The KLM Cargo Pharma Terminal

A Conceptual Design of the Internal Organization and its Size

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Executive Summary

To maintain the competitive advantage after bad years in 2012 and 2013 Air France – KLM – Martinair Cargo (KLM Cargo) got the vision to, amongst others measures, shift their focus towards pharmaceutical freight, also referred to as 'pharma'. Pharma is an interesting commodity because of the stability of the growth of the pharmaceutical industry, the freight is high-yield and it is possible to transport the freight in the hull, the belly, of the passenger aircraft. The latter fits the developments in the fleet where a gradually push-off is planned for the full-freighter aircraft.

Another development affecting KLM Cargo freight operations at Amsterdam Airport Schiphol (AAS) is the airport's plan to expand its passenger terminal. KLM Cargo needs to make way for this expansion and need to relocate their freight terminal. For the development of the new terminal 'Innovation', 'Lean' and 'Safety' are spear points. Considering the attention the company is giving to pharma, it is their wish to handle pharmaceutical freight in a dedicated terminal.

The objective of this research is to make recommendations to KLM Cargo about the design of a new terminal for dedicated handling of pharmaceutical freight by developing and sizing a conceptual design for the internal organization of the terminal fitted to KLM Cargo's product structure, the pharmaceutical industry, and future developments in demand and regulation.

The research question in this practice-oriented research on a design problem for KLM Cargo is:

What would the conceptual design be for the internal organization and its size
for a terminal dedicated to handle pharmaceutical shipments
for Air France – KLM – Martinair Cargo at Amsterdam Airport Schiphol?

The structure of the research is based upon the 'Intervention Cycle' and consists of five parts: analysis, diagnosis, design, intervention and evaluation. The main methodology to get to the conceptual design for the terminal is the method of System Engineering.

Analysis

In the analysis phase the current handling of pharmaceutical shipments at the Amsterdam terminal of KLM Cargo, the pharmaceutical industry's supply chain and the trends and the expected developments in the air cargo market, the pharmaceutical industry and the KLM Cargo demand are researched. With the analysis it is determined what is expected to be required from the system.

The position of KLM Cargo in the air cargo supply chain for distributing pharmaceutical shipments is ground handler and airline. The cargo terminal in Amsterdam is for 80% a transhipment station, mainly handling the trucking flows from the European mainland to intercontinental destinations. In the terminal one closed cool-chain product in active containers and three open cool-chain products on ULDs or Europallets are handled. In 2014 the terminal handled 43.573 shipments, being almost 157.000 m^3 or almost 30.000 tonnes. Pharmaceutical freight is handled within the general freight handling process with just a few dedicated facilities in place. They are spread over the entire terminal, which creates transportation and waiting inefficiencies in the handling process.

By its nature the manufacturing and distribution of pharmaceuticals requires extensive transportation between the nodes in the chain. A reliable cool-chain is important to maintain product integrity. The weak links in the cool-chain appeared to be the transit terminal and the tarmac transport. Exactly in these phases of the supply chain KLM Cargo is involved. Compliancy to the new Good Distribution Practice (GDP) guidelines posed by governments is evident to maintain a competitive advantage.

Pharmaceutical freight is important to KLM Cargo and with that also for the Air France – KLM Group. Fortunately the freight market is expected to keep developing with a slight growth. The cold chain market is expected to develop with a growth rate of about 10% per year. Until 2040 the KLM Cargo experts expects the pharmaceutical commodity to grow with 3% - 4% per year, which is resulting in a growth from 2014 to 2040 of 130%. The shares of the closed and open cool-chain products that KLM Cargo offers are expected to shift dramatically. The most remarkable changes in the modes operated to handle the shipments up- and downstream the terminal are that trucking is going to be assumed loose trucking and that capacity in the fleet shifts towards passenger aircraft.

Diagnosis

To present a suitable concept for the design of the KLM Cargo Pharma Terminal the diagnosis part of the research assesses general airfreight terminal design theory, competitor's pharma terminals and Lean theory on supply chain integration and warehousing. The building stones found in these three areas provide a system level design and identify the requirements for the characteristics of the design that need to be specified in the next phases.

Airfreight terminal design theory presents knowledge of the position of the airfreight terminal in the supply chain, its functions and the design-determining parameters. The terminal is a transitory and sorting facility. Low inventories and a high throughput speed are important for a terminal to stay competitive. For this the system should allow efficient movement, effective storage, easy sortation, accurate and timely inventory control, tight security and effective use of manpower. IATA presents the essential components of a handling facility for perishable freight.

In the past years competitors have been developing dedicated terminals to handle pharmaceutical freight as well. The Aviapartner Brusseld Pharma Hub, the Hyderabad Menzies Air Cargo Pharma Zone, the Lufthansa Cargo Cool Center and the LuxairCARGO Pharma & Healthcare Centre are assessed. Most of them operate a terminal with a medium level of mechanization and are already complying with the recently published GDP guidelines. Only Luxemburg has a terminal two completely separated temperature zones (2°C - 8°C and 15°C - 25°C). Lufthansa operates 17 cool dollies on the tarmac and provides storage space for active containers racks with three levels. Facilities mostly provide in export processes. Import and transit flows are integrated in general freight handling.

One of the spear points for KLM Cargo in the development of the new freight facilities is 'Lean'. The pharmaceutical industry already made numerous efforts to implement Lean in the supply chain. Unfortunately the initiatives have not yet had the desired effect. The industry expects that an integration of the supply chain will activate the efforts. The KLM Cargo Pharma Terminal should play a role in the supply chain integration. The terminal should avoid variation and focus on its primary activities. As the Amsterdam pharma terminal has a strong focus on transhipment, it should avoid becoming a distribution centre. Next to the implementation of Lean to stimulate the integration of the supply chain, Lean thinking tools should be applied in the terminal too to prevent bottlenecks and to clarify the operations and processes. Throughput speed should be high and inventories low in order to help the pharmaceutical industry to decrease the volume of pharmaceuticals in the pipeline.

The assessment of the three elements described above resulted in the description of a system level design and of the elements the design still need to be decided upon. In this phase also the representative peak moment as a base for calculating the size of the terminal is determined.

The eight functions the design needs to be further specified upon are:

1. Handling freight at the landside interface
2. Handling ULDs in the terminal
3. Handling bulk in the terminal
4. Handling ULDs at the airside interface
5. Handling bulk at the airside interface
6. Handling of ACT containers
7. Terminal refinement level
8. Flexibility to the future

The system operational requirements for the functions of the KLM Cargo Pharma Terminal are stated as the final part of the diagnosis phase. They cover a mission definition, performance parameters, operating deployment and distribution requirements, operational life-cycle requirements, utilization requirements, effectiveness factors, environmental factors, interoperability requirements and system maintenance and support requirements.

Design

The next phase is the design phase. In the design phase concepts for the internal organization are composed through Morphological Analysis for the eight functions. The concepts for the configuration of the internal organization are:

- Zero Concept - Close to the current handling with little temperature control
- Modest Concept - Basically equipped terminal for handling through manpower
- Elite Concept - High level of handling quality through an extensive cool-chain
- Compact Concept - Practical handling while maintaining product integrity
- Automated Concept - Fast, automated handling system minimizing human error

Each concept is composed of an alternative for each of the eight functions. In a multi-criteria analysis the preferred concept is identified.

The criteria are based on the qualitative system operational requirements and are implementation time, implementation cost, lifetime costs, operational costs, throughput speed, modularity of the installations, clarity of the installations, flexibility, energy efficiency, GDP compliancy, cool-chain integrity and supply chain integration. Through an Analytical Hierarchy Process three KLM Cargo actors involved in handling pharmaceutical freight weighted the criteria through pairwise comparison. The criteria concerning maintaining the integrity of the pharmaceutical product, throughput speed and the clarity of the operations enabling Lean operations are valued the most important.

In the multi-criteria analysis the concepts are compared in relation to the Zero Concept. A concept can perform on a criterion much worse, worse, equal, better or much better than the Zero Concept. The performances are translated into absolute values, normalized and then with the determined weights translated into a score per criterion. The scores are added up to reveal the most preferred configuration.

The Elite Concept represents the preferred internal organization for the KLM Cargo Pharma Terminal.

Intervention

In the next phase the intervention proposed with the design is discussed. In that phase also the size of the internal organization is determined. In the intervention phase the preferred concept from the design phase is further elaborated on. After establishing a list of the characteristics defining the conceptual design, the required performance in the design phase is translated into sizing the internal organization.

With the Elite Concept the KLM Cargo Pharma Terminal consists of two separate areas, both connected to land- and airside. On is held in 2°C - 8°C and the other one in 15°C - 25°C. Developing the required capacity for the terminal in 2040 is based upon the representative peak moment in 2014. For each area three capacities have been determined: the landside interface capacity, the airside interface capacity and the terminal storage capacity. The terminal capacity consists of a space for Europallets and ULDs. In the 15°C - 25°C area also space is required for storage and servicing of active containers.

Sizing the landside interface is expressed in an amount of doors. The amount required depends on the pharmaceutical shipments per truckload. The airside interface is determined by expressing the amount of cool dollies and dollies for active containers are required.

The space required to store active containers is determined by the footprint of the shipments in the representative peak moment in the terminal. The accumulation of shipments is based upon the throughput times in 2014. Reduction of the throughput times substantially decreases the space required in the terminal.

The volume of freight on and the footprints of Europallets and ULDs determine the space required for storage of shipments in both areas of the terminal in the representative peak moment. The accumulation of shipments is based upon the throughput times in 2014. Performing all handling activities as soon as possible and only buffering the shipments after completing all preparations for departure decrease the required space in the terminal. General reduction of the throughput times substantially has an even more dramatic effect on the size of the storage areas.

Evaluation

The evaluation phase of the research concludes on the developed conceptual design and recommends on the further phases in the design of the KLM Cargo Pharma Terminal.

The conceptual design for KLM Cargo Pharma Terminal is based on the internal organization as proposed in the Elite Concept. Of the five proposed feasible concepts the Elite Concept is preferred. The concept fit best with KLM Cargo's high ambition for the pharmaceutical freight.

Recommended is to do further research to the development of the throughput times. The time shipments dwell in the terminal is not dependent of the throughput speed of the terminal but on the transit times between the flights (or truck operated flights).

An alternative to the cool dollies for the 15°C - 25°C freight would be the 'Insulation Dolly'; a cool dolly that only isolates and protects from ambient weather, and operates without cooling function.

Preface

This master thesis project is the final academic project for the master 'Transport, Infrastructure & Logistics' at the faculty of Civil Engineering and Geosciences at the Delft University of Technology. The project was commissioned by Air France – KLM – Martinair Cargo and involves the development of a conceptual design for a dedicated terminal for handling pharmaceutical freight at Amsterdam Airport Schiphol. The design is focussed on the internal organization and the size of the terminal. The research was carried out in a full-time internship at KLM Cargo.

I would hereby like to thank the TU Delft members of the assessment committee Professor Lodewijks, mr Beelaerts van Blokland, mr Janić, for their willingness to help and their feedback. They have helped to scope the design problem and provided valuable insight on steering this greenfield assignment in the right direction. To the KLM Cargo members in the assessment committee mrs De Walle and mr Starrenburg I am very grateful as well. I thank them for the opportunity they gave me to work on this interesting assignment and to get to know their company from all different angles. Their genuine interest in my process and progress has been of great support.

Special thanks go out to mr Theo Viejou, mr Piet Klein and the other staff members of the Conditioning-Competence Centre who have left no stone unturned to provide me with all the answers and inside information I needed regarding the current operations at the hub in which they are in daily basis involved keeping it running. I look back on working on this research in their department with great pleasure.

July 9th, 2015

Hugo Niemans

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1. Introduction

After the abrupt downfall of worldwide trade at the end of 2008 the market for airfreight has been struggling to resurrect. The financial crises had a direct impact on the global airfreight market due to price pressure and substantially decreasing trade, as shown in Figure 1.1.

After poor performance from 2011 to 2013, the market eventually developed a steady, yet slower growth normal (IATA, 2015).

Figure 1.1: Air FTKs and World Trade Volumes (IATA, 2015)

For Air France – KLM – Martinair Cargo (KLM Cargo) the poor performances of the market led to severe operating losses in 2012 and 2013. To cope with the losses the full-freighter capacity was reduced and new services were developed. One of the new focuses was the service of transporting pharmaceutical freight, often referred to as 'pharma'. The reason to choose for this is threefold: 1) the pharmaceutical industry is expected to grow steadily more than 5 per cent per year, 2) pharmaceutical shipments are high-yielding shipments, and 3) the nature of the pharmaceutical shipments allows transportation in the belly of the aircraft. Belly transportation brings the possibility to profit from the extensive passenger network and to be resistant to the unavailability off full-freighter aircraft (AirFrance KLM Martinair Cargo, 2014b). As a result of the enlarged focus on pharmaceutical freight, new climate-controlled facilities were installed in the Amsterdam hub in order to handle a new range of pharmaceutical products (KLM Royal Dutch Airlines, 2014). Airlines experience little competition of other transportation modes such as ocean transport; air transportation is expected to remain the most suited mode of transportation for perishables (Boeing, 2012).

1.1. KLM Cargo

KLM Cargo is the freight subsidiary of the Air France KLM Group and is considered the largest cargo airline. KLM Cargo operates their networks from two hubs: Amsterdam Airport Schiphol (AAS) and Paris – Charles de Gaulle. The merger of the two cargo companies in the Air France KLM Group, Air France Cargo and KLM Cargo, in 2005 and the addition of Martinair in 2008 resulted in an extensive operating network covering 250 destinations in 116 countries for transporting a wide variety of products. KLM Cargo transports its freight mainly in the belly, the hull, of KLM and Air France passenger aircraft and in the full-freighter aircraft of Martinair.

1.2. Problem Description

In 2018 AAS plans to take its new passenger terminal, known as the 'A-pier', into use. The A-pier is planned to be located at AAS Centre at the site of the current KLM Cargo freight-handling buildings. Therefore part of these buildings need be relocated before construction of the 'A-Pier' starts in 2016.

If the plans go ahead, at first only KLM Cargo's freight building 1 is affected and eventually freight buildings 2 and 3 are expected to need to make way for additional passenger terminal expansions, such as the 'A'-Pier' too. The 'A'-Pier' most likely needs to be operational in 2023 – 2024

Not only the physical environment at KLM Cargo is changing. The regulatory environment of handling is also changing radically. Especially regulations considering pharmaceutical freight are getting stricter and more uniform over the whole world to make sure the integrity of the product can be secured (AirFrance KLM Martinair Cargo, 2014a).

The need for KLM Cargo to relocate presents the chance to create a facility that enables handling processes designed to meet future needs and developments in the industry. The three pillars considered in the new terminal design are 'Innovation', 'Lean' and 'Safety'. Next to that, the integrity of the process and the handling and storage areas, regulated in the Good Distribution Practice (GDP) guidelines, are a determinant factor for the pharmaceutical manufacturers and distributors when choosing a handler and/ or an airline. This should therefore be the focus of KLM Cargo in order to stay considered as the preferred carrier. (AirFrance KLM Martinair Cargo, 2014a; AirFrance KLM Martinair Cargo, 2014b; AirFrance KLM Martinair Cargo, 2011).

1.3. Research Objective

In order to achieve the desired quality improvements for the pharmaceutical freight services, the processes and facilities for pharmaceutical handling and storage need to be designed into the new freight terminal to fit tightening future regulation and customer demand. The terminal is going to be a facility dedicated to the handling of solely pharmaceutical shipments.

The objective of this research is to make recommendations to KLM Cargo about the design of a new terminal for dedicated handling of pharmaceutical freight by developing and sizing a conceptual design for the internal organization of the terminal fitted to KLM Cargo's product structure, the pharmaceutical industry and future developments in demand and regulation.

The research contributes to the knowledge and information about the development of a building for dedicated pharmaceutical freight handling and show how the facility can add to quality improvements, compliance to regulations and adaptability to future developments. The design does no include the geographical location, location related requirements and document and information flows.

The International Air Transport Association (IATA) (2004) recommends that in order to develop a design it is important to carry out trade-off studies for alternative storage systems, facility sizes and efficiency together with the airline itself. This practice-oriented research is focused on the practical design problem of KLM Cargo.

Structuring a practice-oriented research is supported by the 'intervention cycle' of Verschuren and Doorewaard (2010) consisting of the problem analysis, diagnosis, design, intervention/ change and evaluation phases related to operational problems. The focus for this research is found within the design phase of this cycle. It is necessary to have a solid problem analysis and diagnosis, such as backgrounds and causes of the problems, to understand what is required from the design. The design presents an intervention to solve the problem by meeting the developed requirements.

1.4. Research Questions

The research question is:

What should the conceptual design be for the internal organization and its size for a terminal dedicated to handle pharmaceutical shipments for Air France – KLM – Martinair Cargo at Amsterdam Airport Schiphol?

In order to answer the research question four central questions are formulated, the first two with three sub-questions. The central and sub-questions are:

1. What are the requirements and assumptions for the new terminal configuration?

   1.1. What flow and infrastructural elements, based on the current product portfolio and current operations, should be integrated or facilitated in the configuration for the new terminal?

   1.2. What are the expectations of the pharmaceutical industry of an airline's terminal that handles pharmaceutical freight?

   1.3. Which trends and developments should be anticipated on with the new terminal configuration?

2. What elements from the way the industry typically copes with similar design problems can be used and taken into account when making a conceptual design for the new terminal configuration and what system level design for KLM Cargo can be developed from that?

   2.1. What elements from airfreight terminal design theory should be used and taken into account when making a conceptual design for the new terminal configuration?

   2.2. What elements from competitor's dedicated pharmaceutical freight handling facilities should be used and taken into account when making a conceptual design for the new terminal configuration?

   2.3. What elements from Lean theories on supply chain integration and warehousing should be used and taken into account when making a conceptual design for the new terminal configuration?

3. What are the quantitative and qualitative requirements addressing the needs and assumptions and fitting the system level design for the new terminal configuration?

4. What are feasible concepts for the new terminal configuration?

1.5. Approach

First the sub-questions and then central questions are answered in order to come to the conceptual design and present a final answer on the research question. The sub-questions are answered through observational research, literature research and deterministic data analyses.

The general methodology for arriving at the conceptual design is the Systems Engineering method of Blanchard and Fabrycky (2011). The System Engineering method contains a systems design process and can be used for most types of human-made systems. The first step of the system design process is the Conceptual System Design, which applies on this research. For several steps in the methodology research tools such as the Analytic Hierarchy Process, Morphological Analysis and a multi-criteria analysis are integrated.

Structure of the Report

The report is build-up off 16 chapters divided in a structure of a combination of the steps described in the Conceptual Systems Design methodology and the Intervention Cycle of Verschuren en Doorewaard (2010). An overview of the structure is given in Figure 1.2 and appendix 1.

First, in chapter 2, the methodology of Systems Engineering, the applicable theory and the additional methods are analysed and discussed.

Chapter 3, chapter 4 and chapter 5 of which the findings are combined in chapter 6 and cover the first phase of the research: Analysis. The current KLM Cargo operations considering pharmaceutical freight is discussed in chapter 3, the pharmaceutical supply chain in chapter 4 and the trends and developments afflicting both in chapter 5. In chapter 6 the first central question is answered and the needs and assumptions for the development of the internal configuration of the dedicated pharma terminal are identified.

The second phase, the Diagnosis, consists of chapter 7, chapter 8 and chapter 9, which are providing the findings to be combined in chapter 10, and chapter 11. In chapter 7 the theory on airfreight terminal design is researched, in chapter 8 the best-practice terminals of KLM Cargo's competitors are elaborated on and chapter 9 investigates what Lean theory on supply chain optimization and warehousing can add to the new to develop terminal system. Chapter 10 concludes the Diagnosis phase and elaborated on the typical designs for terminal systems similar to the one subject in this research. As last part of chapter 10 a systemic design is composed for the internal configuration of the terminal. Based on the systemic design and the initial requirements and assumptions determined in chapter 6, in chapter 11 the system operational requirements is developed as base for the design phase.

The design phase starts in chapter 12 with the translation of the system operational requirements into qualitative requirements, which are the criteria upon which the alternatives need to be reviewed and compared. It also states the quantitative requirements, the capacity, the terminal system should provide. In the next chapter, chapter 13, five alternatives are generated for consideration. They are generated by the method of Morphological Analysis. In chapter 14 the five alternatives are subject in a multi-criteria analysis, using the criteria developed in chapter 12.

In chapter 15 the result of the design phase, the intervention proposed for KLM Cargo, is elaborated further.

In the evaluating phase, containing chapter 16, the conclusions and recommendations are given.

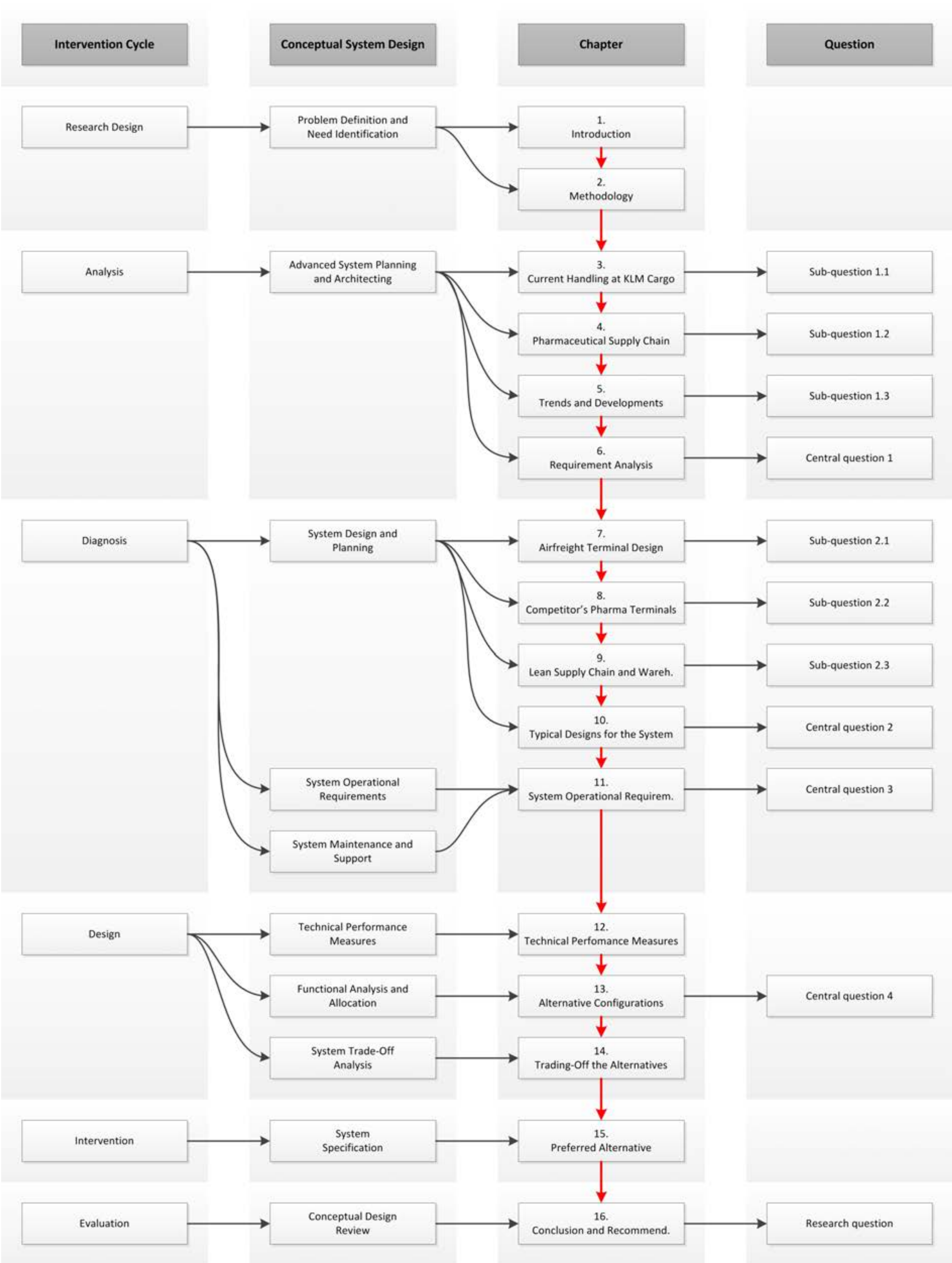


Figure 1.2: Structure of the report

2. Methodology: System Engineering and Analysis

The overall methodology used for this research is the Systems Engineering approach. The choice for Systems Engineering ensures that the design for a terminal for KLM Cargo dedicated to handle pharmaceutical freight responds to the company's requirements and incorporates these requirements already in an early stage of the design process and addresses the requirements in an integrated life-cycle approach. The steps in the life-cycle are given in Figure 2.1.

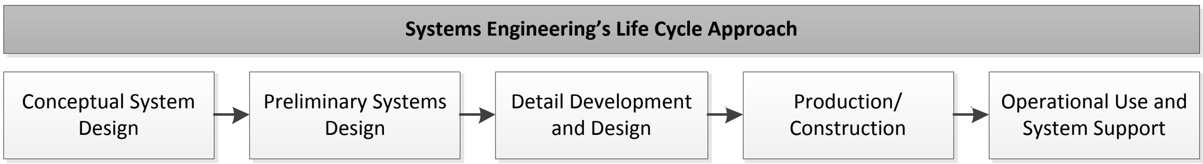


Figure 2.1: Systems Eningeering's Life Cycle Approach

Conceptual System Design

The first step in Systems Engineering is the Conceptual System Design. It is defined by Blanchard and Fabrycky (2011) as: "*an early and high-level life-cycle activity with the potential to establish, commit, and otherwise predetermine the function, form, cost, and development schedule of the desired system and its product(s)*".

The typical steps within the Conceptual System Design are (Blanchard & Fabrycky, 2011):

1. Problem Definition and Need Identification
2. Advanced System Planning and Architecting
3. System Design and Feasibility Analysis
4. System Operational Requirements
5. System Maintenance and Support
6. Technical Performance Measures
7. Functional Analysis and Allocation
8. System Trade-Off Analysis
9. System Specification
10. Conceptual Design Review

In the next paragraphs the ten above-mentioned steps are explained according to the methods presented by Blanchard and Fabrycky (2011). Within the Conceptual Systems Design framework other research tools are added, an overview is given in table 2.1.

Table 2.1: Applied tools within Conceptual Systems Design

Steps in which tools are applied	Applied tools
1. Problem Definition and Need Identification	Designing a Research Project (Verschuren & Doorewaard, 2010)
2. Advanced System Planning and Architecting	Observation and Literature Research
3. System Design and Feasibility Analysis	Observation and Literature Research
6. Technical Performance Measures	Analytic Hierarchy Process and deterministic data analysis
7. Functional Analysis and Allocation	Morphological Analysis and SWOT analysis
8. System Trade-Off Analysis	Multi-criteria Analysis

2.1. Problem Definition and Need Identification

The first step for the conceptual design is defining the problem and identifying the system that is required to be responsive to solve the problem. It is important to define the real problem and not perceived problems in order to avoid unnecessary needs for the system are identified. The step of need identification is an important step to ensure the need is identified correctly, avoiding unnecessary alteration of the design later on in the design process.

The problem is defined and the research is designed according to the methods of Verschuren and Doorewaard (2010), which provides handhelds to determine the research objective, the research framework, the research questions, a theoretical framework, a research strategy and a research planning.

2.2. Advanced System Planning and Architecting

Given the identified need for the system, the capabilities of the system are defined more specific into the system requirements and assumptions in this step. For this step the current operations at KLM Cargo in the Amsterdam terminal are analysed, the pharmaceutical supply chain is analysed and the trends and developments for the future are determined. For this scientific literature and industry publications are researched and practice is observed.

2.3. System Design and Feasibility Analysis

Once the problem, the need and the system requirements are defined, various typical designs are evaluated on their performance and developed into a systemic design. After this evaluation a course of action is determined for the further design and only feasible designs that represent the preferred technical approach are left for further development. It is used as the input for generating the alternatives that are further assessed and developed in step 7 of the Conceptual Systems Design: Functional Analysis and Allocation.

The range of designs for the system of dedicated pharmaceutical handling terminals is researched in the academic literature on terminal design and on warehousing and supply chain theory and with observations in practice.

2.4. System Operational Requirements

The outcomes of the analysis in step 2.2 and the analysis in step 2.3 are combined into a set of system operational requirements by developing the following definitions:

- Mission definition
- Performance and physical parameters
- Operational deployment or distribution
- Operational life-cycle (horizon)
- Utilization requirements
- Effectiveness factors
- Environmental factors
- Interoperability

2.5. System Maintenance and Support

This part of the methodology focuses on the sustainment of the system throughout its life cycle. All elements of the system should be considered in a maintenance and support concept for each design. It includes: levels of maintenance, repair policies, organizational responsibilities, maintenance support elements, effectiveness requirements, and the environment.

The maintenance and support concepts are directly linked to the infrastructure and processes in the designed systems and therefore they can be used to determine the most efficient design for the operational system.

The requirement for the system maintenance and support of the future system is combined with the system operational requirements as it is seen as an integral part of the performance of the new design.

2.6. Technical Performance Measures

The technical performance measures (TPMs) are the qualitative and quantitative values that describe the systems performance. TPMs are characteristics inherent within the design and so are used to meet the requirements of KLM Cargo efficiently and effectively. TPM's follow directly from the system operational requirements and the maintenance and support concepts.

As some of the qualitative TPMs might be contradictive, each TPM is given a relative importance in order to prioritize them for the further design. This is achieved with the Analytical Hierarchy Process (AHP). The AHP is a decision theory basted technique to decompose a problem into comprehensible sub-problems, each of which can be analysed independently. The problem is decomposed in a goal, criteria and alternatives. In each level of the hierarchy the elements are compared pairwise. The pairwise comparison may be done with actual measurements, but can also be done with relative strength or feelings, resulting in prioritization of the elements (Saaty, 1987). Using AHP allows seemingly incomparable elements to be compared in a rational and consistent way (Mayyas & al., 2011)). An important characteristic of AHP is that great attention is given to the consistency of way the prioritization is determined.

AHP is used in various fields from multi-criteria decision making to conflict resolution (Saaty, 1987). A more elaborate description of the AHP is given in appendix 2.

