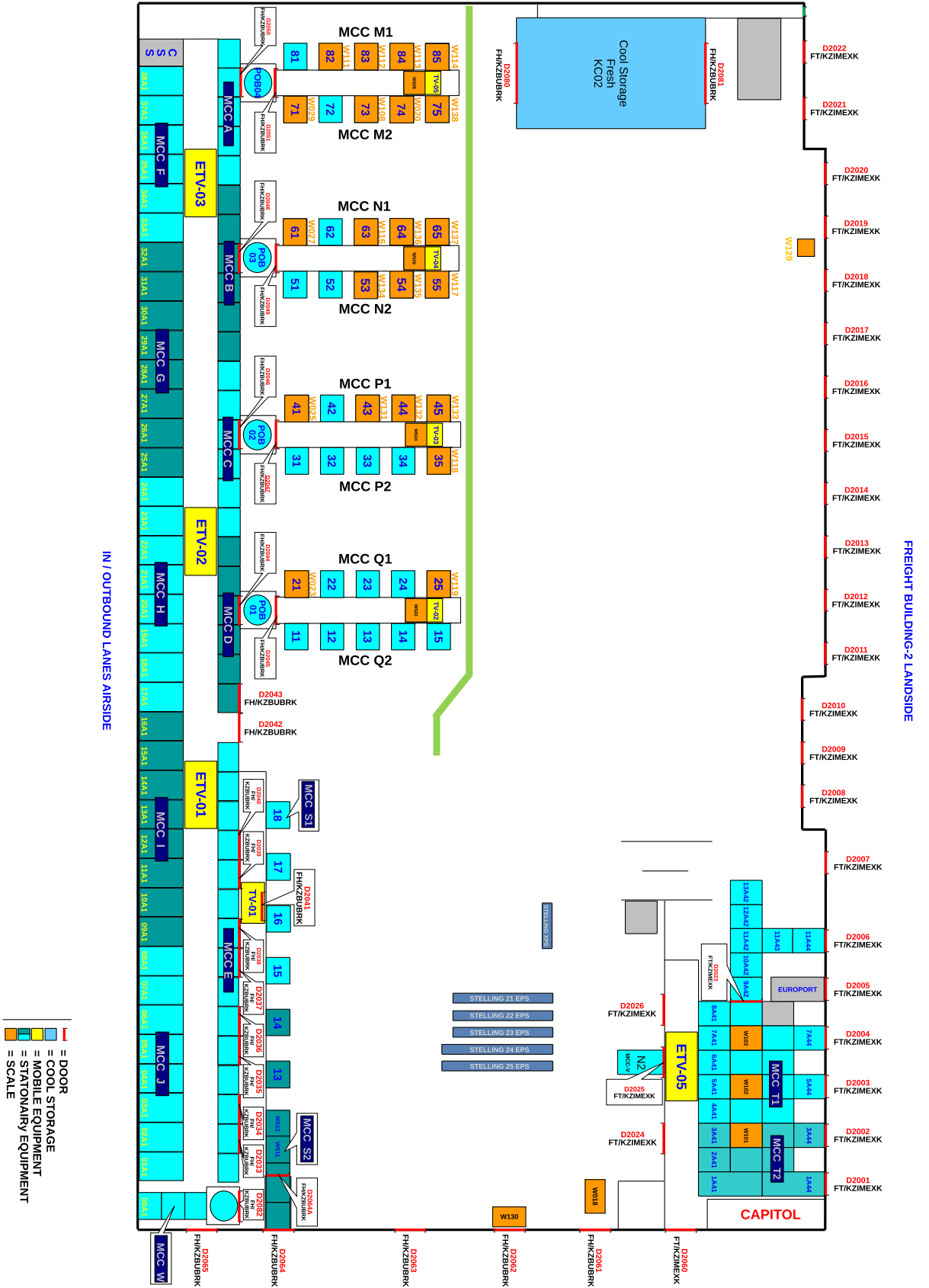


Figure C.1: Map of freight building 2.