2.7. Functional Analysis and Allocation

In this step a functional description is defined to enable to identify the resources necessary for the new system to accomplish its mission. A function is an action to achieve an objective, achieved by system elements. The functional analysis translates system requirements into detailed design criteria and the identification of the resources needed for system operation and support. The purpose of the functional analysis is to present a functional architecture, to function as a base for the physical design.

For this step in the Conceptual System Design methodology a Morphological Analysis (MA) is applied to determines several concepts for the new systems design. The definition is:

"Morphological analysis – extended by the technique of cross consistency assessment (CCA) – is a method for rigorously structuring and investigating the internal properties of inherently non-quantifiable problem complexes, which contain any number of disparate parameters. It encourages the investigation of boundary conditions and it virtually compels practitioners to examine numbers of contrasting configurations and policy solutions." (Ritchey, 1998).

General Morphological Analysis is a method developed by Fritz Zwicky in the middle of the 20th century for "structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes" (Ritchey, Stenström, & Eriksson, 2002). Although its form and conceptual range are more generalized, MA has similarities to typology construction. MA is used in a more divers spectrum of fields such as astrophysics, development of propulsive power plants and propellants, and the legal aspects of space travel and colonisation. The method is especially adequate for the development of the future scenarios because (Ritchey, 1998):

- Many factors involved are non-quantifiable;
- Problems are non-reducible;
- And the conclusions drawn need to be understandable.

For the development of the new KLM Cargo Pharma Terminal the method of Morphological Box is applied. It is a commonly used tool in building design, as it is able to cover all different perspectives of a design (Zeiler & Savanovic, 2009). For a step-wise explanation of how the Morphological Box is constructed see appendix 3.

The method of Morphological Box can be seen as a morphological field containing all of the formally possible relationships involved. Zwicky refers to this as complete, systematic field coverage. From all the configurations in the morphological field the solution space can be determined (Ritchey, 1998).

Examining all possible configurations in a matrix would take a good deal of time and effort, that's why by hand some realistic configurations can be chosen for further evaluation (Ritchey, 1998). For the KLM Cargo Pharma terminal a configuration close to the current situation, a basic configuration, a ambitious configuration, a compact configuration, and an automated configuration.

According to Zwicky (1967) the advantages of MA are that:

- MA is a totality research that strives to derive all solutions in an unbiased way;
- MA helps to discover relationships and configurations that may be overlooked with other methods;
- MA encourages identifying and investigating the boundary conditions.

2.8. System Trade-Off Analyses

The many possibilities that might have arisen are tested later on, in step 8 of the Conceptual Systems Design: System Trade-off Analysis, on their impact on system operational and behavioural characteristics. The composition of the concepts determine to a great extend the design's constructability, produceability, supportability, sustainability, disposability and other life-cycle design characteristics. The implications on reliability, maintainability and the impact on human performance of the system are within the choice for technical approach determined by the design alternatives.

The designed system architectures, the concepts, need to be evaluated in a trade-off analysis. For this a multi-criteria analysis is used. For most design, development and construction problems promising solutions are sought and alternatives are developed and evaluated. The final solution rarely exist in it final form already from the beginning of the problem solving process; it evolved from thorough analyses and altering. To make a sound selection all concepts should be considered, even the ones that at first sight seem to be not even feasible. Concepts can only be compared if all quantitative and qualitative characteristics both are expressed in a common measure (Blanchard & Fabrycky, 2011).

In the multi-criteria analysis (MCA) the outcomes of the AHP, the weighted and normalized criteria, and the MA, the alternatives, come together. As MCA the Simple Multi Attribute Rating Technique (SMART) is used. It is considered to be a more elaborate method to compare alternatives because the criteria for assessment are weighted. SMART can be categorized in the "weighted methods of evaluation" group. The MCA is performed as proposed by De Haan (2009).

The comparison of the concepts in a MCA is always presented in a performance matrix. In the columns the concepts are presented, as the rows present the criteria with. For the weights a column is added to be able to calculate the weighted sums of the scores of the concepts. To use the scores they should be normalized with the following formula $v_{norm.} = \frac{|v_{score} - v_{min}|}{v_{max} - v_{min}}$. The normalized weights for the criteria are already determined with the AHP method.

After the analysis is carried out a robustness analysis, sensitivity analysis and an extreme conditions test need to validate the stability of the outcomes. The robustness analysis determines the stability of the outcomes by doing the MCA over again with the weight factors determined from another actor's perspective. The sensitivity analysis tests whether the outcomes are still the same under different circumstances by changing the weight factors and the extreme conditions test tests the stability of the outcomes when leaving out every criteria once. The outcomes preferably stay stable.

2.9. System Specification

The system specification combines and integrates all previous steps into a document composed of all technical requirements to guide the rest of the (lower level) system design. The system specification is usually the last step of the conceptual design.

2.10. Conceptual Design Review

The conceptual design should be reviewed before the preliminary design is accomplished from a total system point of view. The conceptual design review van be seen as the conclusions and recommendations from the conceptual design phase to take to the next phases to come: the detailed design and development phase, the production and/ or construction phase and the utilization phases.

First Phase in the Intervention Cycle:

Analysis

3. Current Pharma Handling at KLM Cargo

In this chapter KLM Cargo is analysed. First in 3.1 and 3.2 a company profile and its position in the supply chain are given. Chapter 3.3 focuses analysis and assessment of the current operations and processes at KLM Cargo at AAS. In 3.4 the demand and the supply through the terminal are given. Chapter 3.5 elaborates on the terminal facilities in the freight hub at AAS in order to handle pharmaceutical freight.

3.1. Introduction

The last 50 years the airline industry has seen continuous and rapid growth. From the emerging of the industry in the 1950's and 1960's when the annual growth rates were about 10 per cent, until the 2000's, when the industry is considered to be mature. The annual growth rates declined to about 4 per cent. One would imagine this continuous and substantial growth should bring equal profits to the airlines, yet airlines profits are only marginally positive. The reason for this is to find in the nature of the demand, which is cyclical and strongly influenced by external factors and is called 'the airline paradox' (Doganis, 2010).

Overcoming the contradiction means that an airline must match supply and demand for its services in a way that is both efficient and profitable. An airline can do this by being low-cost or high-cost (Doganis, 2010). KLM is considered to be a network or flag carrier, which fit in the high-cost category. KLM is also considered to be a combination carrier, which transports both passengers and freight. Freight is transported in the belly of passenger aircraft, in full freighters and in combination aircraft.

For high-cost airlines freight has an important, and often underestimated, share in the output and revenue of the airline. In 2007 nearly 30% of the revenue tonne-kilometres was generated by freight services. This share tends to increase in the future. In terms of revenue contribution the share of freight is only about 8%, but still is a contribution to the airlines' overall profitability (Doganis, 2010). The contribution of freight to the overall profitability for an airline highly depends on two important factors that influence the cost of airfreight transportation: the labour-intensiveness of the process in the freight-handling terminal and the efficiency of the documentation (Radnoti, 2002).

KLM Cargo handles shipments at AAS from arrival until the departure at either landside or airside. The process and the terminal are analysed in this chapter. First a short history and the company profile are described and then a more extensive explanation of the operation at AAS will be presented.

3.1.1. History of KLM Cargo

KLM Royal Dutch Airlines (KLM) was founded in 1919 and is the oldest airline still operating under its original name. From its establishment the important milestones for KLM Cargo are the addition of the Boeing 747 Combi aircraft to fleet in 1975, the merger of Air France and KLM in 2004 and the acquisition of Martinair in 2008, which eventually resulted in the dedicated cargo company that is part of the group today. Together the three cargo divisions are founded into Air France-KLM-Martinair Cargo. At AAS KLM Cargo handling freight for Air France and KLM operated passenger and combi flights as an in-house activity. For all full-freighter flights the handling is outsourced to Menzies.

AAS is one of KLM Cargo's home bases as it is historically KLM's home base, see Figure 3.1. As from the move of the majority of the airport activities from 'the old Schiphol' at Schiphol Oost to 'the new Schiphol' at Schiphol Centrum in 1967 until today KLM operates freight terminal 'Vrachtstation 1'. Respectively in 1982 and 1992 freight buildings 2 and 3 were added, which are both still in use as well.

Because of the pressure on the results by the aging full-freighter fleet KLM Cargo announced in September 2014 to halve the full-freighter capacity. Five of the six McDonnell Douglas MD-11 aircraft will be phased out until 2016. Of the four Boeing 747-400ERF three will continue to be used at AAS, one will be seen as a spare (Luchtvaartnieuws.nl, 2014). The fifteen Boeing 747 Combi aircraft will be phased out from 2015 onwards (Wikipedia, 2014).

3.1.2. Vision and Mission

KLM and Air France are the primary businesses of the Air France KLM Group concerned with passenger transportation and Air France – KLM - Martinair Cargo is the group's dedicated air cargo business (KLM Royal Dutch Airlines, 2014). From AAS KLM Cargo has the mission to:

- Be closer to the customer
- Bring more value
- Always offer a solution
- Provide easy access to their offer
- Be agile

It fits in KLM's general mission and vision to stay ahead in the industry by outsmarting the competition and being the customers' first choice, an attractive employer for its customers and a stable and profitable company for its shareholders. Through the merger in 2004 between Air France and KLM the airline is able to offer an extensive network and a leading position in the international airline industry.

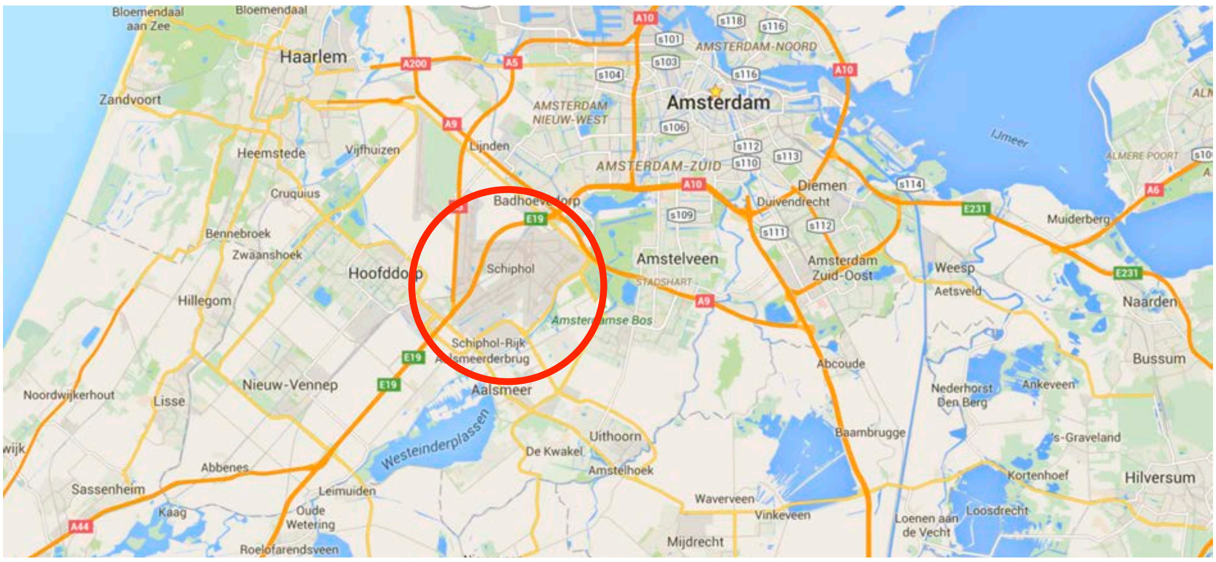


Figure 3.1: Situation of AAS

3.2. Position in the Air Cargo Supply Chain

The air cargo supply chain includes shipping, forwarding outbound, air transport, forwarding inbound and consignment. The shipper typically is the one shipping the goods from A to B, to the consignee. The process in between is considered the air cargo supply chain (see Figure 3.2). KLM Cargo is responsible for the air transport phase in the air cargo supply chain.

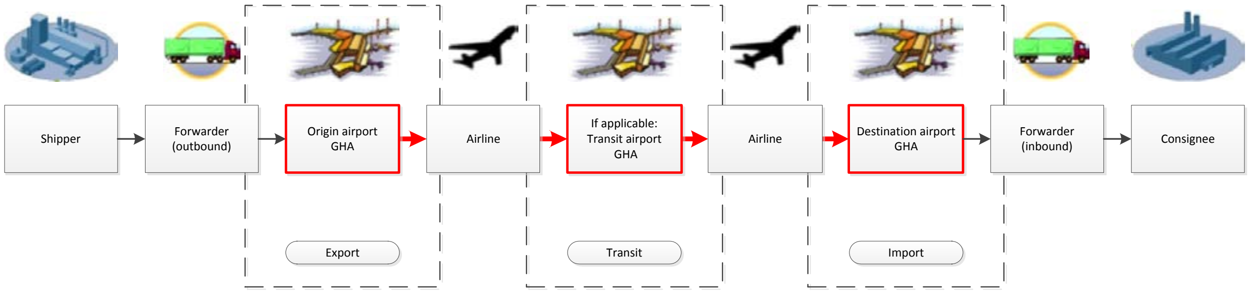


Figure 3.2: A typical air cargo supply chain. Red is the part of the chain where most problems in the cool-chain occur.

3.2.1. Actors

Shipper

The shipper is the party responsible for shipping the goods. For safety reasons the shipper must be registered or known. The shipper is responsible for assembling the transport, making the goods ready for transport (RFT) and to order transport for collection at the shippers warehouse. Upon collection the forwarder will give the shipper a proof of acceptance (POA).

Forwarder (outbound)

The forwarder (expeditor) facilitates the transport from the shipper to the airport. First, when the goods are collected a POA is given to the shipper. The forwarder prepares the goods to be ready for carriage (RFC) by correctly packaging and labelling the goods, preparing the goods for customs (if applicable) and making sure all documents are complete and correct. The next steps are arranging the customs clearance for export, consolidating the goods and finally delivering the goods at the associated ground handling agent (GHA) or the airline. An IATA certified forwarder is referred to as an agent.

Air transporter

The freight forwarder delivers the goods to the terminal of the airline or the airline's GHA. Freight can transported in:

- The belly of a passenger aircraft
- Full-freighters aircraft
- The belly or on the main deck of 'combi' aircraft

Freight is mostly placed in a unit load device (ULD) specially designed to fit into aircraft safely. ULDs can be pallets, animal stables, and regular/ safety/ environmental containers, especially designed to be able to fit exactly into an aircraft type. If freight is not transported in a ULD it could be transported as loose freight, bulk, in the belly in the aircraft. The transportation process starts at landside with the unloading of the forwarders truck, incoming checks and administration, sorting the goods and documents, performing outgoing checks and administration, building ULD's. The ULDs are transported to the airside via ramp transport, security checks and the loading of the aircraft. Once the aircraft has arrived at its destination airport the outer station handles the freight in a similar way as it is handled before: unloading the aircraft and ramp transport at the airside. Breakdown of the ULDs, performing incoming checks and administration, sorting the goods and documents, outgoing checks and administration and loading the truck are the landside activities. Special freight, such as pharmaceuticals, is given special attention through these processes.

Forwarder (inbound)
The forwarder picks-up the freight at the handling terminal of the GHA or the airline. First the shipment documents are collected, customs are cleared and after clearance the freight can be picked-up. Than the forwarder performs incoming checks and breaks down consolidations, to finally deliver the shipment at the consignee. The consignee gives the forwarder proof of delivery (POD).

Consignee
After receiving and checking the shipment the consignee gives the forwarder a POD. The consignee should check the shipment with its administration.

3.2.2. Role of KLM Cargo

The positions KLM Cargo takes in the supply chain are:

- Airline
- Origin airport ground handler (export)
- Transit airport ground handler (transhipment)
- Destination airport ground handler (import)

Between these four tasks the focus is on the air transportation itself. From the viewpoint of the terminal at AAS the role KLM Cargo fulfils is the role of the transit airport ground handler. As seen later on, in chapter 3.4, about 80% of all pharmaceutical shipments passing through the terminal are transhipments.

3.3. Pharmaceutical Products of KLM Cargo at AAS

Pharmaceutical shipments are by definition very high-value shipments that require careful attention and precise temperature control. KLM Cargo specialized in handling this special commodity and currently operates well-equipped facilities.

3.3.1. Characteristics of the Commodity

On time handling and temperature control are essential elements in the handling of pharmaceutical goods. These product driven requirements make it very important there are no time and temperature excursions. The integrity of the product should not be at risk (IATA, 2014).

For the pharmaceutical industry KLM Cargo offers specially designed services to handle the shipments with the care and commitment they need. Offered is a closed cool-chain solution, namely Pharma Active, and further several open cool-chain solutions namely Pharma Control 2-8°C, Pharma Control 15-25°C and Pharma Control 2-25°C (AirFrance KLM Martinair Cargo, 2005).

3.3.2. Handling the shipments

Also pharmaceutical shipments pass through the terminal in a ULD or as loose freight. Multiple ULD types are possible, from dedicated active containers to mixed pallets.

For describing the flows the following distinction is made for pharmaceutical shipments:

- Pharma Active container flows
- T-ULD flows including Pharma Control 2-8°C, 15-25°C or 2-25°C
- M-ULD flows including Pharma Control 2-8°C, 15-25°C or 2-25°C
- Loose freight flows including Pharma Control 2-8°C, 15-25°C or 2-25°C

The flow for the closed cool-chain pharma active containers is a dedicated handling process. The open cool-chain pharma control shipments are handled within the general cargo flows. If the transit time for a shipment is more than 8 hours or if extreme outside or terminal temperatures occur extra care is given to the pharmaceutical shipments. The terminal handles the shipments according to qualification of the shipment by means of a Special Cargo Handling Code (SHC). The SHCs are given in table 3.1(AirFrance KLM Martinair Cargo, 2005):

Table 3.1: Product specifications

Product	Product code*	SHC	Cool-chain	Storage temperature
Pharma Active	S52	ACT	Closed	Ambient
Pharma Control 2-8	S51	COL	Open	2 – 8 °C
Pharma Control 15-25	S53	CRT	Open	15 – 25 °C
Pharma Control 2-25	S50	PIL	Open	Out of extremes

Source: CHM Chapter 5.2 Perishable and Pharmaceutical Shipment.

In this report the pharmaceutical products are referred to according their special handling code.

3.3.3. ACT, COL, CRT and PIL

Although the special handling codes ensure the proper handling and storage of the shipment, but do not by definition communicate the commodity. Only CRT and PIL are dedicated special handling codes for pharmaceuticals. In the booking a commodity usually known, but this is not visible on the air waybill (AWB).

ACT

A shipment defined as ACT container constantly provides the desired temperature between -20°C and 25°C. The ACT containers have the highest priority during aircraft loading. The captain of the aircraft is notified (NOTOC) of the shipment in order to maintain the proper storage temperature in the aircraft as well. On the ground the Conditioning-Competence Centre (CCC) is dedicated to store and monitor every ACT container passing through the terminal. The temperature and the battery- and dry-ice levels are monitored, checked and reported regularly. For ACT shipments 5 types of containers are used:

1. RKN 6 AKE sized active container from Envirotainer, power cooled
2. RKN 2 AKE sized active container from Envirotainer, dry-ice and battery cooled
3. RKN 0 AKE sized active container from C-Safe, dry-ice and battery cooled
4. RAP 8 AAP sized active container from Envirotainer, power cooled
5. RAP 2 AAP sized active container from Envirotainer, dry-ice and battery cooled

COL

A shipment defined as COL needs to be transported and stored in a temperature between 2°C and 8°C. The captain of the aircraft is notified (NOTOC) of the shipment in order to maintain the proper temperature in the aircraft as well. On the ground, CCC monitors the shipments and checks if they have arrived in time to the right cool room or location.

Time restrictions of a COL shipment depends on if it is on T-ULD or that shipment is part of a M-ULD. A COL T-ULD needs to be stored cool within 2 hours after arrival and can be taken out 3 hours before departure. The COL T-ULDs are placed on a dolly and parked on an outgoing lane to the aircraft. Individual COL shipments on a M-ULD need to be split from the M-ULD within 3 hours and be placed in a cool storage within 3,5 hours. From 5 hours before departure the shipment can be taken out of the cool storage to be build-up again onto a M-ULD. Loose freight defined as COL, is stored in the smaller cool storages in freight building 1 and are taken out 1,5 hour before departure.

CRT

A shipment defined as CRT needs to be transported and stored in a room with a temperature between 15°C and 25°C. The captain of the aircraft is notified (NOTOC) of the shipment in order to maintain the proper temperature in the aircraft as well. On the ground, CCC monitors the shipments and checks if they have arrived in time to the right cool room or location.

Time restrictions for CRT shipments under normal circumstances only are applicable to T-ULDs. CRT T-ULDs need to be stored cool within 2 hours after arrival, and can be taken out 3 hours before departure. The CRT T-ULDs are placed on a dolly and parked on an outgoing lane to the aircraft. Only when extreme temperatures occur and normal room temperatures cannot be guaranteed anymore, all other possible CRT shipments will be stored under controlled conditions.

PIL

A pharmaceutical shipment defined as PIL needs to be transported and stored in a temperature between 2°C and 25°C. Active monitoring and the protection from temperature overruns, only applies during extreme weather conditions.

3.4. Demand and Supply in 2014

This paragraph the performance of the pharmaceutical products processed through the AAS hub in 2014 is concerned. The closed cool-chain product (ACT) shipments and the open cool-chain products (COL, CRT and PIL) are elaborated on separately as their characteristics differ fundamentally. In the first paragraph the performance of the closed cool-chain product is shown and in the second paragraph the performance of the open cool-chain products is given. In the third paragraph the performance per week of all pharmaceutical shipments combined is shown and in the last paragraph the modal split for the flows is determined.

Source

The source for this data analysis is KLM Cargo's DataWarehouse (DWH) in SAP Business Objects. The DWH has only been running in January 2014 and is only able to access data over the year 2014. This data is obtained from is an operational universe, which is fed with data from the warehouse management system: CHAIN. The choices and approaches for retrieving the data have been approved and outliers were removed from the datasets obtained. Results have been validated with the manually kept administration (ACT), the operation's expert opinion, and random sampling (bulk belly freight).

3.4.1. Performance of the Closed Cool-Chain Product: ACT

In 2014 the terminal handled 2.966 shipments in active containers through the closed cool-chain. As seen in Figure 3.3 the majority of the shipments were transit shipments passing through. About 60% of the shipments passing through Amsterdam arrive by truck and leave by aircraft (see appendix 4). Characteristics of the ACT shipments are depicted in table 3.2

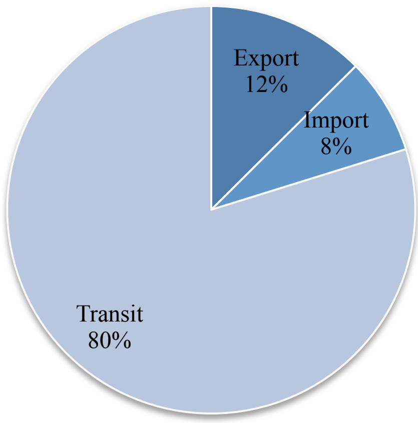


Figure 3.3: Division of ACT Shipment over the flows

Table 3.2: Characteristics of the ACT shipments

Characteristics	Quantification
Shipments	2.966
Containers	6.938*
Average throughput time export	20 hours
Average throughput time import	10 hours
Average throughput time transit	25 hours

* The count of 6.938 containers consisit of all RKN and RAP containers together. In 2014 these2 were 5.097 RKN containers and 1.841 RAP containers. As a RAP container is a double RKN container the total amount of containers handeled can be expressed as $5.097 + (2 \cdot 1.841) = 8.779$ RKN equivalent. The composition of the containers is depicted in Figure 3.4.

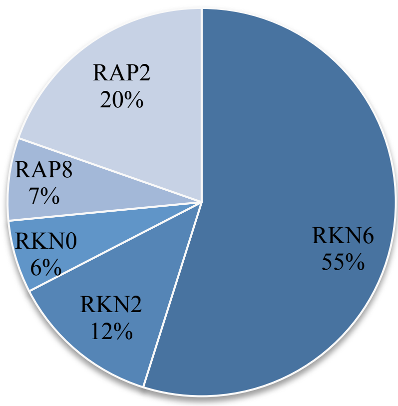


Figure 3.4: Shares of ULD types for ACT shipments

3.4.2. Performance in 2014 of the open cool-chain Products: COL, CRT and PIL

In 2014 the terminal handled 43.573 pharmaceutical shipments through the open cool-chain in the Amsterdam hub. As seen in Figure 3.5 A about 50% of the amount of shipments were PIL shipments, requiring no special temperature controlled storage. Figure 3.5 A, B and C show the characteristics on the COL, CRT and PIL products through the open cool-chain.

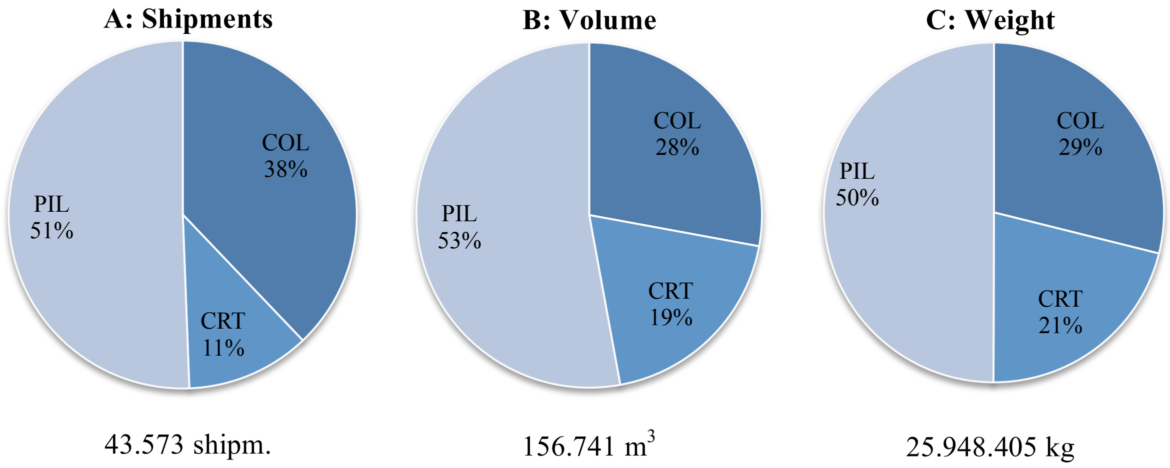


Figure 3.5: Characteristics on the products in the open cool-chain

The average volumes of the shipments are:

- COL 3,27 m^3
- CRT 6,03 m^3
- PIL 4,24 m^3

Also about 80% of the shipments in the open cool-chain is a transit shipment, of which more than 50% is also a transit shipment arriving at the Amsterdam hub by truck and leaving by aircraft. Figure 3.6 A, B and C show the share of the export, import and transit shipments, the average throughput time and the share of the shipments in each flow that need to be stored in controlled temperature rooms (throughput time > 8 hours).

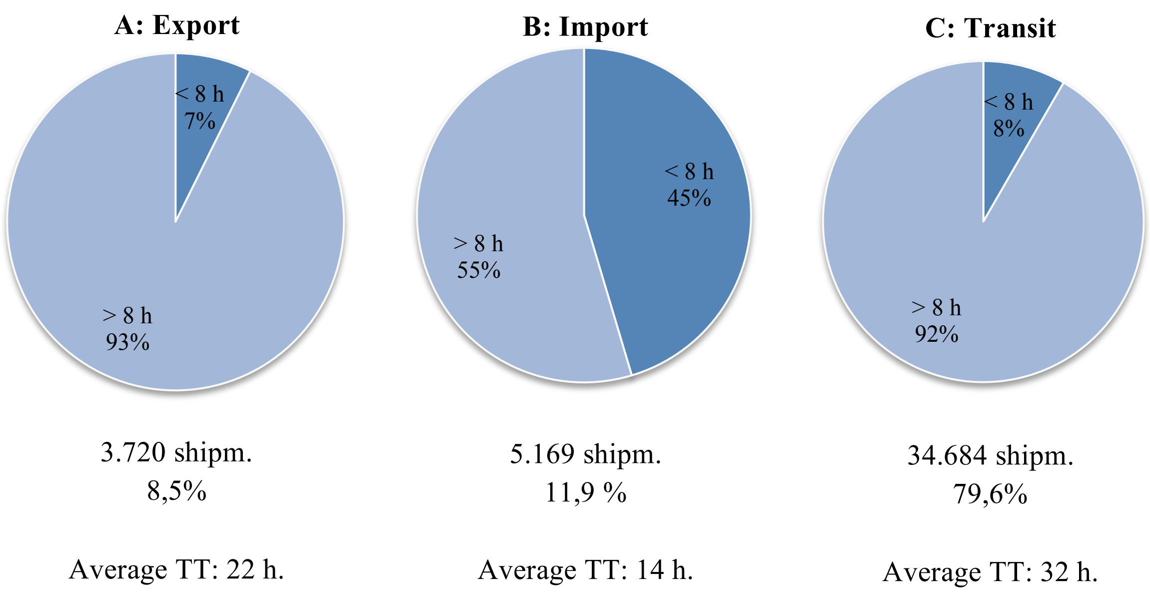


Figure 3.6: Throughput characteristics for the flows

Dividing the flows in export, import and transit is used to show characteristics of the shipments. When one wished to know more on the physical flows through the terminal and the accompanying facilities used the flows need, they should to be more specifically zoomed in upon. Figure 3.7 shows a schematic overview of how these flows between air- and landside would be.

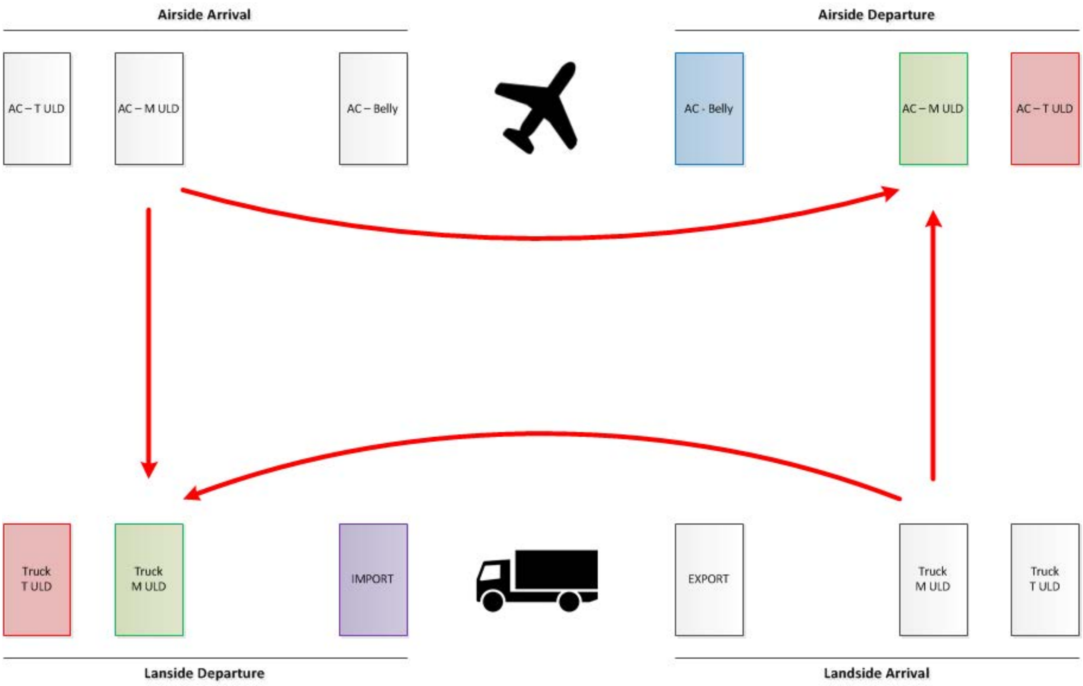


Figure 3.7: Schematic flows between airside and landside arrival and departure

In reality the four schematic arrows represent 23 flows. In appendix 5 the flows are quantified. In the upper row the way the shipment arrives at the warehouse is named, the first column represents the way the shipment leaves the terminal. If these flows are drawn in the same drawing as Figure 3.7 the flows through the terminal look as in Figure 3.8.

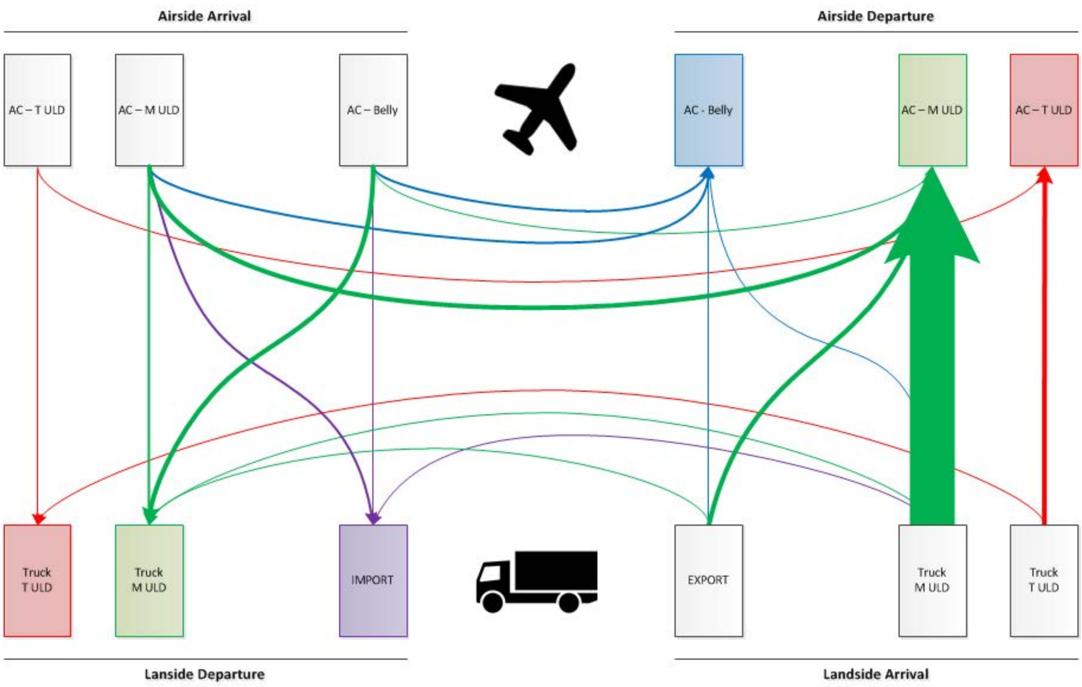


Figure 3.8: Real flows between airside and landside arrival and departure

From Figure 3.8 and appendix 3 can be concluded that:

- 43% of the open cool-chain shipments arrive by truck on a M-ULD and leave the terminal by aircraft on another M-ULD;
- 16% of the open cool-chain shipments are in one stage process transport as bulk load in the aircraft belly;
- the remaining 41% is not definable as those shipments are scattered over the remaining flows;

3.4.3. Modal split

With the tables in appendix 5 the modal split of the transportation of the shipments are determined. The results are given in table 3.3.

Table 3.3: Modal split between truck and aircraft per flow and for the pharma product groups

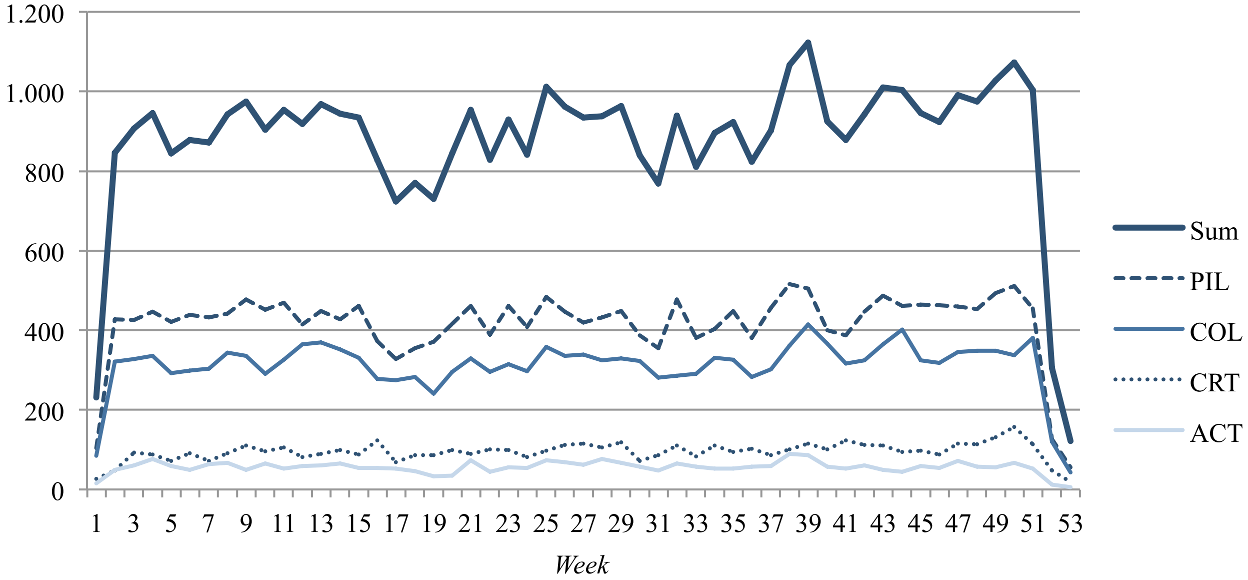
Flow	All pharma	ACT, CRT, PIL	COL
Inbound flow			
- export delivery truck	100%	100%	100%
- export delivery aircraft	0%	0%	0%
- import arrival aircraft	2%	2%	3%
- import arrival aircraft	98%	98%	98%
- transit arrival truck	67%	67%	66%
- transit arrival aircraft	33%	33%	34%
Outbound flow			
- export departure truck	1%	1%	0%
- export departure aircraft	99%	99%	100%
- import delivery truck	100%	100%	100%
- import delivery aircraft	0%	0%	0%
- transit departure truck	7%	9%	4%
- transit departure truck	93%	91%	96%

3.4.4. Performance in 2014 of all pharmaceutical products per week

Figure 3.9 shows the pharmaceutical shipments per week in 2014. From the graph can be concluded that there is a subtle growth in the transportation of pharmaceutical shipments through the Amsterdam hub. The different products seem to not take from each other's shares and follow about the same fluctuations. Noted should be that in week 39 in 2014 the pilots of Air France were on strike and that the peak resulted from freight being rerouted over the Amsterdam hub instead of the Paris hub.

Week 1 and week 53 represent only a partial week as the year changes in these weeks. Around the turn of the year the shipments handled are typically low.

Figure 3.9: Pharma shipments per week from 01-01-2014 until 31-12-2014



3.5. Amsterdam Hub Facilities

Currently the handling of the pharmaceutical shipments is not a dedicated process with dedicated facilities. For handing the pharmaceutical shipments the general and some semi-dedicated facilities are used. The pharma specific facilities are considered to be operating at capacity.

The shipments are handled through the entire KLM Cargo terminal, which consists of the three freight buildings 1, 2 and 3. Although freight buildings 2 and 3 have their own, strictly separated operations, they are interconnected and have in their attic a mutual pallet and container handling system (PCHS) in which they can store up to 2.600 ULDs and from where the ULDs move automatically to their destinations.

The facilities available to handle pharmaceutical freight in the required way are:

- ACT desk
- Cool room for COL ULDs
- Temperature controlled room for CRT ULDs
- Multiple cool rooms for COL shipments

A more elaborate description of the freight buildings and the facilities in place for pharmaceutical freight is found in appendix 6.

3.5.1. Waste Analysis on Operating the AAS Terminal

The processes for handling pharmaceutical freight have been subject to a Value Stream Mapping according to Lean theory and including a waste analysis. Wastes such as overprocessing and behavioural waste are mostly considered to be policy related. In this paragraph the waste related to the terminal configuration is given for both cool-chains.

Closed Cool-Chain

In the handling processes for the ACT containers through KLM Cargo's AAS hub waste is found. Waste related to the configuration of the terminal is summed up in the following list:

- Transportation waste occurs because of large traveling distances between different facilities in the hub;
- Transportation waste occurs because of the processing of the ACTs into the terminal in multiple transportation steps. First the ACT is parked outside the terminal, after that the ACT is processed into the terminal. In between waiting waste occurs. The reason for this extra step is that the service area is not reachable by the tractors used for apron transportation.

Open Cool-Chain

In the handling processes for the COL, CRT and PIL shipments through KLM Cargo's AAS hub waste is found. Waste related to the configuration of the terminal is summed up in the following list:

- Transportation waste occurs because of the processing of the T-ULDs into the terminal in multiple transportation steps. First the T-ULD is parked outside the terminal, after that the T-ULD is processed into the terminal. In between waiting waste occurs.
- Transportation waste occurs because of the unintegrated cool facilities for pharma. To process a T-ULD COL or CRT into the cool room, the ULD needs to go back and forth between the facilities for pharma in freight building 1 and the general ULD handling system in freight buildings 2 and 3. The same accounts for bulk belly freight.
- Transportation waste occurs because of the large amount of buffers the pharma shipments travel through in freight buildings 2 and 3.

3.6. Conclusion

In order to maintain the contribution of KLM Cargo to the profitability of the Air France – KLM Group and to stay a trustworthy partner for the air transportation of pharmaceuticals, viable commodities, such as the pharmaceutical product, need to be facilitated well. The advantage of having the ground handling as an in-house activity should be exploited to strengthen the position in the pharmaceutical supply chain and to substantially improve the cool-chain.

The pharma products offered by KLM Cargo are a closed cool-chain product (ACT) and three open cool-chain products (COL, CRT, PIL). The shipments can be palletized on mixed (M) or through (T) ULDs or be handled just in bulk, loose. The temperature ranges available are 2˚C - 8˚C and 15˚C - 25˚C.

The terminal is suited to handle the amount of pharmaceutical freight. For handling the 46.539 shipments ACT, COL, CRT and PIL in 2014 the terminal is in general big enough, though the special pharma facilities are getting capacity constrained. The terminal is not equipped to supply any more demand for ULD storage in 2˚C - 8˚C and 15˚C - 25˚C cool rooms or ACT containers at the ACT desk.

The split of pharmaceutical freight is about 80% transit and 20% export and import. In the open cool-chain 50% of the shipments are PIL, 40% COL and 10% CRT. CRT shipments appear to be heavier and more voluminous.

About 43% of all shipments arrive the terminal on M-ULD at landside with a transit truck and leave the terminal on M-ULD at airside to depart by aircraft.

About 16% of all shipments are shipped as bulk belly freight in at least one of the transportation legs.

Currently the special pharma facilities are spread over 3 freight buildings and is the pharma freight handled within general cargo flows. In waste analysis on the processes most waste is found in the lack of centralized and dedicated pharma handling. Seen without the context of the current freight-building configuration the following facilities are currently used for handling the pharma products:

- Export flow facilities, namely:
  - Landside: Export acceptance and transit truck unloading
  - Airside: ULD output and belly output
- Import flow facilities, namely
  - Airside: ULD input and belly input
  - Landside: Import delivery and transit truck loading
- Bulk buffers (ULD and belly)
- Build-up ULD buffers
- Breakdown/ build-up area
- ACT service desk and area

4. Pharmaceutical Supply Chain

This chapter provides deeper insights in the pharmaceutical industry and its supply chain. In order to understand the position of KLM Cargo and the airport facilities required, first an introduction is given, that the current development and the actual supply chain is discussed and then some insight is given in the currently applying GDP regulations applying to manufacturers and distributors in the chain.

4.1. Introduction

The pharmaceutical industry is a complex industry that discovers, develops and produces drugs and medicines, which are *"chemical substances used in the treatment, cure, prevention, or diagnosis of disease or used to otherwise enhance physical or mental well-being"* (Dictionary.com, 2014). The dominating players in the industry are the large multinational companies focusing on research and development of prescription and over-the-counter drugs and medicines. Typically they have manufacturing sites in many locations (Shah, 2004).

The pharmaceutical industry is a fast growing and valuable market. The total spending on pharmaceuticals is expected to reach $1,0 trillion in 2014 from there on increasing with an average growth rate of about 5% per year. The USA, Japan and Europe are still the largest market for pharmaceuticals sales, but they experience low growth rates. The increasing growth of sales in emerging markets China, Brazil, Russia and India, the so-called Pharmerging markets, are boosting the growth, because of their expected annual growth rate of 11 – 14% % (Beck, 2013).

The industry's preferred mode to transport raw materials, (semi) finished ingredients and final products is by air. A very effective way of transporting pharmaceuticals by air is to use the active containers (Sales, 2013)

4.2. Supply Chain

A definition of the pharmaceutical supply chain is given by Kaufmann (2005):

"Pharmaceutical supply chain should provide medicines in the right quantity, with the acceptable quality, to the right place and customers, at the right time and with optimum cost to be consistent with health system's objective and also it should make benefits for its stockholders".

The supply chain can be defined as an integrated process where businesses work together to produce goods (Sousa, Liu, Papageorgiou, & Shah, 2011).

The typical supply chain in the pharmaceutical industry is involves the following fice main actors (Susarla & Karimi, 2012) (Pedroso & Nakano, 2009) (Shah, 2004) (Susarla & Karimi, 2012):

1. *Primary manufacturers*
   The primary manufacturer produces the active ingredients.

2. *Secondary manufacturers*
   The secondary manufacturer is concerned with processing the active ingredient into the final products.

3. *Market warehouses/ distribution centres*
   The distribution centres package the pharmaceuticals in suitable sizes that fit the local market's need.

4. *Wholesalers*
   Wholesalers have an important role in the supply chain and they tend to be large and few. About 80% flows through the hand of the wholesalers.

5. *Retailers/ hospitals*

The nodes in the chain are often geographically separated because of tax and transfer price optimization. There are many more secondary manufacturing sites than there are primary manufacturing sites as the very-high value products are usually produced in low quantities at a few locations over the world (Sousa, Liu, Papageorgiou, & Shah, 2011). Transportation from the primary site may take up to one or two weeks by ship or one or two days is transported by air through a cool-chain (Shah, 2004).

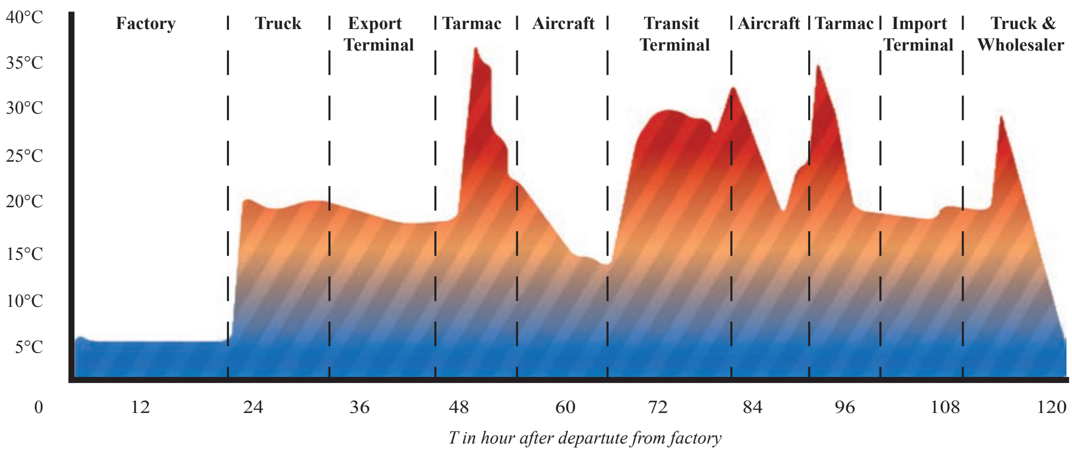
4.2.1. Cool-chain

For moving pharmaceuticals from one node to another it is necessary to have an unbroken cool-chain in place. Handling and quality standards are unified over the world and are necessary to insure product integrity and to comply with customer and regulatory requirements. It is a critical point in the distribution chain (Mertens, 2014) as no package is able to maintain a stable temperature without the environment being temperature-controlled (Higgins, 2011).

4.2.2. Pharmaceutical Air Freight Supply Chain

Moving the pharmaceuticals between the nodes in the supply chain is dominantly (Boeing, 2012) done by air transport, because of the competitive advantages of speed and on-time delivery. As shown in figure 4.1 a large part of the airfreight supply chain is spent on the ground and it poses the most common risk of temperature excursions due to wide variations in ambient temperatures. One of the challenges in the airfreight pharmaceutical supply chain is the prevention of temperature excursions, as business interruptions and supply chain risks are rated number one global business risk for the industry (IATA, 2004).

Figure 4.1: Course of the temperature development through the transportations steps



4.3. Regulation

Worldwide uniformity in regulations for handling pharmaceuticals in the supply chain is necessary to keep pharmaceuticals in the required condition during distribution (Sales, 2013). In Europe the European Commission issued guidelines on good distribution practice (GDP) of medicinal products for human use (European Commision, 2013). The guidelines aim to ensure control of the supply chain and to maintain the quality and the integrity of the medicinal products. Next to the product integrity there should be focus on protection against breakage and protection against adulteration and theft (Mertens, 2014)

Guidelines of 5 November 2013 on GDP on medicinal products for human use

The GDP guidelines state:

"Any person acting as a wholesale distributor has to hold a wholesale distribution authorisation. Article 80(g) of Directive 2001/83/EC provides that distributors must comply with the principles of and guidelines for GDP. Possession of a manufacturing authorisation includes authorisation to distribute the medicinal products covered by the authorisation. Manufacturers performing any distribution activities with their own products must therefor comply with GDP." (European Commision, 2013).

Manufacturers and wholesale distributors in the supply chain must comply with GDP. The guideline contains 11 chapters:

1. Quality Management
2. Personnel
3. Premises and Equipment
4. Documentation
5. Operations
6. Complaints, Returns, Suspected, Falsified Medicinal Products and Medicinal Product Recalls
7. Outsourced Activities
8. Self-inspections
9. Transportation
10. Specific Provisions for Brokers
11. Final Provisions

The GDP involves manufacturers and distributors, but also ground handlers and airlines, like KLM Cargo, which are not directly mandatory to comply. They perform outsourced activities for which regulation is determined in chapter 7.

GDP Guidelines Chapter 7: Outsourced Activities

Manufacturers or distributors are allowed to outsource activities in their processes. GDP states that at all times the manufacturer or distributor (contract giver) is responsible for the activities contracted out to the contract acceptor (e.g. KLM Cargo). In order to establish this a written contract should be drawn up clearly defining the duties of each party.

It is the responsibility of the contract giver to assess the competence of the contract acceptor through the contract and through audits. The audits should check whether the principles and guidelines of the GDP are followed. The contract acceptor should allow audits at any time and should be provided with the necessary information.

The contract acceptor should not outsource any activities and should forward any information that can influence the quality of the product.

GDP Guidelines Chapter 9: Transportation

The principle in the transportation chapter is to make sure the product is protected to breakage, adulteration and theft and that the temperature conditions are maintained within acceptable limits during transport. Transportation is subject to the following:

For temperature sensitive products qualified equipment should be used to ensure transport at the correct conditions. Temperature monitoring equipment should be in place, be used and be calibrated.

Contract acceptor: KLM Cargo

In order for pharmaceutical manufacturers or distributors to comply with GDP the GDP chapter 7 states they should audit KLM Cargo to ensure the principles and guidelines of GDP are followed and that KLM Cargo has the adequate premises and equipment, procedures, knowledge and experience and has competent personnel.

4.4. Conclusion

The pharmaceutical supply chain depends heavily on transportation between the nodes and phases in the production process, which are typically geographically separated. It appeared that problems in the cool-chain occur at ground handling of air transportation. Product integrity has always been an important issue in the pharmaceutical industry.

To ensure product integrity WHO and EU presented the GDP Guidelines. For KLM Cargo the transportation chapter and the outsourced activity rules apply. As KLM Cargo would be a third party in the distribution process the GDP standards do not directly apply, but as they do apply on the manufacturers and distributors it is important for KLM Cargo to offer the services in compliance on what is requested of the distributors.

With the complication of the pharmaceutical industry and supply chain it is important for KLM Cargo to adapt efficiently to this new situation.

5. Trends and Developments

After researching the current situation at KLM Cargo and in the pharmaceutical supply chain the trends and developments are described in this chapter. In order to fit the new KLM Cargo Pharma Terminal to the need of the future, the trends and developments in the air cargo market, the pharmaceutical market and the KLM Cargo situation are researched.

5.1. Introduction

The pharmaceutical industry has shown a stable growth over the years (Cold Chain Consultants, 2014) and will continue to grow at stable rates of on average 5 – 8 per cent per year. The pharmaceutical industry is expected to be worth $1,1 trillion in 2014 (Sales, 2013). With expiring patents and the increasing demand for pharmaceuticals in emerging countries the demand for a global cool-chain will expand. Offering special tailored cool-chain services combined with the safe and fast nature of airfreight ensure airlines of a profitable and sustainable business (IATA, 2004) (Sales, 2013). As global regulation and standardization is tightening to ensure the quality of the cool and supply chain and therewith the integrity of the pharmaceuticals shipped, specialization is required of the airfreight operators (Mertens, 2014).

5.2. Air Cargo Market

The overall airfreight transport market is expected to keep growing with an average of 5,2 % until 2031. The capacity on passenger flights is expanding, as there is a trend of adding highly cargo-capable aircraft to fleets. Extra profit is generated and the extensive passenger network becomes available for freight as well (Boeing, 2012).

Pharmaceutical airfreight is expected to be the fastest growing commodity. The growth is expected to be 12% from 2012 to 2017, mainly driven by the ‘Pharmerging’ markets in Asia and Latin-America. The global character of the pharmaceutical industry and the fact that temperature-sensitive pharmaceuticals are mostly exported from North-America and that Asia and Latin-America are mostly importers present unique transportation challenges (Seabury, 2013) (Gruber, 2012). The nature of the product requires a framework to deal with these challenges and to ensure falsified medicines from entering the supply chain. For this the European Commission has published the GDP guidelines as described in chapter 0.

Airfreight transportation companies should act on the regulations in order to maintain the competitive advantage. First towards other actors in the airfreight supply chain that recognise the pharmaceutical industry experiences stable growth, that pharmaceutical shipments have high-yields and are belly proof. Secondly, also towards the mode shift to ocean freight (Seabury, 2014) The quality delivered by the airfreight related actors within the pharmaceutical supply chain need to increase, otherwise it is expected there will be a moderate shift to ocean freight. Ocean freight is very simple and cost efficient (AirFrance KLM Martinair Cargo, 2014a).

5.2.1. Pressure on the Air Freight Market (Doganis, 2010)

The 21st century has not been very favourable for the airfreight market. First the economic downturn, the terroristic attacks on 11 September 2001, the war in Iraq and a SARS epidemic, and later on from 2004 until 2008 the unusually high fuel prices followed by the economic crises started in 2007 have pressured growth in the airfreight market. It is expected though the growth will re-establish.

In the past decade the nature of airfreight industry has changed. Integrators and forwarders have gained substantial market power over the traditional combination airlines. In order to be taking some share in the expected growth traditional combination airlines first should adapt to the changes in the industry. Many airlines have made the necessary changes and consider the passenger and freight operations as very different products now, each structured in their own subsidiary with own marketing, selling, administration, facilities and procedures. The success for the airfreight operators depends on the way the delivery service is structured and the supply chain is managed. Coping with the operational challenges to provide this customised service to meet the specific market demands seems costly, but should generate a higher yield.

Adapting the IT systems to the new services is inevitable. It should enable high speed tracing, high technology warehousing, automatic and customer focussed reporting systems and the provision of time-guaranteed collection and delivery.

Facing the changes and adapt to the new market demands should enable airfreight operators to charge more for their services, generating higher yields and avert the pressure on rates. Their aim should not just be to just transport freight by air anymore.

Next to the individual challenges airlines are facing, there is also a lot to gain in optimizing the freight alliances. Services and networks should be integrated more and act as one in order to successfully cope with these challenges and stand-up to the long-term threat of the integrators and forwarders.

5.3. Pharmaceutical Industry

Cost awareness is the biggest industry trend. The uncertainty in the market, the response to the price pressure and the rising competition make cost a very important factor on which action is needed. Innovation and the drive for product improvements and distribution chain improvements are very high on the agenda as well. Supply chain improvements are necessary to bring the cost down.

Next to the cost reductions, the need to respond to changes and regulation in the pharmaceutical industry is acknowledged in order to maintain a competitive position. These responses would be optimizing flow, maintaining the right mix and locations of warehouses, efficient use of capacities, inventories and labour (Jaberdidoost, Nikfar, Abdollahiasl, & Dinarvand, 2013).

5.3.1. Drivers for Growth

The reasons for steady average growth of about 5 per cent per year the pharmaceutical industry has seen are mainly the aging population, the increasing health awareness, the rising number of patients and the advances in drug-based treatment research. The expiring patents, tightening regulations, pressured prices and the increasing costs for lawsuits, cancel-out some of the growth. The cold chain market is growing 10 per cent per year (Sales, 2013).

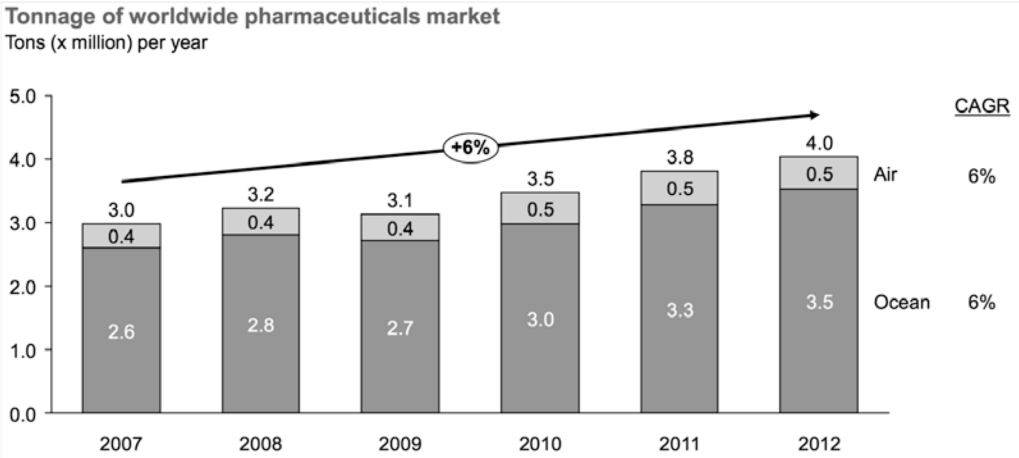


Figure 5.1: Global trade in pharmaceuticals. Source: Seabury Global Trade Database

5.3.2. Supply chain management

The industry's need to stay competitive increases the focus on supply chain management. Lean management is one of the most effective practices to improve supply chains (Staudacher & Bush, 2014). Studies already have shown Lean techniques have been popular in the pharmaceutical industry. The industry has seen many individual initiatives for streamlining operations and processes to reduce the inventory in the chain. Despite the efforts, the benefits have remained limited, as the inventory in the chain was not reduced. Involving the whole supply chain should do so (Spector, 2010). To ensure bottom-line growth drastic cost cuts by means of supply chain optimization are required (Susarla & Karimi, 2012).

As recognised by the industry, widespread supply chain improvements are necessary to create the desired overall progress (Spector, 2010). Traditionally the focus was on drug discovery and marketing, but now much more attention is being paid to the supply chain optimization (Shah, 2004). Recognition of the ability of the supply chain is expected to generate both value for the customer and hence to the shareholder. Restructuring supply chain will require massive reductions in capacity. Optimization of the supply chain can be done by eliminating bottlenecks and balancing between lowest material cost and transportation (Jaberdidoost, Nikfar, Abdollahiasl, & Dinarvand, 2013).

5.3.3. Regulations

Although the airfreight operators are not directly subject to any of the regulations, the manufacturers and distributors who outsource to transport the airfreight operators are required to audit the airfreight operator's facilities for compliance with the standards (Mertens, 2014). This may cause the airfreight operators to be audited many times and by different companies emphasising for different aspects. IATA and other industry-wide associations are taking the lead in a developing a uniform qualification program to meet the pharmaceutical manufacturers and distributors.