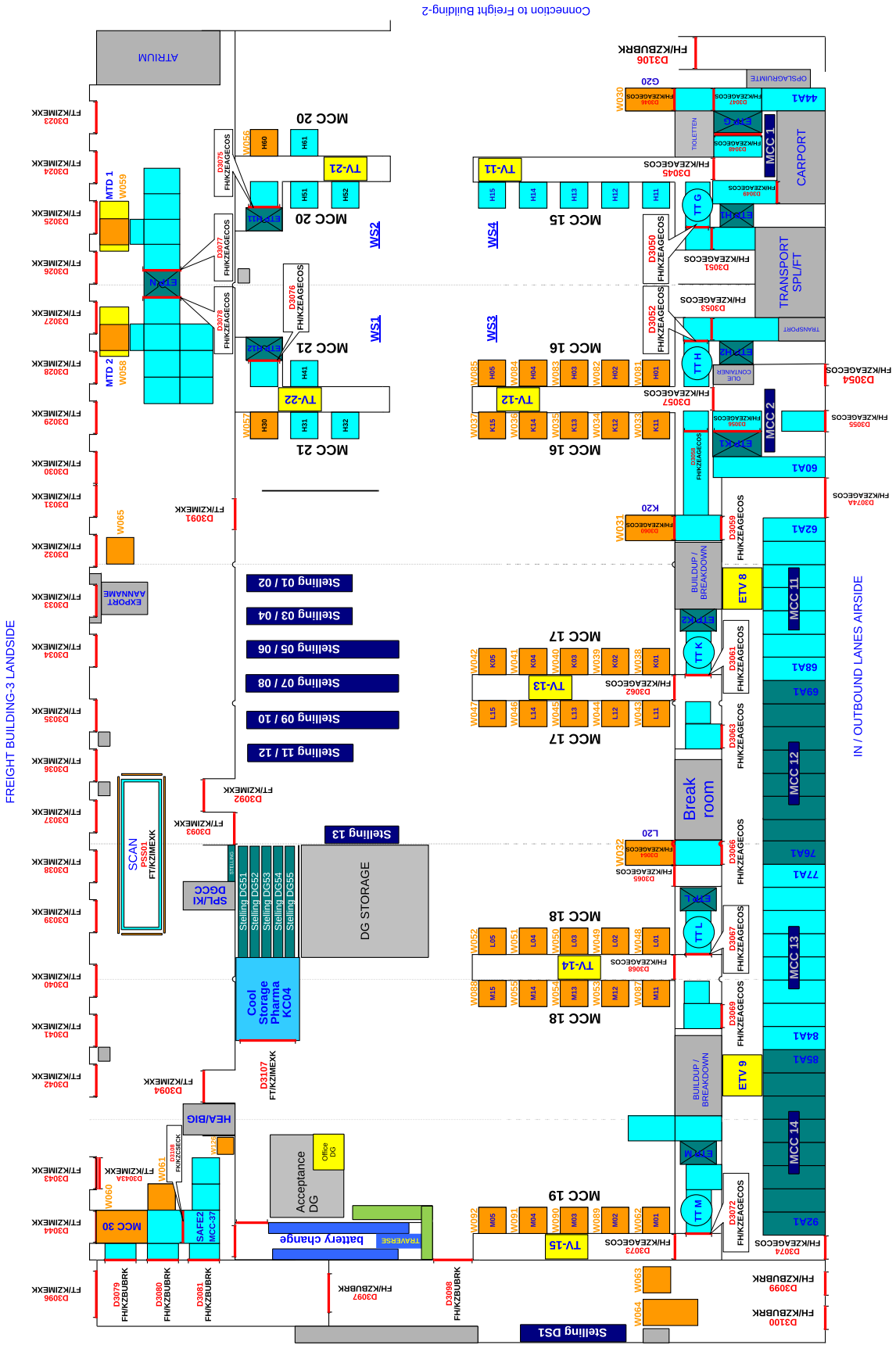


Figure C.2: Map of freight building 3.