Trends Towards 2020

The GDP requirements will probably be updated more often. The latest version of the 2013 guidelines replaced the 1994 version. With the tightening regulations from the industry and the on-going technological developments to gather more detailed information, new and higher standards could set more often. Also the changing way of distributing pharmaceuticals will change. It is expected the packages will be less voluminous.

Until 2020 the focus will be on segregating the pharmaceutical shipments to prevent contamination, as well as to quality and safety concerns resulting in traceability and quality requirements.

Future Focus Points

Quality and safety will become even more important in the future. Humidity is expected to be added to the important factors to be monitored as well. Technology will be soon developed.

As until 2020 segregation of products seems to suffice, it is expected that ultimately fully closed processes will be set to be standard to prevent excursions. This closed cool-chain will be expected to be flexible, fast and able to handle high volumes of small packages.

5.4. KLM Cargo

The developments that affect KLM Cargo need to be analysed. Under normal circumstances only market developments would need to be addressed in a more improvised way but now also the whole facility needs to be redesigned presenting the opportunity to adapt very adequately to the expected future.

In 2018 AAS plans to take their new passenger terminal "A-pier" into use. The A-pier is planned to be located at Schiphol Centum at the location of the KLM Cargo freight-handling buildings. Already in 2016 part of the buildings needs to have been relocated to another location, which still needs to be designed. KLM Cargo aims for quality improvement for the pharmaceutical products especially increasing the operational product integrity by complying with the GDP standards and the implementation of innovative technology. This pharma ambition will influence the design of this new facility.

5.4.1. Product Expectations

In a workshop with a large group of stakeholders involved with the pharmaceutical product at KLM Cargo and external consultants the expected growth over the products has been estimated until 2040.

On the 14th of October 2014 a large group of stakeholders came together in the so called 'Pharma Workshop'. KLM Cargo staff from several layers in the company, a consultant from Cold Chain Consultants and a Capgemini consultant put together their expert opinion on the expectation for the demand for pharmaceutical freight in the future. The result of the workshop is presented in this paragraph.

The general opinion is that KLM Cargo's commodity pharmaceutical airfreight will over all more than double until 2040. The grow will be disproportionally distributed over the products. The reasons for the disproportionality are summarized in table 5.1.

Table 5.1: Reasons for disproportional growth

Product	Intrinsic growth/ decrease	Extrinsic growth of share	Extrinsic decrease of share
ACT	Moderate growth	From COL	n/a
COL	Low growth	From PIL and general freight	To ACT
CRT	High growth	From PIL and general freight	n/a
PIL	High decrease	n/a	To COL and CRT

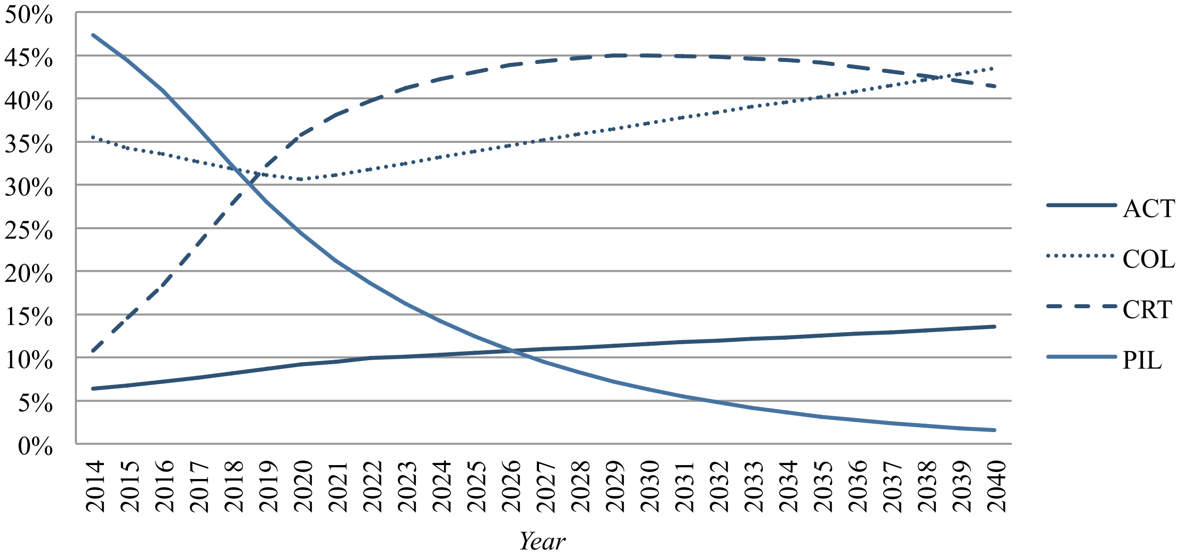
The expected overall growth per product is shown in table 5.2:

Table 5.2: Overall expected growth in shipments per product from 2014 until 2040

Year	ACT		COL		CRT		PIL		Pharma	
2014	2.966	-	16.507	-	5.017	-	22.049	-	**46.539**	-
2015	3.263	10%	16.507	0%	7.024	40%	21.388	-3%	**48.181**	4%
2016	3.589	10%	16.672	1%	9.131	30%	20.318	-5%	**49.710**	3%
2017	3.948	10%	16.839	1%	11.870	30%	18.896	-7%	**51.553**	4%
2018	4.343	10%	17.007	1%	14.838	25%	17.195	-9%	**53.383**	4%
2019	4.777	10%	17.177	1%	17.805	20%	15.476	-10%	**55.235**	3%
2020	5.254	10%	17.521	2%	20.476	15%	13.928	-10%	**57.180**	4%
2021	5.622	7%	18.397	5%	22.524	10%	12.535	-10%	**59.078**	3%
2022	6.016	7%	19.317	5%	24.100	7%	11.282	-10%	**60.715**	3%
2023	6.317	5%	20.283	5%	25.787	7%	10.154	-10%	**62.540**	3%
2024	6.632	5%	21.297	5%	27.077	5%	9.138	-10%	**64.144**	3%
2025	6.964	5%	22.361	5%	28.431	5%	8.224	-10%	**65.981**	3%
2026	7.312	5%	23.480	5%	29.852	5%	7.402	-10%	**68.046**	3%
2027	7.678	5%	24.654	5%	31.046	4%	6.662	-10%	**70.039**	3%
2028	8.062	5%	25.886	5%	32.288	4%	5.996	-10%	**72.232**	3%
2029	8.465	5%	27.181	5%	33.580	4%	5.396	-10%	**74.621**	3%
2030	8.888	5%	28.540	5%	34.587	3%	4.856	-10%	**76.871**	3%
2031	9.333	5%	29.967	5%	35.625	3%	4.371	-10%	**79.294**	3%
2032	9.799	5%	31.465	5%	36.693	3%	3.934	-10%	**81.891**	3%
2033	10.289	5%	33.038	5%	37.794	3%	3.540	-10%	**84.662**	3%
2034	10.804	5%	34.690	5%	38.928	3%	3.186	-10%	**87.608**	3%
2035	11.344	5%	36.424	5%	40.096	3%	2.868	-10%	**90.732**	4%
2036	11.911	5%	38.246	5%	40.898	2%	2.581	-10%	**93.635**	3%
2037	12.506	5%	40.158	5%	41.716	2%	2.323	-10%	**96.703**	3%
2038	13.132	5%	42.166	5%	42.550	2%	2.091	-10%	**99.938**	3%
2039	13.788	5%	44.274	5%	43.401	2%	1.881	-10%	**103.345**	3%
2040	14.478	5%	46.488	5%	44.269	2%	1.693	-10%	**106.928**	3%
Overall growth	**11.512**	**388%**	**29.981**	**291%**	**39.252**	**782%**	**20.356**	**-92%**	**60.389**	**130%**

As the growth is expected to be disproportional the division of the shares of the pharma products change too. The development of the product share from 2014 from 2040 is given in figure 5.2:

Figure 5.2: Development of the Share of the KLM Cargo Pharma Products



The growth predictions fit with the generally expected growth of pharmaceutical airfreight as determined by the pharmaceutical industry (see also chapter 5.2).

5.4.2. Fleet Development

The composition of the fleet used by KLM Cargo is changing. The full-freighters and combi B747 fleet is gradually phased-out, because of high operating cost (see paragraph 3.1.1). The majority of the freight capacity in the future will be accommodated in large wide-body aircraft as the Boeing 777-300ER, the Boeing 787-9 and the Airbus A350-900. The lower-hold capacity is very well suited to transport pharmaceuticals in the required way. Use of passenger aircraft to transport freight will generate extra profits, taking advantage of the dense passenger networks (Boeing, 2012).

5.4.3. Loose Trucking

For the new KLM Cargo freight handling facilities loose trucking is foreseen. If transit truck transportation is referred to as loose trucking it means that the shipments are transported on build-up, ready-for-flight aircraft ULDs but on easier to handle Europallets.

Loose trucking is expected to be a more efficient way of handling as fewer breakdown and building-up is required. Shipments can after arrival at the warehouse directly be stored into the right buffer. The increased unloading time of trucks is assumed to be a disadvantage.

Loose trucking replaces the trucked M-ULD flow into and from Europe. The T-ULD flow is expected to remain the same.

5.5. Conclusion

Pharmaceuticals are expected to be the fastest growing commodity in the product portfolio of KLM Cargo. The combination of the re-establishment of the growth in the airfreight and the pharmaceutical steady growth of the pharmaceutical industry of 5-8% per year, make the commodity very interesting for KLM Cargo to keep focussing on.

The pharmaceutical industry keeps focusing on the distribution and supply chains to maintain their competitive advantage. With that the industry acknowledges the increasing need for improvements in the global cool-chain. As air transport remains the preferred mode for pharmaceuticals, KLM Cargo should seize the opportunity and guarantee the integrity at their part of cool-chain in order to ensure themselves a profitable and sustainable business.

Not only the request of the pharmaceutical industry to improve the distribution and supply chains channels would be the incentive for contracted transporter companies to improve the facilities and the cool-chain, also external regulation is expected to become a determining factor. Currently there is legally no obligation for KLM Cargo as they act as a contractor and the obligation for compliance lies with the pharmaceutical companies. If the contractors do not comply with the standards put on the pharma companies, they will lose customers and market share.

Until 2040 KLM Cargo expects their pharmaceutical products to increase with 3,13% CAGR (compound annual growth rate), which means that it is expected that until 2040 the overall pharma volume more than doubles. Next to the growth a shift within the product share is expected.

The ambition to focus on pharmaceutical freight is not impeded by the development in fleet, as pharmaceutical freight is very suitable to be transported in the belly of wide and narrow body aircraft.

6. Requirement Analysis

In order to fit the new terminal to the nature of the operations at KLM Cargo, to the position in the pharmaceutical supply chain and to the future, the current situation, trends and developments have been analysed in chapter 3, 4 and 5. An overview of assumptions and requirements to be met by the new KLM Cargo Pharma Terminal resulting from these analyses are presented in this chapter. In the first paragraph the assumptions are described, and in the second paragraph the requirements.

6.1. Assumptions

- *Product identification*
  Pharmaceutical shipments labelled with special handling code ACT, COL, CRT and PIL are identifiable as pharma and will be directed to the pharma facilities.

- *Currently required environment*
  PIL product does not need any special facilitation in the new terminal as it can be handled in exactly the same circumstances as COL or CRT. ACT shipments can be stored in CRT circumstances.

- *Future demand for other temperature ranges*
  No expectations are developed on the rise of demand for other temperature ranges. For the design of the terminal it is assumed the terminal needs to be able to adapt to another temperature range when it unexpectedly occurs after all.

- *Loose trucking*
  All transit trucking will be done as loose trucking, which implies export acceptance, import delivery and truck transit related operations can be unified.

6.2. Requirements

- *System*
  The new terminal needs to be an independently operating facility within larger system of the KLM Cargo ground handling for freight.

- *Flows*
  The new terminal needs to facilitate the current pharmaceutical products ACT, COL and CRT. The facilities required are:

  - Export flow facilities, namely:
    - Landside: Export acceptance and transit truck unloading
    - Airside: ULD output and belly output

  - Import flow facilities, namely
    - Airside: ULD input and belly input
    - Landside: Import delivery and transit truck loading

  - Bulk buffers (ULD and belly)
  - Build-up ULD buffers
  - Breakdown/ build-up area
  - ACT service desk and area

- *Temperature ranges*
  The new terminal needs to have two temperature zones (either the entire terminal or just the storage rooms):
  - 2˚C - 8˚C
  - 15˚C - 25˚C

- *Capacity*
  The new terminal needs to facilitate the growing volumes in the future until 2040. The growth from 2014 to 2040 is expected to be 130% from 46.539 to 106.928 shipments.

- *Compliance*
  The new terminal needs to comply with the current and future regulation, such as GDP. GDP reflects on premises, equipment, storage and transportation.

- *Cool-chain improvements*
  The new terminal needs to improve the temperature deviations that are currently experienced at ground handling. Terminal and airside handling at the airport are considered to be the weakest link in the pharmaceutical supply chain for ensuring a cool-chain.

- *Supply chain improvements*
  The new terminal needs to be designed to add to the supply chain integration and activate the Lean initiatives that have been taken by individual players in the pharmaceutical supply chain. For this the KLM Cargo Pharma Terminal needs to enable Lean operations within the terminal bringing supply chain integration also beyond the boundaries of the terminal. The alignment of operations and focussing on the primary activities concerns KLM Cargo, the actor up stream and the actor down stream in the supply chain. For pharma 80% of the shipments passing through AAS the actors up- and down stream in the supply chain are not involved, as these are transhipments.

The next chapters cover the diagnosis phase in the design. In the chapters 7, 8 and 9 research is conducted on how the industry typically copes with developing similar terminals. The research is on theory of developing dedicated pharma facilities, competitors' pharma facilities and on Lean theory in relation to the place of the terminal in the supply chain. From these elements a systemic design for the KLM Cargo Pharma Terminal and a list of system operational requirements is developed in respectively chapter 10 and 11.

Second Phase in the Intervention Cycle:

Diagnosis

7. Airfreight Terminal Design Theory

As a first step towards developing feasible system level designs for the KLM Cargo Pharma Terminal, theories on airfreight terminal design are analysed in order to develop an overview of the currently established view on functions and design-determining variables of airfreight terminal design.

The theories considered are warehouse design theory and the more specific airfreight terminal design theory. Next to the scientific theories, also the practical view point of IATA for developing airfreight terminals is considered in the analysis.

7.1. Warehouse Design

Traditionally warehouses are meant to have an inventory holding function, but more and more they are evolving to transitory and sorting facilities (Maltz & DeHoratius, 2004). No inventory is kept anymore to reduce the high logistics costs caused by the operating warehouses in the supply chain (establish 2005). Decisions like these that determine warehousing costs are to a large extend already determined at the design stage (Rouwenhorst, Reuter, Stockrahm, Van Houtum, Mantel, & Zwijm, 2000).

Although the importance, Baker (2009) comes to the conclusion little has been written about systematic approaches for warehouse design. Warehouse designers have developed some methods but that they are only a little formalized. After combining these methods and a literature search, a list of helpful tools was developed to come to a more structured approach in warehouse design. The list contains eleven steps (Baker & Canessa, 2009), which present a structured, validated view on the development of a warehouse:

1. Define system requirements
2. Define and obtain data
3. Analyse data
4. Establish unit loads to be used
5. Determine operating procedures and methods
6. Consider possible equipment types and characteristics
7. Calculate equipment capacity and quantities
8. Define services and ancillary operations
9. Prepare possible layouts
10. Evaluate and assess
11. Identify the preferred design

The steps extracted from the warehouse design theories come close to the steps for developing a conceptual design within the Systems Engineering and Analysis theory that is used for this research. The warehouse development theories do, besides validating the choice for the Systems Engineering methodology, not yet present the required insights for coming to system level designs for the KLM Cargo Pharma Terminal.

7.2. Airfreight Terminal Design

More specific design methods for warehouses functioning as an airfreight-handling terminal have been developed by Radnoti (2002), IATA (2004), Kazda and Caves (2007) and Ashford, Mumayiz and Wright (2011). As the airfreight-handling terminal has some essentially different functions and is the interface between a multi-modal supply chain, not every aspect of the terminal development is covered by the general warehouse design tools and techniques and an analysis of more specific literature is required.

7.2.1. Function

The airfreight-handling terminal is an essential element in the airfreight supply chain. Without an adequate terminal that is unable to facilitate demand and to be flexible when demand changes, the operations cannot be performed properly (Kazda & Caves, 2007). Due to the complexity of the processes of moving, processing and delivering most of the problems occur on the ground. An airfreight-handling terminal has five functions (Kazda & Caves, 2007):

1. *Conversion between modes of transport*
   The size of load is changed in the terminal. The small loads arriving by truck are consolidated into the larger unit adapted to fit aircraft load sizes (Ashford, Mumayiz, & Wright, 2011).

2. *Sorting, including breakdown loads from originators and consolidating for destinations*
   In the terminal shipments will be sorted on destination or flight (Ashford, Mumayiz, & Wright, 2011).

3. *Storage and facilitating government inspection*
   Storage is necessary to match the airside and landside flow patterns (Ashford, Mumayiz, & Wright, 2011). Storage facilities need to fit the commodity of the shipment. Perishables should be stored in cool rooms (Radnoti, 2002).

4. *Movement of goods from landside to airside or from aircraft to aircraft and viceversa*
   Physical transfer of the shipment from the warehouse into the aircraft. Normally Customs control is included (Ashford, Mumayiz, & Wright, 2011).

5. *Documentation: submission, completion, transmission*
   The efficient operation of a terminal is dependent on modern documentation procedures (Ashford, Mumayiz, & Wright, 2011).

7.2.2. Design-Determining Parameters

The design of the terminal depends on (Kazda & Caves, 2007):

1. *Type of operator and their service standards*
   The airline business model and the aircraft used determine whether freight arrives in bulk or build-up on ULDs and in which volumes freight flows in and out the terminal.

2. *The expected rate of growth of demand and the ultimate capacity required*
   A terminal should be fit to accommodate future demand and developments as well. If not the building will become obsolete. Demand is determined by tariff, time spend in transit, operation frequency and the economic characteristics of the region.

3. *The political and economic setting*
   The availability of labour and the cost of labour are determined by the setting the terminal is located in. Airport, local and governmental policies mainly determine the dwell time for goods to flow through the building, and so have great influence on the required capacity in the warehouse.

4. *The airport and local authority planning constraints*
   Regulations concerning the construction can determine important constraints for the terminal. Height, sustainability and the access are major design decisions for construction and planning.

5. *Mechanisation*
   The factors determining the design are drivers for the decision on the extend of mechanisation in the terminal as well. Overmechanisation can lead to bad economic and operation performance of the terminal (Ashford, Mumayiz, & Wright, 2011). The choice is between (Kazda & Caves, 2007):

   a. *Manual*
      A manually operating terminal is dependent on manpower and forklifts. Labour is costly, but flexible. Often, but not necessarily only, used for low volume terminals

   b. *Semi-mechanized*
      A semi-mechanized terminal is based on roller beds and conveyors. In this case the roller beds are chain driven and the system is equipped with reorienting and transfer dock beds.

   c. *Fully mechanized*
      Terminals with full mechanization elevating transfer vehicles (ETV), automatic storage and retrieval systems and transfer vehicles. It will only work for high volumes of freight and requires expertise on maintenance of the system. Mechanization is considered expensive, but has the advantages of less handling damage and mishandling.

The success of the terminal design depends on the mix of aircraft operating the freight and the adaptability to future fleet compositions and technological development (Ashford, Mumayiz, & Wright, 2011). A good terminal will have systems that allow (Kazda & Caves, 2007):

1. Efficient movement
2. Effective storage
3. Easy sortation
4. Accurate and timely inventory control
5. Tight security
6. Effective use of manpower

7.2.3. Layout

The typical layout for an airfreight-handling terminal is a terminal with a single work floor, processing inbound and outbound flows side by side. The terminal consists of truck docks, acceptance areas for checking and labelling, breakdown areas, sorting buffers, build-up areas, weighting and scanning areas and airside docks (Kazda & Caves, 2007) (Radnoti, 2002).

Freight enters the terminal from either airside or landside. Freight can be either bulk, on a build-up ULD (M or T). For incoming freight awaiting clearance or collection, outgoing freight awaiting consolidation or departure and transhipments temporary storage areas are needed. Bulk freight and M-ULDs require special sorting, build-up and breakdown areas. The last two areas have always been designed manually for each mechanisation scenario.

7.2.4. Sizing

For the revenues only the total amount of freight handled is of importance, but for designing a freight terminal the peaking characteristics influence the system elements. The peaks in the freight terminal are not only determined by the airside peaks, which are closely related to the schedule for passenger aircraft, but also by the landside peaks. Landside peaks are determined by the operations of shippers and forwarders. The balancing of both peaks happens in the freight terminal. Every terminal will have its own characteristic peak composition based monthly, daily and hourly variations based on seasonality, variation of commodities, industrial output, shipper and forwarder preferences, and airside operations. Together with the peaks the dwell time determines the required capacity of the terminal. Throughput time should be fast enough to ensure the product integrity and the speed element of the competitive advantage of airfreight. For sizing Kazda (2007) refers to IATA's Airport Development Reference Manual.

7.3. IATA Airport Development Reference Manual

In its Airport Development Reference Manual IATA (2004) recommends on the principles concerned with airfreight terminal design, and they are elaborated on in this chapter. Where the reference manual focuses on multi-airline, multi-tenant, and multi-commodity terminals, this information is kept out of the research.

7.3.1. Forecasting and sizing

The cargo traffic and the aircraft carrying the freight heavily determine requirements and size of the airfreight-handling terminal. The share bulk, M-ULD and T-ULD and the share import, export and transit determine what space must be provided. If a lot of freight needs to be re-processed (transit) more capacity in e.g. breakdown, build-up and staging facilities are required.

The capacity of the terminal is highly depending on the forecasted demand in the prescribed design peak period. This design demand needs to be determined and could for instance be cargo processed on the peak day, of the average week in the peak month.

7.3.2. Sizing parameters

Next to the freight volumes other characteristics have impact on the size of the terminal as well. Therefore it is important to first gain knowledge about the current operations and the operational ambitions for the future, identify current constraints, define the process requirements and applicable standards, and determine to what extend the operations can be performed outside in stead of inside.

IATA defined some rules of thumb based on the total annual freight volumes and the extend of the automation in the warehouse:

- Low degree of automation 5 tonnes per square meters
- Automated 10 tonnes per square meters
- Highly automated 17 tonnes per square meters

Combined with the peak demand to be facilitated in the terminal the dwell time of the shipments should be considered to determine the capacity. Dwell time should be considered for each step in the process. The volumes should be translated into the bulk freight, M-ULDs and T-ULDs that need to be processed. To that the processing rates of the individual steps for each process (import, export and transit) should be determined.

Separation of the import, export and transit processes required by Customs is experienced to be very inefficient in the space utilization. If possible, an agreement with the authorities should be made to permit a free flow or at least separate storage areas for only import and export.

7.3.3. Siting

The nature of a freight-handling terminal is essentially a transitory sorting facility for which a linear form will have many advantages such as the possibility for expanding without significant implications for the operation and the already built facilities, and the accessibility form air- and landside. In the terminal offices, service areas and special facilities should not be in the way of normal operations. Often these areas are located on the mezzanine level at landside.

The width of the building should be able to provide enough space for the required freight-handling modules required either at air- or landside. These modules are also determining for the column grid. Permanent walls dividing airside from landside should be avoided. The building depth should be as short as possible. For the depth it is important to keep in mind the operational flexibility, the possibility of expansion, the implementation of new handling systems in the future, and fleet developments. Although most terminals have a height of five meters, the equipment used determines this dimension. It is very important to already evaluate on storage systems and handling equipment before determining the height of the terminal. Also the readiness for certain systems and expansion in height should be considered.

The dimensions of the warehouse should fit the storage needed. Storage areas for bulk freight and entire ULDs should be provided for each step in the process.

Next to the operational elements sizing the terminal, the terminal should also have staff facilities, technical facilities, a bypass, and, if applicable, special facilities such as cool rooms, vaults or a dedicated dangerous goods storage area.

7.3.4. Perishable freight

If the perishable freight is separated from the rest of the freight handling facility two types of facilities can apply: a transit facility or a total distribution facility. A transit facility processes freight through the facility fast and efficient. The total distribution facility provides the same, but offers extra services such as repacking, pre-cooling, cold storage, quarantine, quality control, customer and information services, and door-to-door collection and deliveries.

The essential components of a perishable freight-handling terminal are: the processing area, the working area (if applicable), the loading area, transit areas, the inspections area (if applicable), and the Customs area. Other special areas could be: the cool rooms, pre-coolers, treatment rooms, repacking rooms, and quality control rooms.

7.4. Conclusion

The differences between warehouses and airfreight terminals are fading as both their functions are tend increasingly towards transitory sorting facilities in which low inventory is held and throughput speed is high. These are amongst the most important KPIs. Therefore theory on warehouse design cannot be left out the analysis. Although not very specific, the theory validates on a high-level the design decision to make a conceptual design according to the System Engineering methodology.

More specific are the airfreight terminal design theories gathered from the posing literature on airport development. The functions, design decisions and success factors retrieved from these theories are used to develop a system level design.

More practical theory is presented in IATA's Airport Development Reference Manual, which poses specific, commodity-based requirements and sizing methods for the airfreight terminal development.

The high-level warehouse design theory, the more specific airfreight terminal design theory and the practical IATA references together form a base for the development of a feasible system design in chapter 10.

8. Competitors' Dedicated Pharma Facilities

Over the recent years pharmaceutical freight obtained a special status in the air transportation industry. The high-yields and the customer demands forced cargo handlers to handle pharmaceuticals with greater care, resulting in the development of dedicated handling facilities where the required conditions can be guaranteed. In this chapter an overview of some of the industry's best practices are researched, namely:

1. Aviapartner Brussels Pharma Hub (Brussels, Belgium);
2. Hyderabad Menzies Air Cargo Pharma Zone (Hyderabad, India);
3. Lufthansa Cargo Cool Center (Frankfurt, Germany);
4. LuxairCARGO Pharma & Healthcare Center (Luxemburg, Luxemburg).

8.1. Aviapartner Brussels Pharma Hub

At Brussels Airport all BRUcargo companies have a common focus on handling pharmaceutical cargo. The companies invest together in obtaining GDP licences and GDP compliant warehouses. Brussels Airport has the biggest concentration of temperature-controlled facilities. The airport supports the companies in developing facilities and operating procedures and training of personnel, in order to develop a community wide expertise. As a whole, the Brussels Airport pharma handling facilities received the IATA CEIV Pharma certification.

One of the BRUcargo pharmaceutical partners is Aviapartner. Aviapartner has developed:

"a Pharma dedicated hub in order to accept, deliver and handle healthcare products according to the rules and regulations of IATA, Airline's SOP and shipper requirements".

<u>Terminal characteristics</u>

The Aviapartner Brussels Pharma Hub is a 1.300 m^2 warehouse with two controlled temperature zones. The vast majority of the building is kept within a constant 15 – 25˚C (CRT) and 100 m^2 is dedicated for COL shipments to be kept within 2 – 8˚C. The warehouse's inbound flow is through 6 truck docks for bulk cargo, and the outbound flow is through 2 roller beds for aircraft ULDs. Figure 8.1 gives a schematic overview of the layout of the warehouse.

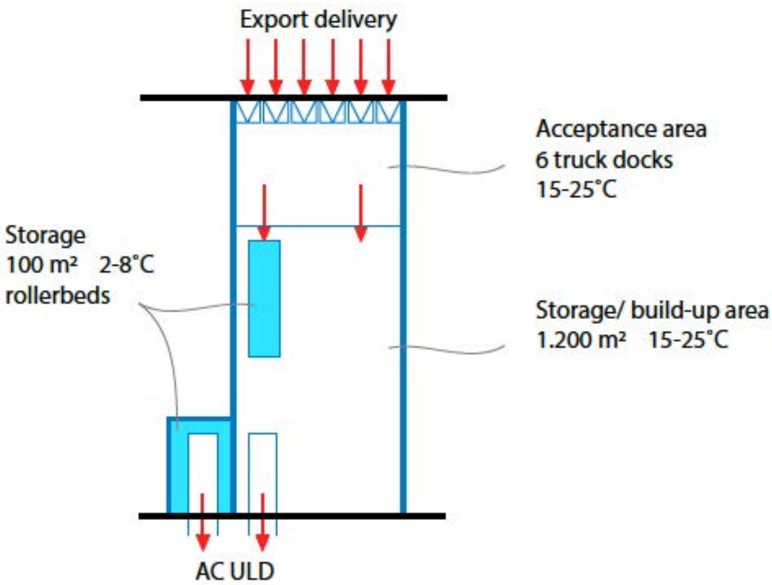


Figure 8.1: Aviapartner Brussels Pharma Hub layout

Other facts:

- Aviapartner aims to have freight stored at the right temperature within 10 minutes after arrival.
- Loose cargo is stored in racks.
- Active container recharging points are available.
- ULD movements through the terminal with forklifts and dollies until they are put on the roller bed for delivery at airside.

8.2. Hyderabad Menzies Air Cargo Pharma Zone

The Mezies Air Cargo Pharma Zone in Hyderabad, India, handles mainly pharmaceutical export shipments. About 70% of all exports, ca. 1.700 tonnes per month at Hyderabad are pharmaceutical shipments. Until recently very little, only 15% of the shipments were handled in the right conditions.

Because of the expectance of a growth for export of pharmaceutical shipments from India and the tightening regulations and inspections, the need arose for a dedicated handling facility. The Menzies Pharma Zone opened in 2010.

Terminal characteristics

The Menzies Air Cargo Pharma Zone is a 1.400 m^2 warehouse with two controlled temperature zones. The vast majority of the building is kept within a constant 15 – 25˚C (CRT) and 150 m^2 is dedicated for COL shipments to be kept within 2 – 8˚C. The warehouse inbound flow is through 5 truck docks for bulk cargo, and the outbound flow is through 2 roller beds for aircraft ULDs (PMC), see Figure 8.2.

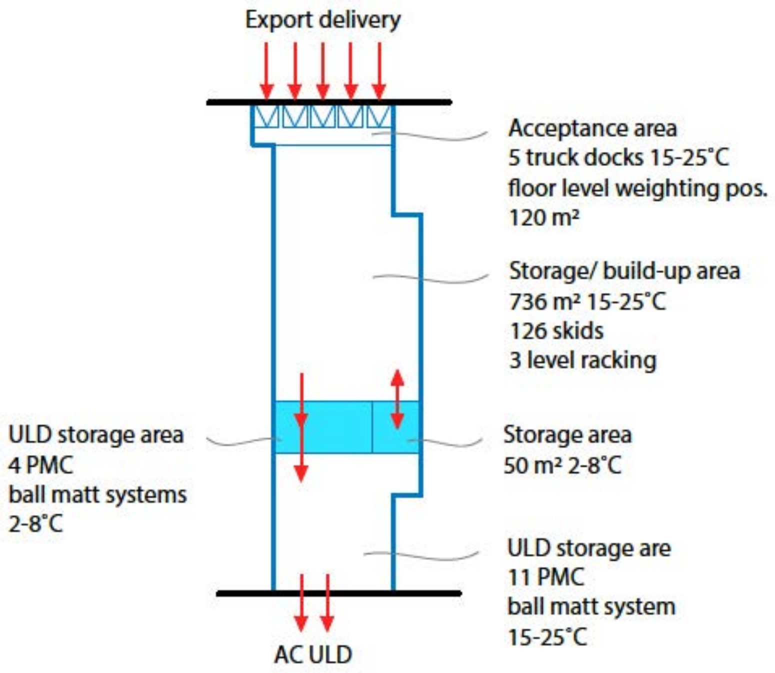


Figure 8.2: Hyderabad Menzies Air Cargo Pharma Zone

Other facts:

- Designed for 30.000 tonnes of pharmaceutical shipments per year.
- ULD movements through the warehouse with forklifts, dollies and ballmatts.

8.3. Lufthansa Cargo Cool Center

Opposed to Aviapartner in Brussels and Menzies in Hyderabad, Lufthansa is (just as KLM Cargo) handler and airline for the pharmaceutical shipments and so has more control over the cool-chain. According to Lufthansa Cargo the focus at the Cool Center is on precise temperature control, exclusive handling, short distances and competent specialists. Though this all counts for export shipments and build up pallets, the acceptance of M-ULDs and the building-up and breaking down of M-ULDs is completely out of scope of this focus. The to be build-up cargo needs to be delivered 6 hours in advance at the general handling warehouse, where no dedicated temperature control is in place. The Lufthansa Cargo Cool Center is GDP certified.

<u>Terminal characteristics</u>

The Lufthansa Cargo Cool Center is a 5.000 m^2 warehouse accommodating 4 temperature zones. The vast majority of the warehouse is kept at 15 – 25˚C (CRT) and 2 – 8˚C (COL). One room is a dedicated freezer and one room accommodates the small share of 5 – 15 C demand. The last temperature zone is the acceptance area. Acceptance of cargo is still done outside, where no temperature control is possible. The acceptance area consists of 5 truck docks. Figure 8.3 gives a schematic overview of the layout of the warehouse.

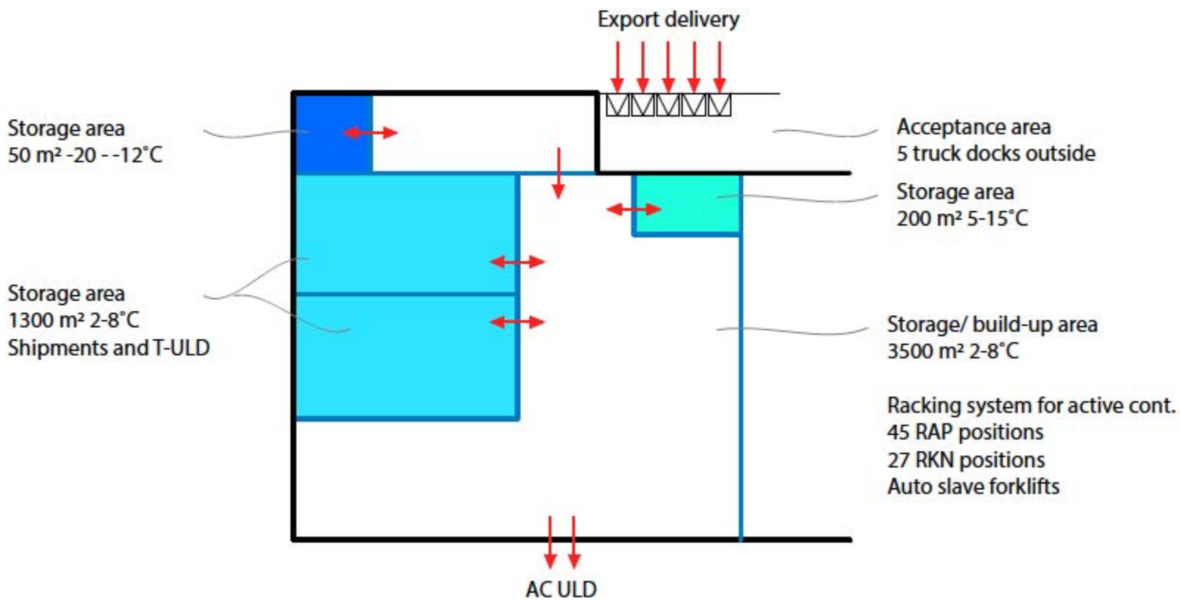


Figure 8.3: Frankfurt Cargo Cool Center

<u>Other facts:</u>

- Racks to store loos cargo.
- ULD storage and active containers in racks as well.
- ULD movements through the warehouse with forklifts and dollies.
- For airside movements 17 cool dollies are available.

8.4. LuxairCARGO Pharma & Healthcare Hub

Just as Lufthansa and KLM Cargo, LuxairCARGO is next to handler also airline and so is able to offer more integrated services. LuxairCARGO recognized 1) the need for reliable global distribution networks to satisfy the market, 2) the risks and major impact on the product quality of the lack of uncontrolled storage and 3) the increased surveillance of regulators, and developed a € 4,0 million dedicated Pharma & Healthcare Hub. The facility is GDP certified.

<u>Terminal characteristics</u>

The LuxairCARGO Pharma & Healthcare Hub is a 3.000 m^2 warehouse split up in two independently operating zones of 15 - 25˚C (CRT) and 2 - 8˚C (COL). The 15 - 25˚C part is 1.600 m^2 and has an inbound flow through 4 truck doors for bulk cargo, whereas the 8 - 8˚C part is 820 m^2 and has an inbound flow through 2 truck doors for bulk cargo. Both departments send their outbound flow of aircraft ULDs in a pallet handling system with 70 temperature controlled ULD positions. Figure 8.4 gives a schematic overview of the layout of the warehouse:

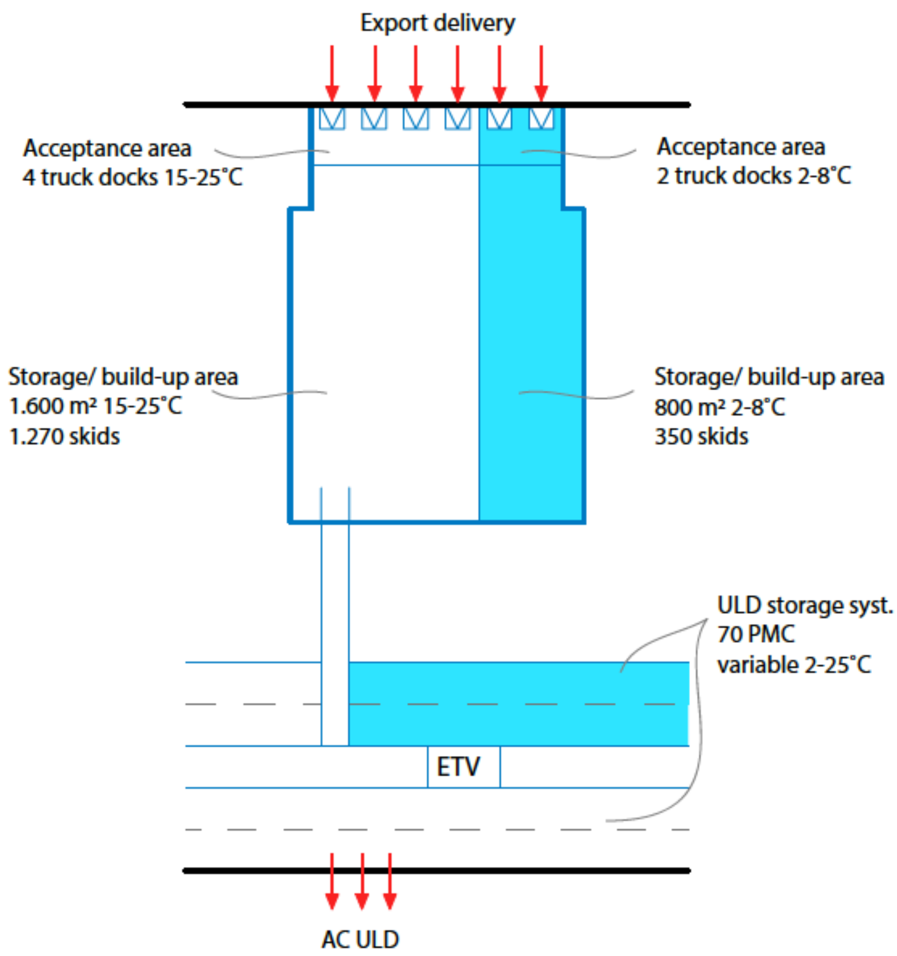


Figure 8.4: LuxairCARGO Pharma & Healthcare Hub

<u>Other facts:</u>

- There is also a frozen area of 30 m^2.
- 200 m^2 active container recharging and servicing space is available.
- ULD movements through the warehouse with forklifts and dollies.

8.5. Conclusion

The general finding from these four examples is that only the export processes are facilitated in the dedicated pharma facilities. Shippers' trucks can be unloaded, the cargo can be stored and it can be build-up onto aircraft ULDs. The pharma centres are not equipped to unload transit ULDs. Transit M-ULDs that need to broken-down or built-up with pharma are handled in the regular cargo handling processes. A pharma handling centre that facilitates import, transit and belly cargo flows has not yet been developed.

Most of the facilities for handling pharmaceuticals operate with two temperature zones, namely 15°C – 25°C (CRT) and 2°C – 8°C (COL). Generally the terminal, including the acceptance area, is kept within CRT conditions and are COL facilities situated within the terminal. It is seen the facilities provides storage for individual shipments and for entire ULDs. A summary of the results is given in table 8.1.

Table 8.1: Summary of findings at other terminals dedicated to handling pharma

Characteristic	Brussels	Hyderabad	Frankfurt	Luxemburg
Size	1.300 m2	1.400 m2	5.000 m2	3.000 m2
GDP	yes	no	yes	yes
Temperature zones	2	2	4	2
Truck docks	6	5	5	4 + 2
Tonnes per year	n/a	30.000	n/a	n/a
Temperature controlled dock	yes	yes	no	yes
Airline and ground handler	no	no	yes	yes
Degree of mechanization	low	low	low	medium
Bulk buffers	racks	racks	racks	racks
Handling bulk belly	n/a	n/a	n/a	n/a
Scanning/ inspections	off site	x-ray machines	off site	n/a
Terminal refinement level	clinical	industrial	industrial	industrial
Airside handling system	ULDs on dollies	ULDs on dollies	cool dollies (17)	ULDs on dollies
ACT handling	horizontal	n/a	racks	horizontal
Flexibility to the future	expandable	large overcapacity	expandable	size constrained

The knowledge provided in this chapter is used in chapter 10 to determine the system level designs that are currently used in the industry, as they should be taken into consideration as well.

9. Lean Supply Chain & Warehousing

As mentioned in the introduction of this research one of the three pillars the development of the new freight-handling facility is that it should be developed in a Lean way. Lean is defined as: *the dynamic knowledge-driven and customer focused process through which all people in a defined enterprise continuously eliminate waste with the goal of creating value* (Murmann & Allen, 2002). Lean originates from the Toyota Production System (TPS) that is based on four pillars known as the 4P's: Philosophy, Process, People & Partners and Problem Solving, with as back bone the focus on achieving stable performance and avoiding instability as a result of variability.

Research on Lean has mainly been on process or product innovation and manufacturing, but should also be applied on the value chains and organizational systems also (Beelaerts van Blokland, Fiksinski, Amoa, & Santema, 2008). Research should include the warehouses and distribution centres (Bartholomew, 2008). The application of Lean has expanded beyond the borders of operation and is more and more used in other levels (Beelaerts van Blokland, 2010):

1. Lean Enterprise and Manufacturing
2. Lean Supply Chain
3. Lean Engineering
4. Lean Value Creation

For the development of the KLM Cargo Pharma Terminal Lean is taken into account especially from a supply chain perspective. In this chapter first an introduction to Lean is given to provide a general knowledge on the concept. After that, in paragraph 2, the theory on Lean Supply Chain is researched in relation to the Pharmaceutical supply chain. In paragraph 3 a practical chapter on the Lean Warehouse is added.

9.1. Introduction to Lean

Generally efforts on Lean Enterprise and Manufacturing focussed on optimizing internal performance of a production facility. It is a practical management and organizational matter directly inspired by Toyota's way of working. Improvement theories are Lean Thinking, Six Sigma and Theory of Constraints.

Lean Thinking can be summarized as improving flow and eliminating waste (Verhagen, 2006). It can be done by applying five principles (Womack & Jones, 2003):

1. Precisely define the values for the customer.
2. Identify the value stream by finding the value adding activities, unavoidable waste steps and the unnecessary steps that are considered immediately avoidable.
3. Make the value stream flow.
4. Products should be able to be pulled through the value stream as fast as possible and upon demand to keep inventory levels as low as possible.
5. Pursue perfection by repeating the processes and looking for constant improvement.

Six Sigma is an improvement theory based on the reduction of variation (Nave, 2002). It focuses on understanding fluctuation of processes and predicting outcomes by using a structured methodology: DMAIC, which stands for Define, Measure, Analyse, Improve and Control.

The Theory of Constraints focuses on system level improvement bearing in mind that the entire system is dependent on its weakest process: the constraint (Nave, 2002).

The next step, on which later in this chapter will be more elaborated on, is the Lean Supply Chain.

Lean Engineering takes the Lean Enterprise and Manufacturing a step further. As Lean Enterprise and Manufacturing is historically focussed on the assemblage, the Lean Engineering already starts far most upstream the supply chain, even before production. Although similar tools and techniques are used, it is an important cost-determining phase in the development of a product. Reducing variability to achieve stability, standardization, automation and the buffers needed for production are all elements that need to be taken into account already in the engineering phase.

When creating a Lean Value Chain actually Lean Enterprise and Manufacturing and Lean Engineering principles are applied over the entire supply chain. Re-arranging activities in the value chain, scaling down the number of suppliers, changing the importance of activities are all measures to obtain a better performing supply chain.

9.2. Lean Supply Chain

Most attention for Lean has been on innovating processes and products, but the Lean principles should be taken to a higher level and be used to innovate on the value chain and system of the entire organisation (Beelaerts van Blokland, Fiksinski, Amoa, & Santema, 2008). To improve overall supply chain efficiency and flexibility the network entities should interface. Sharing information is key in this (Myerson, 2012).

A Lean approach towards the supply chain requires the entities in it to revise the order and delivery processes, improvement of response times and the integration of activities in the chain (Duivenvoorde, Grohn, Beelaerts van Blokland, & Santema, 2005). The entire supply chain should be assessed when aligning it towards customer demand and satisfaction. Every player in the supply chain should focus on its core competences. Typically, waste is caused by long lead times and high inventories. Just-in-time (JIT) delivery should be implemented throughout the chain to avoid these wastes (Hiele, 2007).

Lean Thinking throughout the entire supply chain is defined as the Lean Value Chain. Traditionally the value chain is based upon push (not demand driven) and mass production. More contemporary value chains are based on pull (demand driven) and individualized production. To fit the changing primary and supporting value chains Porter's Value Chain Model (Porter, 1985) has been altered to the Canting Value Chain as shown in Figure 9.1.

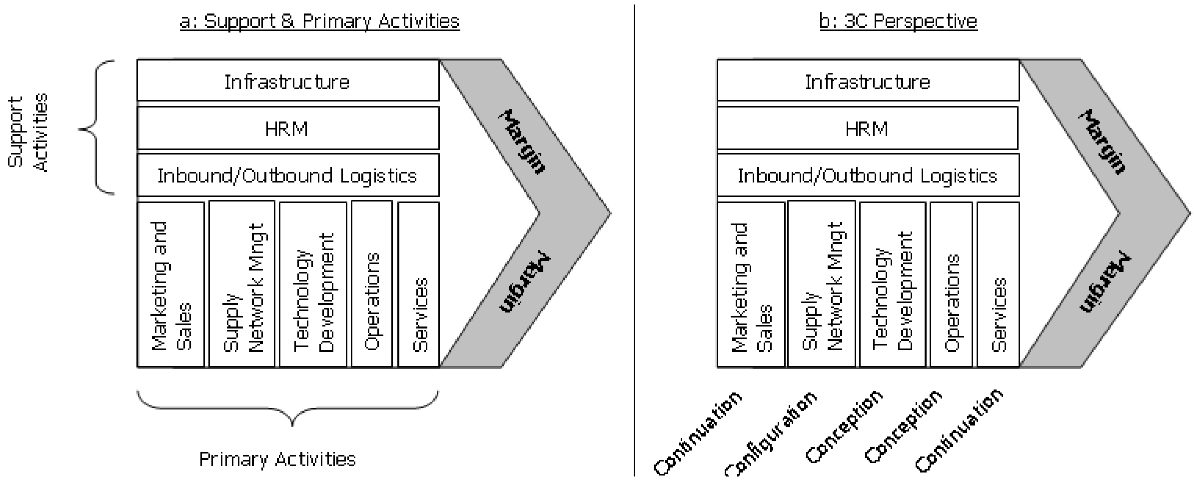


Figure 9.1: a. Canting Value Chain b. 3C Value Chain

This Canting Value Chain fits the primary and support activities of most advanced and modern companies. By changing the old value chain by moving inbound and outbound logistics from primary activities to secondary activities, technology development from secondary to primary activity, and adding supply network management as a primary activity, the Canting Value Chain now is considered Lean. According to Karlsson (1996) a totally Lean enterprise is build up with the elements:

1. Lean Development
2. Lean Procurement
3. Lean Manufacturing
4. Lean Distribution

The five primary activities can be categorised under the three value drivers: continuation, conception and configuration, see also Figure 9.1 B. So the Canting Value Chain is now completely Lean and value adding.

Although it can be concluded that due to specialization and focus on primary activities inbound and outbound logistics became a secondary activity, the importance of logistics is increasing (Beelaerts van Blokland, Titulaer, & Santema, 2010). For logistic companies this presents the opportunity to provide in more integrated and complete services, exactly fitting the new demand.

So not only Lean processes have to be implemented internal in the company but also Lean processes have to be implemented in the supply chain in order to reduce the overall costs. The increased use of technology should enable this Lean supply chain (Myerson, 2012). The only issue of relevance to the customer: the whole value stream. Participants should treat each other as equals with waste as their joint enemy (Womack & Jones, 2003). The steps presented are:

1. Specify value for customer
2. Identify actions required from order until delivery
3. Remove waste
4. Finalize and start over

Bearing this in mind, contributions enabling a Lean process through the supply chain could be made by (Myerson, 2012):

1. *Strategic Alignment*
   Clear supply chain goals and objectives driven by a business strategy that exploits supply chain capabilities.

2. *Supplier Integration*
   Develop relationships to build on partnerships sharing capabilities, operational information, and activities.

3. *Planning Effectiveness*
   Planning should be more formalized and structured for both short-term and long-term. Feedback loops should be used to address variances and vulnerability and continuity planning.

4. *Relationship Management Technology*
   Partners in a supply chain should work together. Together business plans can be made in order to facilitate in collaborative planning to fit replenishing requirements to shipping requirements. Successful implementation would mean inventory reductions, lower logistic costs and customer service improvements.

9.2.1. Pharma Value Chain

As recognised by the pharmaceutical industry, a widespread supply chain improvement is necessary to create the desired overall progress (Spector, 2010). The industry's need to stay competitive increases the interest in supply chain management. Lean management is one of the most effective practices to improve supply chains (Staudacher & Bush, 2014). Studies already have shown Lean techniques have been popular in the pharmaceutical industry. The industry has seen many individual initiatives for streamlining operations and processes to reduce the inventory in the chain. Despite the efforts, the benefits have remained limited, as the inventory in the chain wasn't reduced. Involving the whole supply chain should do so (Spector, 2010).

Traditionally the focus had always been on drug discovery and marketing, but now much more attention is being paid to the supply chain optimization. The pharmaceutical industry recognizes the ability of the supply chain to generate both value for the customer and to the shareholder and that restructuring it will require reductions in capacity (Shah, 2004).

To meet the pharmaceutical industry in this KLM Cargo needs to review their facilities, operations and position in the supply. For this research on the development of a conceptual design for the KLM Cargo Pharma Terminal theory on the Lean Warehouse is most applicable.

9.3. Lean Warehouse

The primary ways that a Lean warehouse differs from a traditional one are the lack of any bottlenecks in its basic process as an obvious transparency in the flow of work processes. Some customers are depending on the warehousing companies to solve nettlesome logistical problems, as it is their secondary activity.

In this case the warehouse is used for a competitive advantage. Practically, the five steps of Lean Thinking can be applied to the warehouse operations as most Lean concepts work well in a warehouse, especially 5S, VSM, team building, kaizen, problem solving, error proofing, kanbans/pull systems, line balancing, cellular applications, and general waste reductions. In Lean warehouse employees perform many of the same tasks (Bartholomew, 2008).

Generally the efficiency of the assembling of the orders and value stream mapping the warehouse to suggest improvements and to translate the current state map into the future state map, for which implementing the 5S is a good place to start, are the Lean opportunities present in warehouses (Myerson, 2012). The more Lean the warehouse's layout, the more integrated the understanding of transportation and warehousing. As in all Lean practices the goal is to improve flow, eliminate waste and reduce inventory.

For a warehouse it is not just the physical facility that is essential to the Lean effort, but even more important the training of the employees and the awareness of and involvement with what is happening in the warehouse. It is important to go out on the floor and follow a shipment (Bartholomew, 2008).

9.4. Conclusion

Despite the many initiatives by companies in the pharmaceutical supply chain for implementing Lean theory, the efforts do not accomplish the desired effect. The pharmaceutical industry indicates this falls due to the lack of wide spread application of Lean and lack of integration in the supply chain.

As logistics are becoming secondary activities for the production companies, they depend more on the primary activities of the logistic companies. This shift in the supply chain is caused by the application of Lean in the value chain of production companies. As the industry stated, a revision of the roles of the companies in the pharmaceutical supply chain is necessary. Procurement and distribution are underexposed topics (Alicke & Lösch, 2010).

This means the role and the internal organization of KLM Cargo need to be revised and made Lean as well. The advantage of an entity as KLM Cargo is that their production is always based on demand: pull, therefore emphasis is on avoiding variability to provide stability. Delivery and order principles, response times and the integration in the chain are important variables in this.

The integration in the chain is done with the above-presented tools and with the goal to Lean the supply chain, avoid waste and serve a powerful proposition to the customer in a broad-based effort of the whole chain. A lot of time and costs can be saved, as the whole chain is a Lean Value Stream. Gains made in the manufacturing process shouldn't be made undone by slow and costly transportation (Alicke & Lösch, 2010).

10. Typical Designs for the System

This chapter answers the next step in the System Engineering methodology by combining all previous conclusions to determine the possible typical design for the KLM Cargo Pharma Terminal. After the assumptions and requirements formulated for the Advanced System Planning and Engineering in chapter 6, research was conducted on the way the theory and industry typically deals with designing terminals to handle pharmaceutical freight. For that airport development theories, practical IATA guidelines, best-practices and Lean theory are examined. With the research a wide variety of possible design directions is found.

Now in the System Design and Feasibility Analysis phase the assumptions and requirements found in chapter 6 are used to determine which of the higher-level design directions found in the previous chapters 7, 8 and 9 are applicable in the KLM Cargo case for developing a dedicated Pharma Terminal. Not for all elements involved in KLM Cargo's situation typical designs are found. Assumptions are made on these elements, fitting the higher level of the system's design.

10.1. Foundation for the Design

From the theory on terminal design is found that design of a cargo terminal is determined by:

1. The type of operator and service standards
2. The expected rate of growth of demand and the ultimate capacity required
3. The political and economic setting
4. The airport and local authority planning constraints
5. Point 1 until 4 determine: Level of mechanization

To determine the system's design for this research the type of operator and service standards, the expected rate of growth and the ultimate capacity required and resulting the level of mechanization will be elaborated on in the next paragraphs. The descriptions of these elements do not determine a physical design yet; they impose a framework in which the designs are generated later in chapter 13.

10.1.1. Type of Operator and Service Standards

The type of operator and the service standards mainly refers to the airline's future type of freight traffic. Demands from other entities in the pharmaceutical supply chain and the end customer are influencing the future type of freight and services are offered by KLM Cargo.

The pharmaceutical supply chain clearly indicates the distribution and transportation stages in the supply chain need to be improved in order to make sure the many other initiatives to streamline the chain will be effectuated and will finally pay off. The pharmaceutical industry indicated Lean is the preferred tool to accomplish the desired integration.

To accomplish the integration in the supply chain the entities in it should interface more efficient. As to avoid variability the entities should focus on their primary activities and as the interfacing becomes an increasingly important factor, an existing entity or a new to be introduced entity to the chain should embrace this important factor as a primary activity.

For the Amsterdam terminal operations of KLM Cargo the interfacing with other entities in the chain only concerns 11% of the pharmaceutical shipments; 89% of the shipments are transit. According to the principle of avoiding variability to provide stability this means that no on-site integration of import export services that do not exist already to accommodate the transit flows should be integrated into the KLM Cargo process to integrate the pharmaceutical supply chain. Facility should be optimally serving transit flow to avoid waste and create value for the end customer. This means, in order to achieve the required integration, some of KLM Cargo's currents services should be pushed off to entities up and downstream the chain. From an Amsterdam terminal point of view KLM Cargo will stay the transporter and not the logistics provider.

The characteristics concerned with the demand from the pharmaceutical supply chain influencing the type of operator and service standards are:

A. the flows through the terminal (export, import, transit);
B. the way freight is containerized (bulk, Euro pallet, ULD), and;
C. the special needs for handling the commodities.

A: Flows Through the Terminal

The handling through the terminal is focused on the closed cool-chain and open cool-chain products, being handled under respectively the special handling codes ACT and COL, CRT and PIL. There will be a shift in the share of these products. ACT and CRT will relatively strong increase, COL will grow moderate and PIL will heavily decrease. Also it is expected that the active ULDs used for ACT shipments will be partly replaced by passive containers which do not need the special care and can just be handled as general packaged individual shipments.

The flows through the terminal can be accommodated by two temperature ranges 2˚C - 8˚C and 15˚C - 25˚C. Although it is not specifically expected, the terminal should be flexible enough to also accommodate another temperature range for which demand may arise in the future.

Other pharma hubs are mostly designed for these outgoing flows of export and trucked transit, but have less emphasis on the import flows and (aircraft) transit flows. With the new KLM Cargo Pharma Terminal an all-covering facility, which accommodates import, export and transit flows.

B: Containerization

The prediction of the containers used in the future is mostly deviating on the way transit truckloads are containerized. Currently KLM Cargo loads fully flight safe and build-up aircraft ULDs into trucks for truck operated transit flights. Competitors do not do this and for the future it is expected that KLM Cargo will not do this anymore and containerize truckloads onto Europallets, also referred to as loose trucking. This is an important change for pharma operations.

The aircraft ULD flows and the bulk belly flows are not changing opposed to current operations. Competitors do facilitate bulk belly flows in their pharma terminals but as KLM Cargo's network is also served by Embraer passenger aircraft operations, which do not fit ULDs. The wide-spread network can only be maintained through the possibility to transport in bulk. As the current share for KLM Cargo for pharma shipments transported as bulk shipments in the belly of the aircraft is about 16% this is an important flow to facilitate in the new terminal.

C: Special Needs for Pharma

The special needs for pharma concern efficient airside handling, storage under the right conditions and with the active containers the supply of power, dry-ice and batteries. Specific requirements for equipping the terminal with the special measures in this matter are determined by the GDP regulations concerning the premises, equipment, storage and transportation facilities to ensure product integrity from current and future standards. The level of ambition and the interpretation for the terminal to be compliant to GDP guidelines is to be determined in chapter 13.

Other pharma hubs get their terminal suited for pharma shipments by developing an overall temperature of 15˚C - 25˚C and facilitating some buffer zones in 2˚C - 8˚C. Physical measures in the terminal mostly contain design decisions to avoid the accumulation of dust and dirt, such as power floated concrete floors and rounded corners.

10.1.2. Expected Growth of Demand and the Ultimate Capacity Required

In paragraph 5.4.1 the expected growth for each of the four pharma product groups is given. Figure 10.1 shows a summary of the expectations.

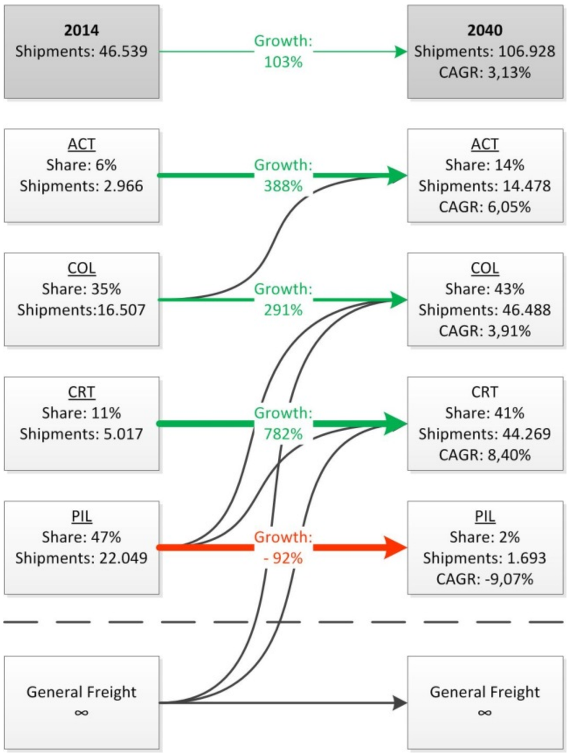


Figure 10.1: Expectations for the product developments

The growth and the demand required for 2040 is 130% compared to 2014, which more than doubles the number of shipments from 46.539 to 106.928. The overall CAGR is between 2,56% and 3,71%.

To determine the capacity required for the terminal a design peak needs to be determined (Ashford, 2011). The representative design peak is determined from figure 3.9 in paragraph 3.4.4. The graph is shown again here in figure 10.2, but with the addition of the demarcation (in red) of the peak moment. KLM Cargo agreed on this to be a representative moment to base the design upon.

Figure 10.2: Determining the Representative Peak Week

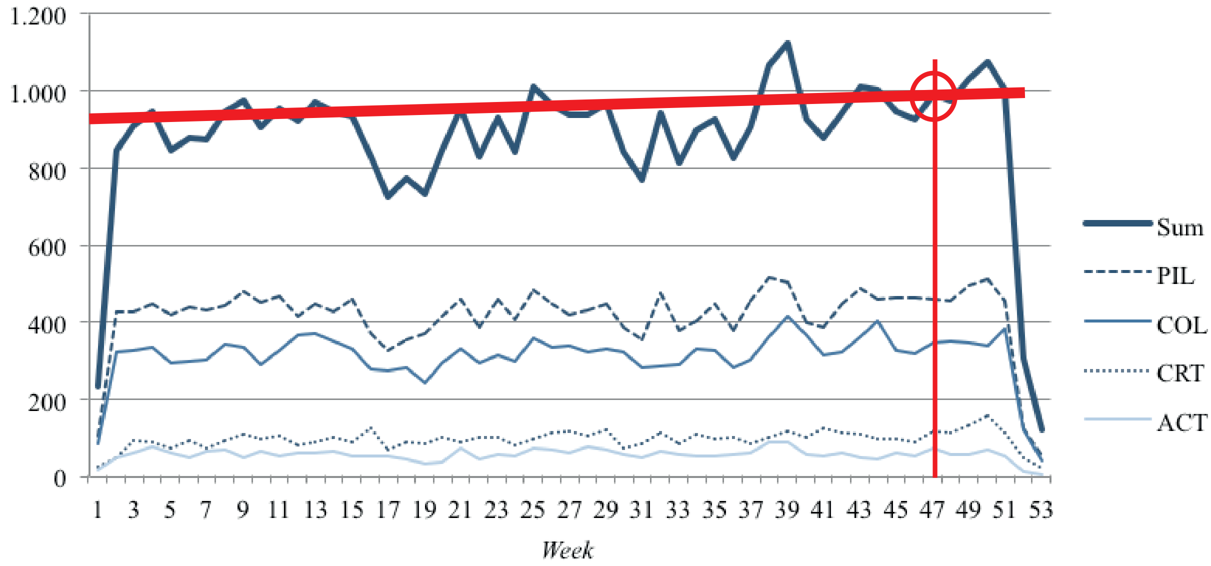


Figure 10.3: Determining the representative peak week

From this peak moment can be determined that the new terminal configuration should designed to handle 1.026 shipments per week. The data available for the pharmaceuticals handled in this week is used to determine representative peak behaviour. The data is retrieved from DWH, which provides the specific arrival date and time of per shipments and data to determine the annual average of volume, number of pieces and throughput time per product per flow. In chapter 11 the performance parameters that are composed with the available data are further described.

10.1.3. Political and Economic Setting

The Netherlands has one of the highest educated workforces in Europe. Flexibility, motivation, high productivity and good working attitude are amongst their virtues (PWC, 2014).

The dedicated terminal will be designed to operate with a team of GDP trained and highly specialized personnel, comparable with the CCC employees and the ACT desk staff. The difference will be that in the future their role is more involved in the physical handling instead of only monitoring.
The regulatory regime in The Netherlands requires for all shipments to be scanned for … and requires some pharmaceutical shipments containing veterinary or phytosanitary products to be inspected upon arrival in Amsterdam. The thoroughness of the inspections is with great respect to the transit time of the product. Most of the time the products can leave within 12 or 48 hours and make their connection as planned. Import shipments that are subject to inspections have to be taken care of by the consignees themselves.

10.1.4. Airport and Local Authority Planning constraints

Planning constraints from posed by AAS or authorities are not yet considered, as the geographical location is not concerned in this research. Next to that the geographical location for the to be relocated KLM Cargo operations is still in the negotiation phase.

10.2. Typical Systems Designs and Feasibility Analysis

In the above chapter 10.1 a directing description of the new terminal design is given without making physical design decisions yet. This paragraph elaborates on the possible design decisions found in literature and in practice. Also the distinction is made weather a design possibility is feasible or not. The results are given in table 10.1.

Table 10.1: Typical designs and suitability for KLM Cargo Pharma Terminal

Parameter	Typical Design	Feasible
Direction	Only export	No
Mechanization	Low/ medium degree	Determine later
Function	Sorting facility*	Yes
Truck operated flights	Loose trucking	Yes
Temperature ranges	Two: 2˚C - 8 ˚C and 15 ˚C - 25 ˚C	Yes
Acceptance area	Controlled temperature	Determine later
Bulk storage	Racks	Determine later

* From the Lean theory point of view minimal variation, high throughput speeds and low inventories in the chain supply chain integration is necessary. As about 80% of the KLM Cargo Amsterdam activities concern transit shipments, the integration of the supply chain for export and import needs to be out of the scope of the KLM Cargo premises, enabling the terminal to primary focus onto its focus as sorting facility.

10.3. Preferred Course of Action

From this chapter can be concluded that the systems design for the KLM Cargo Pharma Terminal is going to be:

- a facility dedicated to the handling of pharmaceutical freight ACT, COL, CRT and PIL;
- a multi-directional sorting facility accommodating export, import and transit flows and not a total distribution facility;
- a facility focused on transit flows with a sub focus on export and import flows;
- a facility focused improving Lean operations and supply chain integration by providing high throughput speed, low inventory, and clear operations;
- a facility interconnected with the terminal for handling general cargo so that mixed commodity truckloads and ULDs can be accepted and broken down in the KLM Cargo Pharma Terminal after which general freight is entered in the general proccess;
- a facility flexible and adaptable to the expected, and estimated demand for 2040 of 106.928 shipments per year;
- a facility with two temperature zones namely 2˚C - 8 ˚C and 15 ˚C - 25 ˚C;
- a facility that is able to adapt to an unforeseen future demand for another temperature range;

- a facility able to handle loose trucking on Euro pallets, aircraft ULDs, bulk belly and the conversion between those type of containerization;
- a facility with manual breakdown and build-up of pallets;
- a facility GDP compliant and able to also comply with expected, future regulations;
- a facility fitting the financial situation of Air France – KLM and KLM Cargo;
- and a facility fitting the political and economic situation.

More specific design decisions on this initial design for the facility are made in a further stage of the methodology. Although for the degree of mechanization, the type of acceptance area and the way of storing bulk in the terminal, some typical designs have been given, in this stage no decisions are made yet. Together with the parameters for the design on which no typical designs are available the decisions on both of them will be made later in the Morphological Analysis and the multi-criteria analysis. Based on the functions described in chapter 6 and what has already been considered a feasible design decision the parameters considered to further specify the design are:

1. Handling Freight at the Landside Interface
2. Handling ULDs in the Terminal
3. Handling Bulk in the Terminal
4. Handling ULDs at the Airside Interface
5. Handling Bulk at the Airside Interface
6. Handling of ACT Containers
7. Terminal Refinement Level
8. Flexibility to the Future

11. System Operational Requirements

After defining the direction for the design on a system level in chapter 10, now the system specific requirements for this design can be formulated in this chapter. The requirements focus on the system of the physical internal organization of the KLM Cargo Pharma Terminal and are formulated from the point of view that the internal organization is independently operating within the larger system of KLM Cargo operations.

To develop a design for a maintainable system the requirements and maintenance concepts are defined in this chapter. Focus for maintenance is for the performance of the system equally important as the focus on the primary infrastructure itself (Blanchard & Fabrycky, 2011). As GDP guidelines are specifically concrete they have been a determining factor for the system's operational requirements.

11.1. System Operational Requirements

The system's operational requirements are developed in the:

1. Mission definition
2. Performance parameters
3. Operational deployment and distribution requirements
4. Operational life-cycle requirements
5. Utilization requirements
6. Effectiveness factors
7. Environmental factors
8. Interoperability requirements
9. System maintenance and support requirements

Mission Definition

The primary goal of the system is to provide segregated handling of pharmaceutical shipments through the KLM Cargo facilities from the apron collection or truck unloading phase until the delivery at the platform or loading of the truck.

The system has to move the shipment segregated from other commodities and as fast as possible from the arrival location at the terminal to the right place for departure. For that the system needs to sort and consolidate shipments onto the applicable containerization, to provide the possibility of a temporary buffer, and, for ACT, to perform the required service to the active containers. Secondary activities of the system are to provide export and import buffers, weighting and volume scans for export.

The system has to achieve its primary goal while complying to GDP guidelines to maintain the product integrity and to reduce the inventory of pharmaceuticals in the supply chain. Also appropriate storage conditions and the cool-chain should be provided, by maintaining storage conditions during transportation, by getting the shipments out of the weather conditions as fast as possible and by applying just-in-time principles to the export and import flows. This all should be covered in a energy efficient system.

Performance Parameters

In this deterministic assessment for the capacity of the system the data about the shipments handled in the design peak week (determined in chapter 10.1) is used to develop representative patterns for the movements at landside, movements at airside and the accumulation of shipments in the terminal. In the calculation distinctions are made between ACT, COL, CRT and PIL shipments. Depending on the configuration of the internal system of the terminal some product groups can be used to calculate a combined required capacity.

Movements at landside consist of:

- Inbound trucks with import shipments
- Inbound trucks with transit shipments
- Outbound trucks with export shipments
- Outbound trucks with transit shipments

Movements at airside consist of:

- Inbound aircraft with import shipments
- Inbound aircraft with transit shipments
- Outbound aircraft with export shipments
- Outbound aircraft with transit shipments

The mode (truck or aircraft) the export, import and transit shipments arrive and depart with is determined by the annual average split for this per (combination of) product group, given in table. 3.3 in paragraph 3.4.3.

The accumulation of shipments in the terminal is determined by enumerate the shipments, pieces or volume for each product group. The arrival time for each shipment is known and with the help of the annual averages for throughput time per product group, also the departure time can be approached. It is regardless of from which flow the shipment originated. The number of pieces and the volume involved in per shipment is determined from the annual average from 2014 as well.

As the terminal system requires different facilities for ACT and COL shipments, the terminal occupancy of these product groups are determined separately.

Operational Deployment and Distribution Requirements

The KLM Cargo Pharma Terminal is part of a greater complex for the KLM Cargo freight handling facilities at AAS. The terminal is connected to the, also new to develop, terminal, which handles general KLM Cargo freight. Lateral movements between the facilities should be possible. The system is not required to be interfacing directly with the other systems.

To facilitate the system's functions and to comply with requirements the following equipment should be in place when operating the system (GDP):

- Temperature and humidity controlling installations in all temperature controlled areas.
- Dedicated vehicles and equipment should be used.
- Monitoring and cleanness is of great importance.

Operational Life-Cycle Requirements

The system is to be developed within the KLM Cargo Terminal being part of the KLM Cargo facilities and needs to be constructed within the same time as the rest of the facilities. Construction and installation shall not deviate or enlarge implementation time and cost of the facility as a whole.

Although demand projections are only given until 2040, the system is designed to be at least suitable until then. After that time span demand is not to oversee yet. The system should achieve its mission through a system that is adaptable to future developments in demand.

Utilization Requirements

The system is to be operated by skilled and special trained personnel in order to comply with GDP guidelines to ensure the integrity of the product. It should be understandable for employees and customers how the system works. The dedicated pharma team is responsible for in time and adequate maintenance and support of the system. The operational cost of the mechanization and the cost of the manpower should be kept as low as possible.

Effectiveness Factors

As KLM Cargo and the KLM network is operated non-stop through the year, the system's operational availability should be non-stop through the year as well. The system should provide the possibility for some elements to be out of service for maintenance or malfunction once in a while by having facilities in place to ensure continuous operation without compromising the operational quality. According to the GDP guidelines equipment repair, maintenance, and calibration should be carried out in such a way that the integrity of the medicinal product is not compromised.

Environmental Factors

The environmental control is essential for the system to fit the pharmaceutical commodity. Extensive temperature and humidity monitoring and control should be in place to ensure the required temperature zones. Shipments should be as soon as possible be protected from external conditions and stored inside. Inside it is important to avoid direct sunlight reaching the shipments.

Maintaining the optimal environmental conditions within the terminal will demand extensive effort and energy use. The minimal impact on the environment and the efficient use of energy are important requirements of the terminal.

Interoperability Requirements

As mentioned the KLM Cargo Pharma Terminal is an independently operating, dedicated facility for the handling of pharmaceuticals, operating within the bigger system of freight handling of KLM Cargo. The system does not directly interface with the general operations facility but some lateral connection should be in place to enable building-up and breaking down mixed commodity ULDs or to send back or retrieve wrongfully delivered shipments.

Although the internal system of the KLM Cargo Pharma Terminal is autonomous, pharma operations will share some support departments with the general freight operating facilities, such as documentation, transportation and security.

System Maintenance and Support Requirements

Providing requirements for the maintenance and support systems for the conceptual design for the terminal's internal organization is in this phase of the design essential as they relate strongly to the mission and (financial) performance of the system. The most important maintenance requirement on the system is that it is able to operate uninterrupted.

For the shipments in the open cool-chain and the passive containers in the closed cool-chain generally no support is required. On the other hand the active containers in the closed cool-chain require servicing and support facilities, currently facilitated as described in chapter 6. To support the activities at the ACT desk the following is required:

- Service area for repairing active containers.
- Weighting facilities for weighting the active containers.
- Storage space for: batteries, dry-ice and labels and tags.

As a support to the primary activity of the system a storage system should be provided to easily store and retrieve empty ULDs and used active containers.

GDP guidelines give attention to the daily maintenance of all pharma facilities. These guidelines also apply on the internal organization of the terminal, and state standards for the impact of external factors, cleanliness, pest control programs, separation of personnel areas and other hazardous or radioactive shipments. The facility is required to facilitate in those demands.

11.2. Conclusion

The qualitative system operational requirements following from this chapter are:

- the system is required to take the GDP guidelines into account;
- the system is required to provide cool storage and cool-chain;
- the system is required to provide an high throughput speed;
- the system is required to be energy efficient;
- the system is required to be flexible to future developments;
- the system is required to avoid long implementation time;
- the system is required to avoid high implementation costs;
- the system is required to avoid high operating costs;
- the system is required to be clear to personnel and customers;
- the system is required to be set up in a modular way;
- the system is required to add to the integration of the supply chain;
- and the system is required to avoid high lifetime costs.

The quantitative system operational requirements following from this chapter are:

- the system is required to provide sufficient capacity at the interface between the terminal and the landside;
- the system is required to provide sufficient capacity at the interface between the terminal and the airside;
- the system is required to provide sufficient storage capacity within the terminal;
- the required capacity is determined by the share of freight handled in week 47 in 2014;
- and the required capacity is based upon 106.928 shipments per year.

Third Phase in the Intervention Cycle:

Design

12. Technical Performance Measures

To determine the validity of the choices to be made to complete the systems design from chapter 10 up until the level of a conceptual design stating concretized design decisions, the concepts for the system's designs need to fulfil the requirements named in the previous chapter, chapter 11. The system operational requirements state two kinds of requirements: qualitative requirements and quantitative requirements. In this chapter first the qualitative requirements are translated into the criteria to be used in the multi-criteria analyse and then the quantitative requirements are translated into performance parameters.

12.1. Qualitative Requirements: Criteria for the Multi-Criteria Analysis

In order to be able to compare the different concepts for the configuration in a multi-criteria analysis the qualitative requirements developed in the System Operational Requirements in chapter 11 are transformed into criteria, which are thereafter prioritized with the Analytical Hierarchy Process developed by Saaty, which is explained in appendix 2.

12.1.1. Criteria Development

The qualitative requirements from the System Operational Requirements and the criteria they are developed into are shown in table 12.1.

Table 12.1: Qualitative System Operational Requirements and the Corresponding Criteria

Nr	System Operational Requirement	Criterion
1	The system is required to avoid long implementation time	Implementation time
2	The system is required to avoid high implementation costs	Implementation cost
3	The system is required to avoid high lifetime costs	Lifetime cost
4	The system is required to avoid high operating costs	Operational cost
5	The system is required to provide an high throughput speed	Throughput speed
6	The system is required to be set up in a modular way	Modularity installations
7	The system is required to be clear to personnel and customers	Clarity of installations
8	The system is required to be flexible to future developments	Flexibility
9	The system is required to be energy efficient	Energy efficiency
10	The system is required to take the GDP guidelines into account	GDP compliancy
11	The system is required to provide cool storage and cool-chain	Cool-chain integrity
12	The system is required to add to the integration of the supply chain	Supply chain integration

12.1.2. Criteria Descriptions

The criteria developed in paragraph above are described here:

1. *Implementation time*
   The implementation time considers the physical construction time of the terminal. Complex equipment and facilities increase the implementation time of the terminal. It represents the urgency of KLM Cargo to be able to move into the new facility.

2. *Implementation cost*
   This criterion considers all the cost for development of the terminal's system until it is fully operational. The costs of the building structure and finishing, equipment, facilities, and required space are included. It represents the willingness and ability of KLM Cargo to invest in the new facility.

3. *Lifetime cost*
   A far-reaching aspect of the design is the cost required during the lifetime of the system in order to maintain it operable. Possibly retaining the quality of the facilities, equipment and temperature control and monitoring pose a substantial burden on the liquidity. Lifetime costs represent part of the fixed costs of operating the terminal. It represents the willingness and ability of KLM Cargo to operate a system requiring capital-intensive maintenance.

4. *Operational cost*
   A variable share in the costs for operating the terminal are the operational costs, containing the costs for labour and running the systems. The costs for temperature-controlled areas and facilities, equipment and the manpower are included in the criterion. It represents the willingness and ability of KLM Cargo to operate a system requiring capital-intensive operations.

5. *Throughput speed*
   The criterion concerning the throughput speed addresses the ability of the system to process freight in an efficient and fast way. In order to provide short-connections a high throughput speed is required. The suitability of the mechanization to the involved volumes of freight and ability of the system to adapt to short-notice deviating situations determine to a large extend the throughput speed of the system. It represents the necessity conceived by KLM Cargo to provide in a high-speed product.

6. *Modularity installations*
   A modular set up system provides a responsive and stable system, as operation of the systems is considered to be less dependent on the performance of one of the elements in the system. In a modular setting the installations are only used when needed, and so can be shut down if not. Next to that, continuity in case of periodic maintenance or unexpected breakdown is provided through a modular setup, as it is likely that always part of the modules are kept operable. It represents the necessity conceived by KLM Cargo to provide a continuous and scalable system.

7. *Clarity of installations*
   The criterion taking the clarity of the installations into account addresses the ability of the system to operate in an orderly manner, which is understandable for employees and presentable towards customers. A clear installation enables proper utilization of the system and is considered to be one of the main elements supporting the visibility aspect of Lean theory. It represents the whish conceived by KLM Cargo to exploit the representatively of the system for marketing ends and the conviction of KLM Cargo to increase the quality of the operations through providing an understandable workspace to employees.

8. *Flexibility*
   The ability of the system to adapt to structural and unforeseen market developments and changes in demand in the long term, such as diversifying in products and services, or increasing or decreasing demand. Next to that, the flexibility criterion addresses the ability of the system to adapt to short-term peaks in the operation, through for instance the possibility of expanding or the interoperability and multifunctionality of facilities and equipment. It represents the adaptability and the responsiveness to changes required by KLM Cargo to keep provide the at that moment required system.

9. *Energy efficiency*
   The criterion considers the performance of the energy efficiency of the building and the operation. The areas continuously cooled or temperature controlled, the amount of cool equipment and the ability to fit the energy use to the volumes handled, by for instance shutting down (modular) cool facilities if not used, determine the performance. It represents the ambition level of KLM Cargo to operate an environmentally responsible system.

10. *GDP compliancy*
    Although it is not a question whether an alternative is GDP compliant or not, this criterion judges the way the alternative handles and addresses the guidelines for the compliancy of the premises, equipment, storage and transportation with GDP. The guidelines can be interpreted in an ambitious way and can be integrally be implemented in the system or be projected on the operations in an improvised way. It represents the sustainability required by KLM Cargo be prepared and covered for tightening regulations and industry demands.

11. *Cool-chain integrity*
    The way the cool-chain is facilitated into the new design is essential for the handling of pharmaceutical freight. For instance: should the cool-chain be unbroken from acceptance to delivery or is a system also complying with the guidelines but showing a lower level of ambition also sufficient. It represents the ambition KLM Cargo to provide an system preserving the product integrity of the shipments.

12. *Supply chain integration*
    This criterion addresses a Lean issue. The industry indicates the Lean initiatives required should concern supply chain integration. The system for the KLM Cargo Pharma terminal should add to this. Decreasing inventories and the products in the pipeline are the incentives of the supply chain integration. As explained in chapter 9 this could be achieved by decreasing variation, focussing on primary activities and revising order and delivery principles and decreasing the response times. It represents willingness and perceived necessity of KLM Cargo to contribute to streamlining the pharmaceutical supply chain.

12.1.3. Weighting the Criteria

The above-explained criteria are weighted according the Analytical Hierarchy Process (AHP) method, which is performed in three levels of the KLM Cargo management: strategic, tactical and operational in order to obtain a widely supported system.

Strategic management

The rating by the highest level of management involved in this exercise is represented by the voice of Ms. Renate de Walle. She is the director of the product market group Pharma and involved in everything related to the pharmaceutical freight transported by KLM Cargo from sales and marketing to compliance and operations.

Tactical management

Mr. Mark Starrenburg represents the voice of mid-level management in this exercise. He is manager of the CCC, the department responsible for the worldwide operations of perishable (fresh and pharma) shipments, directing a qualified staff and maintaining dedicated facilities.

Operational management

The most operationally involved management layer is represented by the operational managers at the AAS terminal Mr. Piet Klein and Mr. Theo Viejou. They are for pharmaceutical freight on a daily base involved in (directing) the monitoring, customs and inspections related activities, ACT container handling, maintaining the (cool) facilities and acting in case of breakdown of the pharma related system. They are equally responsible for a wider variety of activities concerning fresh shipments.

Their three AHP tables including the consistency checks are added to this report in appendix 7, and the results are presented in table 12.2

Table 12.2: Relative importance of the criteria as a result of the AHP method

Nr	Criterion	Weights of Strategic Management	Weights of Tactical Management	Weight of Operational Management
1	Implementation time	1%	2%	2%
2	Implementation cost	2%	2%	2%
3	Lifetime cost	4%	4%	4%
4	Operational cost	7%	5%	4%
5	Throughput speed	18%	10%	8%
6	Modularity installations	4%	6%	16%
7	Clarity of installations	7%	11%	12%
8	Flexibility	7%	11%	9%
9	Energy efficiency	9%	7%	6%
10	GDP compliancy	16%	13%	9%
11	Cool-chain integrity	16%	20%	22%
12	Supply chain integration	10%	8%	4%
Total		**100%**	**100%**	**100%**

12.1.4. Conclusion

The weighted criteria are used to perform the multi-criteria analysis. Initially the multi-criteria analysis is performed with the weights of all three management perspectives. By doing so, the outcomes are checked for robustness already in the initial comparison. After that only the sensitivity check is required. The rankings of the three different management layers are compared in table 12.3.

Table 12.3: Comparison of the ranks of the three management levels

Rank	Weights of Strategic Management	Weights of Tactical Management	Weight of Operational Management
1	Throughput speed	Cool chain integrity	Cool chain integrity
2	GDP compliancy	GDP compliancy	Modularity installations
3	Cool-chain integrity	Clarity of installations	Clarity of installations
4	Supply chain integration	Flexibility	Flexibility
5	Energy efficiency	Throughput speed	GDP compliancy
6	Flexibility	Supply chain integration	Throughput speed
7	Clarity of installations	Energy efficiency	Energy efficiency
8	Operational cost	Modularity installations	Supply chain integration
9	Modularity installations	Operational cost	Lifetime cost
10	Lifetime cost	Lifetime cost	Operational cost
11	Implementation cost	Implementation cost	Implementation cost
12	Implementation time	Implementation time	Implementation time

12.2. Quantitative Requirements: Performance Parameters

In this paragraph the calculations for the future capacity are presented. The calculations depict on conceptual level the landside, airside and terminal capacity, which the configuration should provide in order to facilitate the demand in the representative peak moment (as determined in chapter 10) in 2040. In chapter 15 the calculated capacity is specifically translated into the spatial implications.

The capacity calculations consist of three steps:

1. *Unravelling the representative peak week in 2014*
   The peak week in 2014 is developed into the maximum number of shipments 1) per hour handled at the land- and airside and 2) accumulated in the terminal in that week. The calculations are performed for several product combinations, in order to provide applicability to the alternative configurations.

   For the land- and airside movement capacity multiple calculations are performed. The split here is useful because some of the concepts consider a dedicated handling for COL at air- and landside. The calculations are made for:
   - All pharma
   - ACT, CRT and PIL
   - COL

   The terminal capacity calculations are performed for multiple product (combinations). The division of the products this way is useful because ACT needs special facilities, COL needs cool area, and CRT and PIL can be handled the same way as all concepts for the configuration of the terminal operate within an environment suitable for both. The calculations are made for:
   - ACT
   - COL
   - CRT and PIL

2. *Determining the share of the annual shipments is handled at the peak moment*
   For the maximum number of shipments handled at land- and airside and accumulated in the terminal in 2014 is determined what percentage of the total annual number of shipments of the product (combination) groups in 2014 this represents.

3. *Project the percentages on the 2040 annual demand*
   The percentages are used to calculate the amount of shipments of the product (combination) groups handled in a representative peak moment in 2040. This peak moment is determined to represent the required capacity for the terminal.

   The capacity of the land- and airside operations is expressed in shipments per hour.

   The capacity of the terminal is expressed in required storage spaces for the shipments of each product (combination) group. How much space is required for the number of shipments is determined after the preferred concept for the terminal configuration is determined.

12.2.1. Unravelling the Representative Peak Week in 2014

In the peak week in 2014 the terminal handled 1.026 shipments. Table 12.3 explains the spread of shipments over the days, the flows and product groups.

Table 12.4: Number of shipments per flow per product in the representative peak weak in 2014

Day	E-ACT	I-ACT	T-ACT	E-COL	I-COL	T-COL	E-CRT	I-CRT	T-CRT	E-PIL	I-PIL	T-PIL
Mon	2	1	3	5	2	4	5	0	4	8	12	13
Tue	0	1	12	4	3	48	2	1	13	19	6	61
Wed	0	0	18	6	5	46	0	0	15	9	19	64
Thu	0	3	4	5	3	40	2	1	11	6	12	54
Fri	0	0	2	5	2	31	3	2	3	15	8	48
Sat	0	0	16	2	2	102	2	0	20	3	9	82
Sun	0	1	9	1	6	30	0	3	27	0	14	26
Flow	**2**	**6**	**64**	**28**	**23**	**301**	**14**	**7**	**93**	**60**	**80**	**348**
Prod.		**72**			**352**			**114**			**488**	
Total						**1.026**						

From all the shipments the actual arrival time in DWH can be found. Together with the annual average throughput time per flow and product group it can be determined when the shipments depart. The throughput times per flow per product group are given in table 12.5.

Table 12.5: Annual average throughput time per flow per product in 2014

Flow	E-ACT	I-ACT	T-ACT	E-COL	I-COL	T-COL	E-CRT	I-CRT	T-CRT	E-PIL	I-PIL	T-PIL
TT(h)	20	10	25	19	17	29	24	13	34	23	11	34

With the arrival times and departure times an arrival and departure pattern is determined. These arrival patterns per flow and product group can be transformed in new arrival and departure patterns to expose the landside and the airside movements. For this the annual average of the mode of the arrival and the departure of the shipment per flow per product (combination) group is considered. The modal split is given in table 3.3. in paragraph 3.4.3.

Landside and Airside Movements

In appendix 8 the land- and airside movement patterns are given for:

- All pharma
- ACT, CRT, PIL
- COL

The results of the maximum hourly movements per product (combination) group for the land- and airside interface are given in table 12.6.

Table 12.6: Maximum hourly movements of shipments per product (combination) group in 2014

Interface	All pharma	ACT, CRT, PIL	COL
Landside	19	13	9
Airside	23	16	13

Terminal Storage Space

In appendix 9 the terminal occupation patterns are given for 1) all pharma, 2) ACT, CRT, PIL, and 3) COL separately.

The results of the maximum number of shipments per product (combination) group occupying the terminal are given in table 12.7.

Table 12.7: Max. terminal occupation in shipments per product (combination) group in 2014

Terminal occupation	ACT	COL	CRT and PIL
Shipments	19	109	174
RKN equivalent	54	n/a	n/a
Volume (m3)	n/a	410	931
Pieces	n/a	1.124	1.988

12.2.2. Determining the Share of the Annual Shipments Is Handled at the Peak Moment

The capacity figures determined in the paragraph above need to be expressed in a percentage of the annual total of shipments handled, in order to project this share onto the estimated numbers for 2040.

The annual figures for 2014 are given in chapter 3.4 and summarized in table 12.8.

Table 12.8: Shipments through the Amsterdam terminal in 2014

Products	Shipments
ACT	2.966
COL	16.507
CRT	5.017
PIL	22.049
Total	**46.539**

The peaks developed in paragraph 12.2.1 for the movements at the interfaces with landside and airside are expressed in % of the annual amount of shipments processed through the Amsterdam terminal in 2014 in table 12.9.

Table 12.9: Land- and airside peaks expressed in % of annual shipments handled in 2014

Product group	Total annual shipments	Landside peak/ hour	% of ann. shipments	Airside peak/ hour	% of ann. shipments
All pharma	46.539	19	**0,042**	23	**0,049**
ACT, CRT, PIL	30.032	13	**0,042**	16	**0,054**
COL	16.507	9	**0,052**	13	**0,082**

The peaks developed in paragraph 12.2.1 for the occupancy of the terminal are expressed in percentage of the annual amount of shipments processed through the Amsterdam terminal in 2014 in table 12.10.

Table 12.10: Terminal occupancy peak expressed in % of annual shipments handled in 2014

Product group	Total annual shipments	Max. terminal occupation	% of ann. shipments
ACT	2.966	19	**0,641**
COL	16.507	109	**0,660**
CRT and PIL	27.066	174	**0,643**

12.2.3. Project the Percentages on the 2040 Annual Demand

In paragraph 5.4.1 in table 5.2 development of the pharmaceutical shipments to be handled in the Amsterdam terminal until 2040 is estimated. The estimate for 2040 is given in table 12.11.

Table 12.11: Shipments through the Amsterdam terminal in 2040

Products	Shipments
ACT	14.478
COL	46.488
CRT	44.269
PIL	1.693
Total	**106.928**

With the help of the percentages determined in the previous paragraph and the estimated number of shipments in 2040 the required land- and airside and terminal capacity is determined.

The percentages of the annual freight that need to be handled in the 2040 peak moment at the land- and airside interface are shown in table 12.12 In the table also the annual totals are given and the required capacity in shipments per hour is determined.

Table 12.12: Land- and airside peaks expressed in shipments per hour based on the annual shipments handled in 2040

Product group	Total annual shipments	Landside peak (%)	Shipments / hour	Airside peak (%)	Shipments/ hour
All pharma	106.928	0,042	**44**	0,049	**52**
ACT, CRT, PIL	60.440	0,042	**25**	0,054	**33**
COL	46.488	0,052	**24**	0,082	**38**

The percentage of the annual freight in the 2040 peak moment occupying the terminal is shown in table 12.13. In the table also the annual totals are given and the required capacity in number of shipments is determined.

Table 12.13: Terminal occupancy peak expressed in number of shipments based on the annual shipments handled in 2040

Product group	Total annual shipments	Terminal occupation peak (%)	Shipments
ACT	14.478	0,641	**93**
COL	46.488	0,660	**307**
CRT and PIL	45.962	0,643	**295**

12.3. Conclusion

The required capacity to be provided by the terminal system in 2040 is determined for two scenarios:

1. Terminal with one temperature zone to interface the land- and airside
2. Terminal with two temperature zones both interfacing land- and airside

In case of one temperature zone the new terminal system needs to provide the capacity as presented in table 12.14.

Table 12.14: Required capacity in case of a terminal system with one temperature zone

System element	Products	Capacity required					
Landside interface	All pharma	44	shipments/hour				
Airside interface	All pharma	52	shipments/hour				
Terminal storage	ACT	93	shipm. or	264	RKN equiv.		
	COL	307	shipm. or	1.155	m3 or	3.165	pieces
	CRT and PIL	295	shipm. or	1.578	m3 or	3.370	pieces

In case of two temperature zones the new terminal system needs to provide the capacity as presented in table 12.15.

Table 12.15: Required capacity in case of a terminal system with two temperature zones

System element	Products	Capacity required					
Landside interface	ACT, CRT, PIL	25	shipments/hour				
	COL	24	shipments/hour				
Airside interface	ACT, CRT, PIL	33	shipments/hour				
	COL	38	shipments/hour				
Terminal storage	ACT	93	shipm. or	264	RKN equiv.		
	COL	307	shipm. or	1.155	m3 or	3.165	pieces
	CRT and PIL	295	shipm. or	1.578	m3 or	3.370	pieces

13. Configuration Concepts for the Terminal

Once the requirements formulated in chapter 11 have been translated into the criteria in chapter 12 and the systemic design is developed in chapter 10, several concepts for the terminal configuration are developed in this chapter. The concepts are compared with each other in chapter 14.

For developing the conceptual designs for the internal configuration of the KLM Cargo Pharma Terminal, this chapter first presents an introduction of the precise system that needs to be configured, how the systemic design is the basis for this and what the functions are to be varied on. In the second paragraph the concepts used to determine five configurations using the method of Morphological Analysis. The created concepts are elaborated on in the third paragraph. The final paragraph summarizes an overview of the concepts.

13.1. Introduction to Composing the Concepts

In chapter 10 the design is determined on systemic level. The chapter concludes with the parameters of the design on which the configuration needs to be decided on. These parameters are of functional kind. The way they are substantiated need to fit within the systemic design decisions.

The parameters objectify the elements in a terminal system for handling freight between landside and airside, providing the required buffering, environment and conversion between modes. The system contains handling in the interface with landside, in the interface with airside and in the terminal itself. Movements for individual shipments, ULDs and ACT containers need to be considered.

The eight parameters used as functions to compose the system's design that were defined in chapter 10 are listed below and given in Figure 13.1:

1. Handling Freight at the Landside Interface
2. Handling ULDs in the Terminal
3. Handling Bulk in the Terminal
4. Handling ULDs at the Airside Interface
5. Handling Bulk at the Airside Interface
6. Handling of ACT Containers
7. Terminal Refinement Level
8. Flexibility to the Future

Parameter 1: Handling Freight at the Landside Interface
Handling bulk freight at landside contains the unloading of export, loading of import and the loading and unloading of transit trucks. Export and import is handled in bulk and the transit trucks are considered to be operated as loose trucking, which means the freight is build-up on Europallets. The export, import or transit trucks also could contain ULDs, such as ACT containers. The way the bulk freight, the Europallets and the occasional ULDs are handled at landside is described in this parameter.

Parameter 2: Handling ULDs in the Terminal
This parameter describes the way the ULDs are handled within the terminal. Handling contains build-up/ breakdown, movement, buffer and storage of the ULD. The flows that are considered in this

parameter are the incoming ULD flows and the outgoing ULD flows for ULDs that are built-up in the terminal and ULDs that just pass through and do not need any alteration. ULDs mainly move at the airside of the terminal.

Parameter 3: Handling Bulk in the Terminal
The terminal functions as a node connecting all the freight flows. Individual shipments are moved, stored and buffered in the right conditions and environments in order to be build-up on a ULD or to leave the terminal in bulk.

The pharmaceuticals shipments need to be handled in the required temperature zone. It could be that facilities need to be separated from each other in order to provide so. Modularity in these facilities can be used to increase the flexible use of the installations in place.

The origin of freight handled in bulk in the terminal could at landside be from export or transit trucks or at airside from broken down ULDs or bulk belly freight. The destination of bulk freight in the terminal could be at landside import delivery or a transit truck or at airside bulk could ne build-up on a ULD or leave the terminal as bulk belly freight.

Parameter 4: Handling ULDs at the Airside Interface
The airside is an important interface for handling departing and arriving ULDs. Before flight the ULDs are gathered at the airside interface in order to be transported to the aircraft. Upon arrival the ULDs are gathered there before being processed into the terminal, which can be for breakdown of M-ULDs or for only buffer and storage of T-ULDs. The time ULDs are exposed to ambient temperatures should be as short as possible. It is important the handling system in the terminal fits the typical volume and weight of pharmaceutical freight and that it is able to provide the required responsiveness.

Parameter 5: Handling Bulk at the Airside Interface
Freight to be transported in bulk in the belly of the aircraft is not build-up onto ULDs but transported in bulk. Also the delivery and collection of the freight at the aircraft is in bulk. The mode of transport from and to the belly needs to take the integrity of the product into account. For the collection of the shipments before departure and after arrival different systems can be used.

Parameter 6: Handling of ACT containers
Handling the ACT containers is considered a to be a specialized activity. From the landside acceptance until the airside delivery the ACT container needs deviating and careful attention. The degree the ACT container (passive or active) flows through the general process depends on the caution in the general process. Once arrived at the buffer area the container needs special servicing and storage. Upon departure the ACT container needs to be delivered to the right destination, this can be import delivery, transit truck departure or aircraft departure. It is important for the reliability and the performance of the container that it is kept from temperature extremes and within controlled areas as long as possible.

Parameter 7: Terminal Refinement Level
The required finishing of the terminal to a large extend determined in the GDP regulations. Proper finishing and nifty details are in order to keep the facility clean, pest free and easily maintainable. Next to that, the refinement level of the terminal depends on the ambition level of KLM Cargo. They could decide to only make the minimum of installations upon the regulatory required level or decide that the entire terminal should be created to show their professionalism to the customer and communicate the delicacy of the product and the therefore required mind-set to the personnel.

Parameter 8: Flexibility to the Future
The ability of the terminal to adapt to the increasing or decreasing demand, to changes in the expectations for future demand, the development of unforeseen product requirements on the long term, but also short-term peaks and drops in demand, are considered in this variable. It determines the flexibility of the terminal to cope with all these changes in demand.

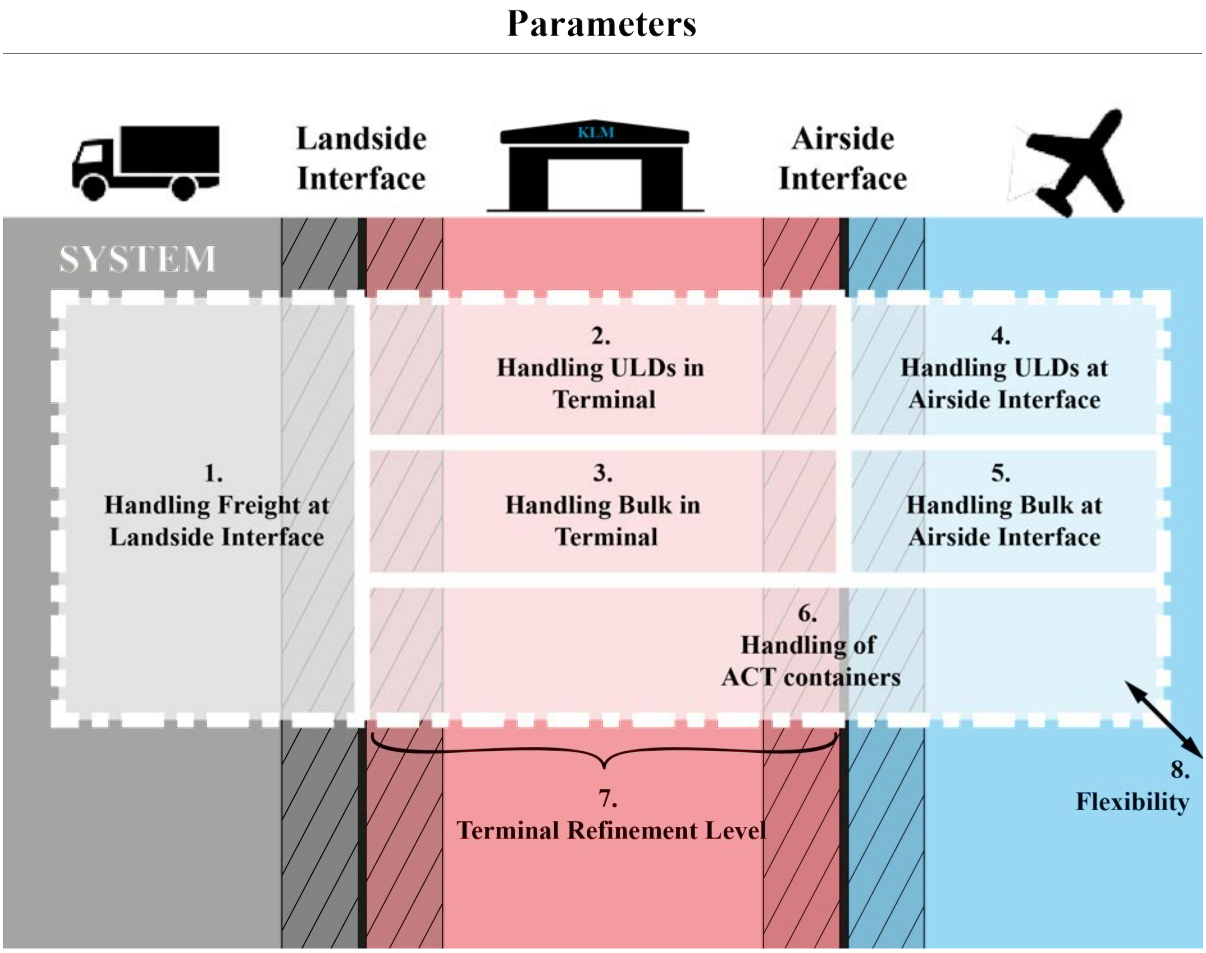


Figure 13.1: Parameters in the system

13.2. Composing the Concepts with Morphological Analysis

Each of the eight functions of which the concepts for the configuration are composed can be fulfilled in alternative ways. The spectrum of alternatives for the functions are, according to the method for Morphological Analysis, allocated in a Morphological Box. The Morphological Box and alternatives are explained in appendix 10. By combining an alternative for each function different concepts for the configuration of the system can be composed. As explained in paragraph 2.7 the methodology allows to hand pick some concepts for further comparison.

The composition of configuration from the parameter's alternatives is based on five design concepts:

1. The Zero Concept
2. The Modest Concept
3. The Elite Concept
4. The Compact Concept
5. The Automated Concept

13.3. Five Concepts for the Terminal Configuration

In this paragraph the concepts for the configuration are elaborated on.

13.3.1. The Zero Concept

Mission Definition

The first concept considered is a configuration very close to the way the current KLM Cargo terminal is configured. In the terminal shipments are handled in a highly mechanized, industrial environment with the handling refinements and precision associated with high volumes of general cargo. To make the system suitable for handling pharmaceutical shipments several installations are in place, such as temperature-controlled storage rooms and an ACT service desk where tractors can drop-off their dollies with the ACT containers. When shipments or ULDs are not in storage the ambient temperature is neither controlled nor monitored. A more elaborate description of the current operation at KLM Cargo for pharmaceutical freight is given in chapter 3.

Physical Parameters

See table 13.1.

Operational Deployment

This system relies on the availability of basic shipment and ULD handling equipment, such as forklifts, Europallets, tractors and dollies. Because of the high degree of mechanization in handling ULDs, the Zero Concept requires a relatively small amount of employees for handling ULDs.

Operational life-cycle

The implementation time of the Zero Concept is relatively long, because of the extra time required for the installation of the highly mechanized PCHS.

Maintenance and Support

The high level of automation in the Zero Concept through the PCHS requires a relatively large amount of maintenance. The continuity of the system is dependent on the performance and reliability of this system, so it is essential to perform preventive and periodic maintenance.

Conclusion

The Zero Concept is the configuration with the least dedication to facilitating pharmaceutical freight. In accordance with how the system is currently used, this configuration for the dedicated pharma terminal is proposed to be as if pharmaceutical freight were general freight and only needs some minimal adaptions to ensure proper handling and product integrity.

Although the basic level of availability of temperature-controlled rooms, this configuration of the terminal is relatively energy efficient. In the current situation the cool rooms are not build-up in a modular way, therefore overcapacity cannot be shut down and capacity cannot be used to compensate a capacity constraint in another process. The system is inflexible to cope with short-term and incidental demand fluctuations.

A PCHS normally is found useful when processing large volumes. In this case the measure might be too strong, and therefore slow, expensive and requiring a relatively large amount of maintenance. At the other hand the PCHS decreases the amount of the human error and the amount of employees necessary to make the system work. Working with a complex system such as a PCHS decreases the flexibility of the system as a whole to adapt to unforeseen, future changes in expected demand.

Table 13.1: Morphological box for composing the Zero Concept

Parameters	Parameter Alternative 1	Parameter Alternative 2	Parameter Alternative 3	Parameter Alternative 4	Parameter Alternative 5
1 Handling Freight at the Landside Interface	**PA1.1** Outside truck unloading bay, unloading with forklifts	**PA1.2** Controlled truck unloading dock, unloading with forklifts	**PA1.3** Controlled truck unloading dock, unloading with automated system		
2 Handling ULDs in the Terminal	**PA2.1** Fully mechanized system to handle ULDs	**PA2.2** Semi mechanized system and airside PCHS to handle ULDs	**PA2.3** Manual system to handle ULDs	**PA2.4** Cool dollies to handle ULDs	
3 Handling Bulk in the Terminal	**PA3.1** Forklifts to handle individual shipments	**PA3.2** Compact stackers to handle individual shipments	**PA3.3** Hand pallet trucks to handle individual shipments	**PA3.4** Sorter system to handle individual shipments	
4 Handling ULDs at the Airside Interface	**PA4.1** Tractors and dollies to transport ULDs	**PA4.2** Tractors and cool dollies to transport all pharma ULDs	**PA4.3** Tractors and cool dollies to transport COL and CRT ULDs	**PA4.4** Tractors and cool dollies to transport COL ULDs	**PA4.5** Insulation dollies to transport ULDs
5 Handling Bulk at the Airside Interface	**PA5.1** Belly carts to transport airside bulk belly freight	**PA5.2** Dedicated van to transport airside bulk belly freight	**PA5.3** Cool dollies to transport airside bulk belly freight		
6 Handling of ACT Containers	**PA6.1** Tractors and dollies to handle ACT containers	**PA6.2** Pallet slaves, tractors and dollies to handle ACT containers	**PA6.3** Roller- and ball beds, tractors and dollies to handle ACT containers	**PA6.4** Connection to PCHS, tractors and dollies to handle ACT containers	
7 Terminal Refinement Level	**PA7.1** Terminal with clinical finishing, two temperature zones (15-25, 2-8)	**PA7.2** Terminal with clinical finishing, general temperature control in 15-25	**PA7.3** Terminal with industrial finishing, two temperature zones (15-25, 2-8)	**PA7.4** Terminal with industrial finishing, general temperature control in 15-25	**PA7.5** Terminal with industrial finishing, no general temperature control
8 Flexibility to the Future	**PA8.1** Terminal designed to fit 2040 demand	**PA8.2** Terminal designed to fit 2040 demand, but is able to adapt to short-term fluct.	**PA8.3** Terminal designed to gradually adapt to the forecasted demand		

13.3.2. The Modest Concept

Mission Definition

The second concept considered is an configuration that aims to achieve the required level of quality for handling the pharmaceutical freight with the least amount of specialization and dedication. A terminal for low volumes suitable most types of freight is composed, without compromising product integrity or underestimating the demands the industry might impose in the future. In order to do so the terminal is completely temperature-controlled, and provides different ranges of temperature for shipment and ULD buffering. The freight is processed with a small amount of basic devices, mainly relying on manpower and human planning and control.

Physical Parameters

See table 13.2.

Operational Deployment

The system relies on the availability of basic shipment and ULD handling equipment, such as hand pallet trucks, Europallets, tractors and dollies. Because of the low degree of mechanization in handling neither shipments nor ULDs, the Modest Concept requires a substantial amount of employees for operating the terminal.

Operational life-cycle

The implementation time of the Modest Concept is relatively short, because of the simplicity and modularity it is build-up with.

Maintenance and Support

The low level of automation in the Modest Concept avoids the necessity of large amount of technical maintenance. The continuity of the system is dependent on the performance and compliancy to industry's standards requiring extensive cleaning and training programs for employees.

Conclusion

The Modest Concept is a basic equipped configuration, yet dedicated to maintaining product integrity of the pharmaceutical shipments. The terminal's system is composed of elements in such a way that its function and capacity is flexible, without compromising on the possibility to deliver the required quality in handling.

Although the truck unloading area has no temperature-control, the exposure of freight to the ambient temperatures does pose a negligible risk. It is sheltered from rain and the shipments are brought into controlled areas very shortly after unloading. The risk posed by the outside operations at landside are considered to not exceed the effects of the exposure of the shipments at airside.

A manual system is seen in countries with low costs for labour and low volumes of freight. In this case the system might be capacity constrained, and therefore slow, unclear and requiring a lot of manpower to make it work. At the other hand a manual system can be responsive and dedicated without requiring technical maintenance.

Working with a system as proposed here decreases its flexibility as a whole to adapt to unforeseen future changes in expected demand. Although it is flexible in the short-term demand changes, the imposed elements in the system are considered to be less flexible.

Table 13.2: Morphological box for composing the Modest Concept

Parameters	Parameter Alternative 1	Parameter Alternative 2	Parameter Alternative 3	Parameter Alternative 4	Parameter Alternative 5
1 Handling Freight at the Landside Interface	PA1.1 Outside truck unloading bay, unloading with forklifts	PA1.2 Controlled truck unloading dock, unloading with forklifts	PA1.3 Controlled truck unloading dock, unloading with automated system		
2 Handling ULDs in the Terminal	PA2.1 Fully mechanized system to handle ULDs	PA2.2 Semi mechanized system and airside PCHS to handle ULDs	PA2.3 Manual system to handle ULDs	PA2.4 Cool dollies to handle ULDs	
3 Handling Bulk in the Terminal	PA3.1 Forklifts to handle individual shipments	PA3.2 Compact stackers to handle individual shipments	PA3.3 Hand pallet trucks to handle individual shipments	PA3.4 Sorter system to handle individual shipments	
4 Handling ULDs at the Airside Interface	PA4.1 Tractors and dollies to transport ULDs	PA4.2 Tractors and cool dollies to transport all pharma ULDs	PA4.3 Tractors and cool dollies to transport COL and CRT ULDs	PA4.4 Tractors and cool dollies to transport COL ULDs	PA4.5 Insulation dollies to transport ULDs
5 Handling Bulk at the Airside Interface	PA5.1 Belly carts to transport airside bulk belly freight	PA5.2 Dedicated van to transport airside bulk belly freight	PA5.3 Cool dollies to transport airside bulk belly freight		
6 Handling of ACT Containers	PA6.1 Tractors and dollies to handle ACT containers	PA6.2 Pallet slaves, tractors and dollies to handle ACT containers	PA6.3 Roller- and ball beds, tractors and dollies to handle ACT containers	PA6.4 Connection to PCHS, tractors and dollies to handle ACT containers	
7 Terminal Refinement Level	PA7.1 Terminal with clinical finishing, two temperature zones (15-25, 2-8)	PA7.2 Terminal with clinical finishing, general temperature control in 15-25	PA7.3 Terminal with industrial finishing, two temperature zones (15-25, 2-8)	PA7.4 Terminal with industrial finishing general temperature control in 15-25	PA7.5 Terminal with industrial finishing, no general temperature control
8 Flexibility to the Future	PA8.1 Terminal designed to fit 2040 demand	PA8.2 Terminal designed to fit 2040 demand, but is able to adapt to short-term fluct.	PA8.3 Terminal designed to gradually adapt to the forecasted demand		

13.3.3. The Elite Concept

Mission Definition

The next concept considered is a configuration that aims to achieve a high and ambitious level of quality for handling the pharmaceutical freight. A terminal for low volumes of pharmaceutical freight is composed here without compromising product integrity or underestimating the demands the industry might impose in the future. To make the system suitable for doing so the terminal is split in two completely temperature-controlled areas to provide equal precision in both ranges of temperatures for shipment and ULD handling.

Physical Parameters

See table 13.3.

Operational Deployment

The system relies on the availability of more advanced shipment and ULD handling equipment. Next to compact stackers, Europallets, tractors and dollies it uses pallet slaves for the ACT containers, cool dollies and an airside PCHS with individually customizable temperatures. Because of the partial mechanization in handling ULDs, the Elite Concept is only requiring manpower for operations requiring human interference to assure quality.

Operational life-cycle

The implementation time of the Elite Concept is relatively long, yet not as long as for the Zero Concept, because of the time required for the installation of the airside PCHS and the two temperature-controlled areas.

Maintenance and Support

The level of automation in the Elite Concept through the airside PCHS requires maintenance, as well do the cool dollies and the two independent systems for temperature control and monitoring. The continuity of the system is dependent on the performance and reliability of these systems, so it is essential to perform preventive and periodic maintenance. The compliancy to industry’s standards require extensive cleaning and training programs for employees, which need to be maintained as well.

Conclusion

The Elite Concept is the configuration with the highest dedication to facilitating pharmaceutical freight according to GDP guidelines and by providing the highest quality cool-chain. The terminal’s system is composed in such a way that it is unsuitable, or at least over qualified and equipped, for handling most other commodities. The focus is on pharmaceutical freight and its specific needs.

The temperature-control in the terminal in two temperature zones of which one is continuously held at 2˚C - 8˚C, makes this concept relatively energy inefficient. As the two zones are providing the right temperature already for handling terms such as modularity are not applicable. The system is able to cope with short-term and incidental demand fluctuations, as the storage is provided in the terminal without being bound to the size of the cool area.

The combination of the airside PCHS for ULD buffering, the specific equipment and the human responsiveness in the system makes the degree of mechanization fit the commodity and the volume, and provides a fast, high- quality, yet costly throughput. Although the airside PCHS has a determined capacity, working with such a system increases the flexibility of the system as a whole to adapt to unforeseen future changes in expected demand because of the restructuring possibilities in the large temperature controlled area and the possibility to add to the modular set-up of e.g. the racks.

Table 13.3: Morphological box for composing the Elite Concept

Parameters	Parameter Alternative 1	Parameter Alternative 2	Parameter Alternative 3	Parameter Alternative 4	Parameter Alternative 5
1 Handling Freight at the Landside Interface	**PA1.1** Outside truck unloading bay, unloading with forklifts	**PA1.2** Controlled truck unloading dock, unloading with forklifts	**PA1.3** Controlled truck unloading dock, unloading with automated system		
2 Handling ULDs in the Terminal	**PA2.1** Fully mechanized system to handle ULDs	**PA2.2** Semi mechanized system and airside PCHS to handle ULDs	**PA2.3** Manual system to handle ULDs	**PA2.4** Cool dollies to handle ULDs	
3 Handling Bulk in the Terminal	**PA3.1** Forklifts to handle individual shipments	**PA3.2** Compact stackers to handle individual shipments	**PA3.3** Hand pallet trucks to handle individual shipments	**PA3.4** Sorter system to handle individual shipments	
4 Handling ULDs at the Airside Interface	**PA4.1** Tractors and dollies to transport ULDs	**PA4.2** Tractors and cool dollies to transport all pharma ULDs	**PA4.3** Tractors and cool dollies to transport COL and CRT ULDs	**PA4.4** Tractors and cool dollies to transport COL ULDs	**PA4.5** Insulation dollies to transport ULDs
5 Handling Bulk at the Airside Interface	**PA5.1** Belly carts to transport airside bulk belly freight	**PA5.2** Dedicated van to transport airside bulk belly freight	**PA5.3** Cool dollies to transport airside bulk belly freight		
6 Handling of ACT Containers	**PA6.1** Tractors and dollies to handle ACT containers	**PA6.2** Pallet slaves, tractors and dollies to handle ACT containers	**PA6.3** Roller- and ball beds, tractors and dollies to handle ACT containers	**PA6.4** Connection to PCHS, tractors and dollies to handle ACT containers	
7 Terminal Refinement Level	**PA7.1** Terminal with clinical finishing, two temperature zones (15-25, 2-8)	**PA7.2** Terminal with clinical finishing, general temperature control in 15-25	**PA7.3** Terminal with industrial finishing, two temperature zones (15-25, 2-8)	**PA7.4** Terminal with industrial finishing, general temperature control in 15-25	**PA7.5** Terminal with industrial finishing, no general temperature control
8 Flexibility to the Future	**PA8.1** Terminal designed to fit 2040 demand	**PA8.2** Terminal designed to fit 2040 demand, but is able to adapt to short-term fluct.	**PA8.3** Terminal designed to gradually adapt to the forecasted demand		

13.3.4. The Compact Concept

Mission Definition

Without giving in on the required quality of handling the pharmaceutical freight, the measures that are taken in the Elite Concept, which might be considered to unnecessarily exceed the requirements, are scaled down to making this Compact Concept. The configuration aims to meet the requirements with a compact terminal system. It tries to balance the quality provided with an operational practicality.

Physical Parameters

See table 13.4.

Operational Deployment

The system relies on the availability of more advanced shipment and ULD handling equipment. Next to compact stackers, Europallets, tractors and dollies it also uses pallet slaves for the ACT containers, cool dollies and an airside PCHS. The Compact Concept is not requiring manpower for storing ULDs.

Operational life-cycle

The implementation time of the Compact Concept is relatively long yet not as long as for the Zero Concept and the Elite Concept, because of the time required for the installation of only an airside PCHS and the temperature control and monitoring installations.

Maintenance and Support

The level of automation in the Compact Concept through the airside PCHS requires a certain amount of maintenance, as well do the (limited amount of) cool dollies and systems for temperature control. The continuity of the system is dependent on the performance and reliability of these systems, so it is essential to perform preventive and periodic maintenance. The compliancy to industry's standards require extensive cleaning and training programs for employees, which need to be maintained as well.

Conclusion

The Compact Concept is the configuration with the focus on the balance between the practical side of operations and the high quality facilitation for pharmaceutical freight in GDP guidelines and cool-chain. The terminal's system is composed in such a way that it is unsuitable or at least over qualified and equipped for handling most other commodities. The focus is on the practical throughput of pharmaceutical freight while providing high quality care.

The temperature control in the terminal is continuously held at 15˚C - 25˚C in this concept, while the other temperature zone is modularly facilitated by means of cool rooms inside the terminal. The configuration of the terminal is relatively energy inefficient. The system is able to cope with short-term and incidental demand fluctuations, as the part of storage is provided in the terminal without being bound to the size of the cool area. The modular 2˚C - 8˚C facilities are adaptable to falling demand, by shutting down some of the modules.

The combination of the airside PCHS for ULD buffering, the specific equipment and the human responsiveness in the system makes the degree of mechanization fit the commodity and the volume, and provides a fast, high-quality, yet costly throughput. Although the airside PCHS has a determined capacity, working with such a system increases the flexibility of the system as a whole to adapt to unforeseen future changes in expected demand because of the restructuring possibilities in the large temperature-controlled area and the possibility to add to the modular set-up of e.g. the racks.

Table 13.4: Morphological box for composing the Compact Concept

Parameters	Parameter Alternative 1	Parameter Alternative 2	Parameter Alternative 3	Parameter Alternative 4	Parameter Alternative 5
1 Handling Freight at the Landside Interface	**PA1.1** Outside truck unloading bay, unloading with forklifts	**PA1.2** Controlled truck unloading dock, unloading with forklifts	**PA1.3** Controlled truck unloading dock, unloading with automated system		
2 Handling ULDs in the Terminal	**PA2.1** Fully mechanized system to handle ULDs	**PA2.2** Semi mechanized system and airside PCHS to handle ULDs	**PA2.3** Manual system to handle ULDs	**PA2.4** Cool dollies to handle ULDs	
3 Handling Bulk in the Terminal	**PA3.1** Forklifts to handle individual shipments	**PA3.2** Compact stackers to handle individual shipments	**PA3.3** Hand pallet trucks to handle individual shipments	**PA3.4** Sorter system to handle individual shipments	
4 Handling ULDs at the Airside Interface	**PA4.1** Tractors and dollies to transport ULDs	**PA4.2** Tractors and cool dollies to transport all pharma ULDs	**PA4.3** Tractors and cool dollies to transport COL and CRT ULDs	**PA4.4** Tractors and cool dollies to transport COL ULDs	**PA4.5** Insulation dollies to transport ULDs
5 Handling Bulk at the Airside Interface	**PA5.1** Belly carts to transport airside bulk belly freight	**PA5.2** Dedicated van to transport airside bulk belly freight	**PA5.3** Cool dollies to transport airside bulk belly freight		
6 Handling of ACT Containers	**PA6.1** Tractors and dollies to handle ACT containers	**PA6.2** Pallet slaves, tractors and dollies to handle ACT containers	**PA6.3** Roller- and ball beds, tractors and dollies to handle ACT containers	**PA6.4** Connection to PCHS, tractors and dollies to handle ACT containers	
7 Terminal Refinement Level	**PA7.1** Terminal with clinical finishing, two temperature zones (15-25, 2-8)	**PA7.2** Terminal with clinical finishing, general temperature control in 15-25	**PA7.3** Terminal with industrial finishing, two temperature zones (15-25, 2-8)	**PA7.4** Terminal with industrial finishing, general temperature control in 15-25	**PA7.5** Terminal with industrial finishing, no general temperature control
8 Flexibility to the Future	**PA8.1** Terminal designed to fit 2040 demand	**PA8.2** Terminal designed to fit 2040 demand, but is able to adapt to short-term fluct.	**PA8.3** Terminal designed to gradually adapt to the forecasted demand		

13.3.5. The Automated Concept

Mission Definition

The mission of the last alternative is to handle the pharmaceutical shipments and ULDs in an automated way. Its quick response times and continuous operation possibilities require a lower level of temperature-control in the terminal. A terminal for high volumes of pharmaceutical freight is composed here without compromising product integrity or underestimating the demands the industry might impose in the future. To make the system suitable for doing so the terminal is temperature controlled in one temperature range, with added facilities for buffering in the 2˚C - 8˚C range. The freight is processed fast and dedicated and specializes devices, which are automated where possible.

Physical Parameters

See table 13.5.

Operational Deployment

The system only relies on the availability of basic shipment and ULD handling equipment for airside movements, such as tractors and dollies. Because of the high degree of mechanization in handling shipments and ULDs inside the terminal, the Automated Concept requires a little amount of employees for handling the pharmaceutical freight. Only build-up and breakdown is a manual activity.

Operational life-cycle

The implementation time of the Automated Concept is relatively long, because of the extra time required for the installation of the highly mechanized PCHS, the sorter and the automated truck (un)loading system. The lead-time of the implementation of automation in trucks cannot be ignored.

Maintenance and Support

The high level of automation in the Automated Concept through the PCHS, the sorter and the truck loading and unloading system requires a large amount of maintenance. The continuity of the system is dependent on its performance, so it is essential to perform preventive and periodic maintenance.

Conclusion

The Automated Concept is the configuration with largest degree of automation for the dedicated facilitation of pharmaceutical freight. The terminal's system is composed in such a way that the it is unsuitable or at least over qualified and equipped for handling most other commodities, as the system is designed for the weight and volumes of the pharmaceutical freight. The focus is on fast, automated throughput without the risks posed by human errors.

The integral temperature-control in the terminal is continuously held at 15˚C - 25˚C in this concept, while the other temperature zone is modularly facilitated in cool rooms in this area. The configuration of the terminal is relatively energy inefficient. The system is able to cope with short-term and incidental demand fluctuations, as the part of storage is provided in the terminal without being bound to the size of the cool area. The modular 2˚C - 8˚C facilities are adaptable to falling demand, by shutting down some of the modules.

A PCHS normally is found useful with large volumes to be processed through it. In this case the measure might be too strong, and therefore slow, expensive and requiring a relatively large amount of maintenance. At the other hand, the PCHS decreases the required manpower. The truck loading and unloading system is increasing throughput speed. Working with a complex system such as a PCHS decreases the flexibility of the system as a whole to adapt to unforeseen changes in expected demand.

Table 13.5: Morphological box for composing the Automated Concept

Parameters	Parameter Alternative 1	Parameter Alternative 2	Parameter Alternative 3	Parameter Alternative 4	Parameter Alternative 5
1 Handling Freight at the Landside Interface	**PA1.1** Outside truck unloading bay, unloading with forklifts	**PA1.2** Controlled truck unloading dock, unloading with forklifts	**PA1.3** Controlled truck unloading dock, unloading with automated system		
2 Handling ULDs in the Terminal	**PA2.1** Fully mechanized system to handle ULDs	**PA2.2** Semi mechanized system and airside PCHS to handle ULDs	**PA2.3** Manual system to handle ULDs	**PA2.4** Cool dollies to handle ULDs	
3 Handling Bulk in the Terminal	**PA3.1** Forklifts to handle individual shipments	**PA3.2** Compact stackers to handle individual shipments	**PA3.3** Hand pallet trucks to handle individual shipments	**PA3.4** Sorter system to handle individual shipments	
4 Handling ULDs at the Airside Interface	**PA4.1** Tractors and dollies to transport ULDs	**PA4.2** Tractors and cool dollies to transport all pharma ULDs	**PA4.3** Tractors and cool dollies to transport COL and CRT ULDs	**PA4.4** Tractors and cool dollies to transport COL ULDs	**PA4.5** Insulation dollies to transport ULDs
5 Handling Bulk at the Airside Interface	**PA5.1** Belly carts to transport airside bulk belly freight	**PA5.2** Dedicated van to transport airside bulk belly freight	**PA5.3** Cool dollies to transport airside bulk belly freight		
6 Handling of ACT Containers	**PA6.1** Tractors and dollies to handle ACT containers	**PA6.2** Pallet slaves, tractors and dollies to handle ACT containers	**PA6.3** Roller- and ball beds, tractors and dollies to handle ACT containers	**PA6.4** Connection to PCHS, tractors and dollies to handle ACT containers	
7 Terminal Refinement Level	**PA7.1** Terminal with clinical finishing, two temperature zones (15-25, 2-8)	**PA7.2** Terminal with clinical finishing, general temperature control in 15-25	**PA7.3** Terminal with industrial finishing, two temperature zones (15-25, 2-8)	**PA7.4** Terminal with industrial finishing, general temperature control in 15-25	**PA7.5** Terminal with industrial finishing, no general temperature control
8 Flexibility to the Future	**PA8.1** Terminal designed to fit 2040 demand	**PA8.2** Terminal designed to fit 2040 demand, but is able to adapt to short-term fluct.	**PA8.3** Terminal designed to gradually adapt to the forecasted demand		

13.4. Overview

In table 13.6 an overview is given of the composition of the alternatives for the eight functions determining the different concepts for the terminal configuration.

Table 13.6: Parameters of the generated concepts

Parameters	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
1 Handling Freight at the Landside Interface	PA1.2 Controlled truck unloading dock, unloading with forklifts	PA1.1 Outside truck unloading bay, unloading with forklifts	PA1.2 Controlled truck unloading dock, unloading with forklifts	PA1.2 Controlled truck unloading dock, unloading with forklifts	PA1.3 Controlled truck unloading dock, unloading with automated system
2 Handling ULDs in the Terminal	PA2.1 Fully mechanized system to handle ULDs	PA2.3 Manual system to handle ULDs	PA2.2 Semi mechanized system and airside PCHS to handle ULDs	PA2.2 Semi mechanized system and airside PCHS to handle ULDs	PA2.1 Fully mechanized system to handle ULDs
3 Handling Bulk in the Terminal	PA3.1 Forklifts to handle individual shipments	PA3.3 Hand pallet trucks to handle individual shipments	PA3.2 Compact stackers to handle individual shipments	PA3.2 Compact stackers to handle individual shipments	PA3.4 Sorter system to handle individual shipments
4 Handling ULDs at the Airside Interface	PA4.1 Tractors and dollies to transport ULDs	PA4.1 Tractors and dollies to transport ULDs	PA4.2 Tractors and cool dollies to transport all pharma ULDs	PA4.4 Tractors and cool dollies to transport COL ULDs	PA4.3 Tractors and cool dollies to transport COL and CRT ULDs
5 Handling Bulk at the Airside Interface	PA5.1 Belly carts to transport airside bulk belly freight	PA5.1 Belly carts to transport airside bulk belly freight	PA5.2 Dedicated van to transport airside bulk belly freight	PA5.3 Cool dollies to transport airside bulk belly freight	PA5.3 Cool dollies to transport airside bulk belly freight
6 Handling of ACT Containers	PA6.1 Tractors and dollies to handle ACT containers	PA6.3 Roller- and ball beds, tractors and dollies to handle ACT containers	PA6.2 Pallet slaves, tractors and dollies to handle ACT containers	PA6.2 Pallet slaves, tractors and dollies to handle ACT containers	PA6.4 Connection to PCHS, tractors and dollies to handle ACT containers
7 Terminal Refinement Level	PA7.5 Terminal with industrial finishing, no general temperature control	PA7.4 Terminal with industrial finishing, general temperature control in 15-25	PA7.1 Terminal with clinical finishing, two temperature zones (15-25, 2-8)	PA7.3 Terminal with industrial finishing, two temperature zones (15-25, 2-8)	PA7.2 Terminal with clinical finishing, general temperature control in 15-25
8 Flexibility to the Future	PA8.1 Terminal designed to fit 2040 demand	PA8.1 Terminal designed to fit 2040 demand	PA8.3 Terminal designed to gradually adapt to the forecasted demand	PA8.2 Terminal designed to fit 2040 demand, but is able to adapt to short-term fluct.	PA8.1 Terminal designed to fit 2040 demand

Based on the performance measures of Kazda and Kaves (2007) (given in chapter 7), a SWOT analysis is used to determine the differences between the concepts. The performance measures are:

1. Efficient movement
2. Effective storage
3. Easy sortation
4. Accurate and timely inventory control
5. Tight security
6. Effective use of manpower

The analysis is presented in table 13.7.

Table 13.7: SWOT analysis of the configurations for KLM Cargo Pharma Terminal

Parameters	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Strengths	- Familiarity personnel - Use of basic equipment	- Ensuring product integrity (1 zone) - Use of basic equipment - Simplicity	- Ensuring product integrity (2 zones) - Multi-level storage - Responsiveness	- Ensuring product integrity (one zone) - Multi-level storage - Responsiveness	- Ensuring product integrity (one zone) - Throughput speed - Low need for manpower
Weaknesses	- No temp. control - Suitability PCHS - Inflexibility - Need for maintenance	- Suitability manual handing - Only one level storage - Need for manpower	- Expensive equipment - Overqualified	- Integrity COL shipments in terminal	- Suitability PCHS
Opportunities		- Adapting to new regulatory demands - Interchangeable use of terminal	- Adapting to new regulatory demands - Adapting to deviat-ing forecasts	- Adapt to short term demand fluctuations	- Marketing
Threats	- Deviating demand forecasts	- Deviating demand forecasts	- Adapting to demand for new products - Suitability airside PCHS capacity	- Suitability airside PCHS capacity	- Deviating demand forecasts - Outdating of systems

The descriptions of the five concepts for the configuration of the KLM Cargo Pharma Terminal and the SWOT analysis helps to compare the concepts in the multi-criteria analysis in chapter 14.

14. Trading-Off the Concepts

In this chapter the concepts created with the Morphological Analysis in chapter 13 are compared with each other through the weighted criteria developed in chapter 12. For the comparison a multi-criteria analysis is used. First, the performed analysis and its outcome is explained in 12.1. In 12.2 the validity of the outcomes is tested. The chapter ends with a conclusion.

The multi-criteria analysis (MCA) chosen here is a weighted method of evaluation: SMART. The use of a SMART-table is particularly suitable for comparing alternatives to weighted criteria. The methodology is explained in paragraph 2.8.

14.1. Multi-Criteria Analysis

The concepts are compared on each criterion by use of a Scorecard, stating the relative performance of the concepts. The performances are given in the impact table in table 14.1 and explained in appendix 11.

Table 14.1: Impact table of the performance of the concepts in the MCA

		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--
Criterium 2	Implementation cost	0	++	-	0	--
Criterium 3	Lifetime costs	0	++	0	+	--
Criterium 4	Operational costs	0	--	-	-	+
Criterium 5	Throughput speed	0	0	+	+	++
Criterium 6	Modularity installations	0	-	+	++	-
Criterium 7	Clarity of installations	0	-	++	+	-
Criterium 8	Flexibility	0	0	++	+	-
Criterium 9	Energy efficiency	0	0	-	+	-
Criterium 10	GDP compliancy	0	+	++	+	++
Criterium 11	Cool-chain integrity	0	-	++	+	++
Criterium 12	Supply chain integration	0	--	-	0	+

The scores used for the Scorecard technique are relative and all relate to the Zero Alternative. The scores assigned are + +, +, 0, - and - -. The meaning of each score is given intable 14.2:

Table 14.2: Scorecard scores used in the MCA

Performance	**Explanation compared to Zero Concept**
+ +	Much better performance
+	Better performance
0	Equal performance
-	Worse performance
- -	Much worse performance

The scores assigned to the concepts in the impact table are translated into absolute scores from -2 to 2. Thereafter the absolute scores are normalized, to ensure the worst scoring concept is assigned 0 and the best scoring concept is assigned a 1. The weights then are applied on the normalized scores.

All three sets of weights are used, as one level of management cannot be valued superior over the other one. Hence, the MCA is performed with the three different weights. Besides avoiding choosing one set of weights over the other, performing the MCA with the three weights also indicates the robustness of the outcomes.

In order to provide only one outcome for validation the MCA is also executed with the averages of the weight.

The outcomes of the MCAs are presented in table 14.3, where the outcomes are coloured from green to red representing respectively the best and the worst alternative. All MCAs are given in appendix 12.

Table 14.3: Outcomes of the MCA analyses

	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Strategic weights	30,998	23,701	66,485	63,811	66,529
Tactical weights	34,567	24,552	73,069	67,104	55,634
Operational weights	35,010	22,367	73,931	71,552	47,153
Average	**33,525**	**23,540**	**71,162**	**67,489**	**56,439**

Results From the Multi-Criteria Analysis

From all management's layers the Elite Concept is the preferred configuration. The configuration scores very well on clarity, flexibility, GDP compliancy and cool-chain integrity, some of the criteria highly weighted by the different actors. The configuration's focus on the operational quality and ambition towards the pharmaceutical product's integrity fits best to the wishes of KLM Cargo.

The Compact Concept is from two out of the three actors' perspective the second best configuration for the terminal. It only scores much better than the Zero Concept on one criterion: the modularity of the installations. On the other hand the configurations scores only on one criterion worse than and two times equal to the Zero Concept. On the rest of the Compact Concept performs better. The slightly better performance is mainly caused by the operational efficiency implemented in the configuration.

Third scores the Automated Concept. From strategic point of view the Automated Concept comes in second and from tactical and operational perspective the configuration comes in third. It scores very well on throughput speed, GDP compliancy and cool-chain integrity, but has a poor performance on cost, flexibility and energy efficiency. Although the criteria on which the configuration scores poorly are not weighted very important, all together they outweigh the positive scores in order to be preferred.

The Modest Concept scores worst, even worse than the Zero Concept. The advantages of the configuration do not impress KLM Cargo's management. It is the least capital-intensive configuration and further scores about equal to the Zero Concept.

14.2. Validation of the Results

To validate the results from the multi-criteria analysis three tests are performed in this paragraph: the robustness analysis, the sensitivity analysis and the extreme conditions test. The validation analyses are based on altering the weights. First changing the perspective from which the weights are assigned. Then changing the weight slightly by decreasing each criterion's weight with 10% and eventually be completely excluding the criterion. The backing theory is elaborated on in paragraph 2.8.

14.2.1. Robustness Analysis

According to the theory the robustness analysis is performed by replacing the criteria's weights in the multi-criteria analysis with weights from another actor's perspective. Considering that the initial multi-criteria analysis already is performed with the weights from three actors and considering that the unanimous preferred alternative is the Elite Alternative, the outcome is considered robust.

14.2.2. Sensitivity Analysis

With altering the weights of the criteria the sensitivity of the outcome of the multi-criteria analysis is assessed. This test requires the multi-criteria analysis to be performed again, one time for each of the twelve criteria. The weight of each criterion is subsequently decreased by 10% and the absolute value of the reduction is proportionally spread over the eleven other criteria. The Sensitivity Analysis is added to this report in appendix 13.

In all cases the Elite Concept is still the preferred configuration. The outcome of the initial multi-criteria analysis seems to be insensitive to changes in the weights.

14.2.3. Extreme Conditions Test

For the Extreme Condition Test each criterion is sequentially removed from the calculation (weight becomes 0), and the absolute value of the removed weight is proportionally spread over the eleven remaining weights. The test is repeated for each of the 12 criteria. The extreme conditions tests are added to this report in appendix 14.

In 83,3% of the tests the Elite Concept is still the preferred alternative and in 16,7% of the tests it is the Compact Concept. Only excluding the most important criteria (GDP compliancy and cool-chain integrity) change the outcome. The Zero Concept, the Modest Concept and the Automated Concept are in no case the preferred alternative.

14.3. Conclusion

The outcomes of the MCA state the Elite Concept is the preferred configuration for the KLM Cargo Pharma Terminal. It embodies the company's wishes for a high-quality terminal and the willingness of the company to clear funds to make substantial investments to develop such a terminal. The results are the same for different actors involved with the terminal and are considered stable. Even in the Extreme Conditions Test the result gravitates to the Elite Concept.

Fourth Phase in the Intervention Cycle:

Intervention

15. Conceptual Design

In this last chapter, before ending the research with the conclusions and recommendations, a description of the conceptual design for the KLM Cargo Pharma Terminal is presented. The description is build-up of the description the internal organization of the preferred configuration and its required capacity and size. Now the configuration of the system is determined in chapter 14, it is possible to determine how the capacity requirements calculated in paragraph 12.2 can be translated into a sizing paragraph.

15.1. Internal Organization

From the multi-criteria analysis in chapter 14 results that the Elite Concept embodies the best the ambition of KLM Cargo. The configuration is focused on clarity of the operations, flexibility to short-notice and future changes, GDP compliancy and cool-chain integrity; the elements that are considered most important.

The internal organization of the terminal dedicated to handle pharmaceutical shipments is summarized with the following characteristics:

- It is a facility dedicated to the handling of pharmaceutical freight ACT, COL, CRT and PIL.
- It is a facility with two areas: one for handling ACT, CRT and PIL, and one for COL.
- The temperature in the area for ACT, CRT and PIL is kept in a range from 15°C until 25°C.
- The temperature in the area for COL shipments is kept in a range from 2°C until 8°C.
- Both areas are considered to house a multi-directional sorting facility accommodating export, import and transit flows (not a total distribution facility). The focus is on the transit flow.
- Both areas facilitate in:
    - connection to the landside;
    - temperature controlled docks for truck loading and unloading;
    - storage of individual shipments on Europallets in thee level high racks;
    - build-up and breakdown pits;
    - storage of ULDs in an airside PCHS;
    - connection to the airside.
- Both areas operate:
    - compact stackers for movement of Europallets;
    - cool dollies for all tarmac ULD transportation;
    - a common dedicated cool van for bulk belly freight;
    - powered roller- and ball beds for (horizontal) movement of ULDs.
- Both areas have a clinical look and finishing.

- ACT handling is facilitated in the 15°C - 25°C zone:
    - ACTs are stored in three level high racks;
    - the racks enable servicing;
    - pallet slaves are used to move the ACTs.

- Bulk belly freight is transported to the tarmac with a dedicated cool van. Shipments are collected from their temperature zone manually;

- The proposed system is flexible to future demands deviating from the forecasts:
    - storage for build-up ULDs is modular;
    - rack capacity can be added when required;
    - other temperature ranges can be added when required;
    - the system can handle unforeseen peaks;
    - the system is designed to comply with future regulations.

- The facility is focused improving Lean operations and supply chain integration by providing high throughput speed, low inventory, clear operations and a responsive system;

- The facility is interconnected with the terminal for handling general cargo so that mixed commodity truckloads or and ULDs can be accepted and broken down in the KLM Cargo Pharma Terminal;

The Elite Concept provides in an internal organization enabling responsive operations, which are very dedicated on the product. The throughput speed can be high, but mostly will be low because of the connection times between flights. The responsiveness is mainly there because of the manpower planned. Although the labour-intensiveness of a concept determines to great extend the profitability of a terminal, this terminal is preferred.

15.2. Sizing

In chapter 12.2 the required capacity of the configuration is determined. Now the internal organization of the configuration resulted from the multi-criteria analysis, the required capacity can be given a size. The calculations concern two parts of the system 1) the interfaces with the landside and the airside, and 2) the terminal. In table 15.1 and table 15.2 the required capacities are repeated.

Table 15.1: Maximum hourly movements of shipments per product group in 2040

Interface capacity	ACT, CRT, PIL	COL
Landside	25	24
Airside	33	38

Table 15.2: Maximum terminal occupation in shipments per product group in 2040

Terminal occupation	ACT	COL	CRT and PIL
Shipments	93	307	295
RKN equivalent	263	n/a	n/a
Volume (m3)	n/a	1.155	1.578
Pieces	n/a	3.165	3.370

The sizing of the terminal is dependent on the throughput speed and the point of conversion is of importance. Is the freight broken down after arrival and build-up for as soon as possible or this point leaning further to the point of departure? Because this is yet to determine in the operations the calculations are made with three operational profiles:

1. 25% of the shipments consolidated the way they arrive, 75% consolidated the way they depart;
2. 50% of the shipments consolidated the way they arrive, 50% consolidated the way they depart;
3. 75% of the shipments consolidated the way they arrive, 25% consolidated the way they depart.

The terminal calculations are based upon the throughput speed as seen in 2014. To show the effect of increasing the throughput speed some variations are shown.

15.2.1. Capacity of the Interfaces

With the decision of operating two temperature zones, two interfaces with the landside and the airside occurred. In 2014 the landside and airside movements in the 2014 peak hour for these product groups are further specified in table 15.3. With the growth factor of 2,01 for the ACT, CRT and PIL shipments and 2,82 for COL shipments the peak hour behaviour in 2040 is estimated.

Table 15.3: Landside and airside movements in a peak hour

	ACT, CRT and PIL		COL	
	2014	2040	2014	2040
Landside incoming transit truck	12	23	8	20
Landside incoming export delivery	0	0	0	0
Landside outgoing transit truck	0	0	0	1
Landside outgoing import delivery	1	2	1	3
Total landside	**13**	**25**	**9**	**24**
Airside incoming from aircraft	3	7	2	5
Airside outgoing from aircraft	13	26	11	33
Total airside	**16**	**33**	**13**	**38**

Landside Capacity

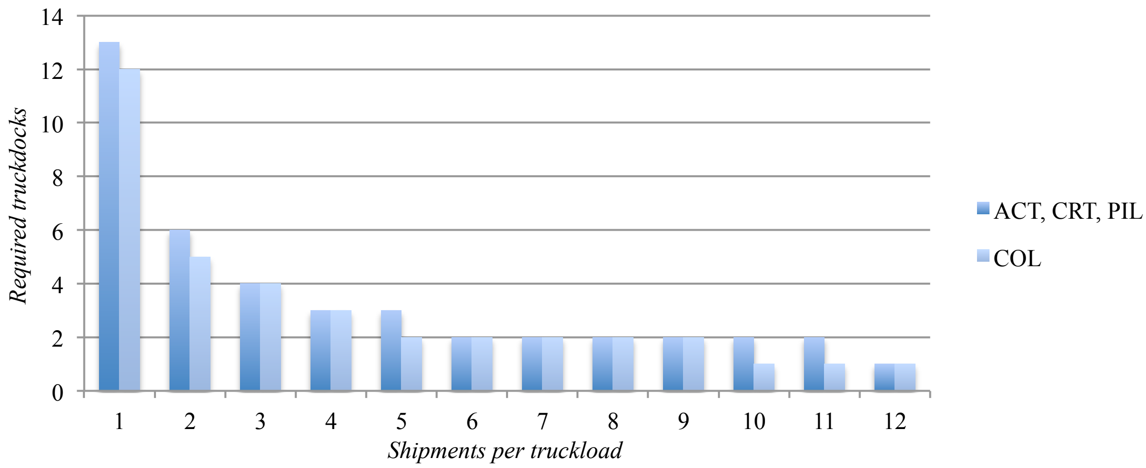
For the ACT, CRT and PIL handling at landside in total 25 shipments need to be handled, of which 23 are incoming on a transit truck, and 2 shipments go out the terminal as import delivery picked up by an agent.

For the COL handling at landside in total 24 shipments need to be handled, of which 20 are incoming on a transit truck, 1 shipment goes out on a transit truck and 3 shipments go out the terminal as import delivery picked up by the agent.

The amount of truck docks required for the handling of these landside movements depends on the unloading time of a truck and the amount of shipments handled in one truckload. The unloading and loading of a transit truck is estimated to be 0,5 hours (Ancra Systems BV, 2015).

The amount of truck docks is determined by: $\frac{(un)loading\ time \times shipments}{shipments\ per\ truckload}$. The development of the docks required is given in figure 15.1.

Figure 15.1: Landside truck docks



Trucks can be loaded with mixed freight containing general shipments and pharma shipments. The truck is unloaded at the KLM Cargo Pharma Terminal and the non-pharma shipments are delivered into the truck acceptance area of the general freight-handling terminal, while the pharma shipments are processed further into the pharma terminal.

The complete calculations are found in appendix 15.

Airside Capacity

The size for the capacity required at the airside depends whether the shipments are build onto ULDs, are ACTs or is bulk belly. From appendix 5 is the share of the shipments in the peak hour determined for ULDs, ACTs and bulk belly. In appendix 15 where the calculations all calculations are presented, the shares are depicted. With the percentages the flows are determined for the peak hour. Results are presented in table 15.4.

Table 15.4: Shipments on ULDs, ACTs and bulk belly in the peak hour

	ACT, CRT and PIL	COL
Bulk belly shipments	6	4
Shipments on ULD	24	34
ACT shipments	3	n/a
Total	**33**	**38**

To determine the equipment required for handling the demand in peak hour the following variables are used:

- Handling time: 1,5 hour (KLM minimum)
- ULD volume: 12,59 m^3, load factor 80% (KLM builds 10 m^3)
- Shipment volume CRT/PIL: 5,96 m^3
- CRT/ PIL shipments per ULD: $\frac{10\ m3}{5{,}96\ m3} = 1{,}69\ shipment$
- Shipment volume COL: 3,27 m^3
- COL shipments per ULD: $\frac{10\ m3}{3{,}27\ m3} = 3{,}08\ shipment$
- ULD per cool dolly: 1 ULD
- ACT per dolly: 2 RKN equivalent

The results of the calculations for the equipment required are given in table 15.5.

Table 15.5: Required equipment at airside to provide peak hour capacity

	ACT, CRT and PIL	COL
Cool dollies	21	16
Dollies for ACT	5	n/a

For both delivering the ULDs at the terminal and collecting ULDs at the terminal 5 access points to the airside PCHS are planned. As a typical train contains 5 dollies two trains can be handled at the same time.

15.2.2. Terminal Storage Spaces

As explained in the introduction of this chapter (15.2) the calculations to determine the terminal size is determined based upon the throughput speed in 2014 and executed for the three operational scenarios. As last the effect of decreasing the throughput time is shown. Table 15.6 shows the throughput times.

Table 15.6: Decreased the throughput times

Flow TT 2014	E-ACT	I-ACT	T-ACT	E-COL	I-COL	T-COL	E-CRT	I-CRT	T-CRT	E-PIL	I-PIL	T-PIL
- 0,0%	20	10	25	19	17	29	24	13	34	23	11	34
- 12,5%	18	9	22	17	15	25	21	11	30	20	10	30
- 25,0%	15	8	19	14	13	22	18	10	26	17	8	26
- 37,5%	13	6	16	12	11	18	15	8	21	14	7	21
- 50,0%	10	5	13	10	9	15	12	7	17	12	6	17
- 62,5%	8	4	9	7	6	11	9	5	13	9	4	13
- 75,0%	5	3	6	5	4	7	6	3	9	6	3	9

ACT Storage spaces

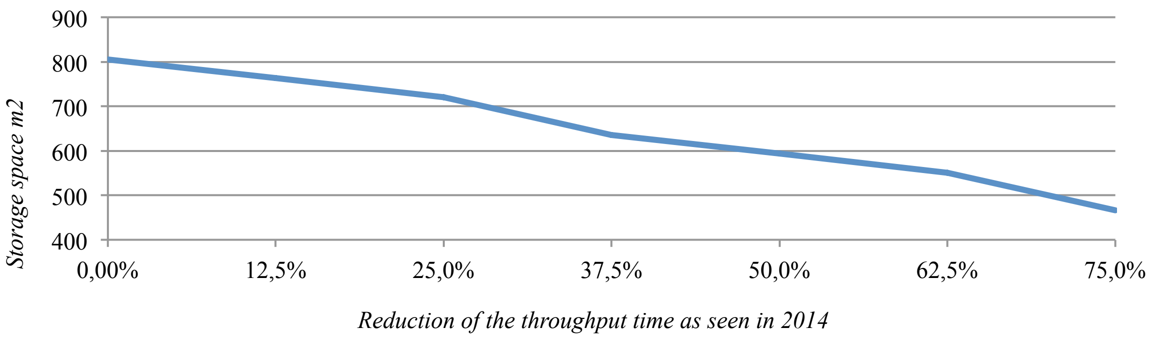
In the 15°C - 25°C area the ACT shipments are handled. With the same throughput time as in 2014 the maximum number of ACT shipments to be stored in 2040 in the terminal is 93 shipments. As ACT shipments consist of multiple containers of multiple sizes, it is necessary to bring them back in a sizeable measure, the RKN equivalent. The estimated RKN equivalents in the 2040 situation is $\frac{93}{19} \times 54 = 263$ RKN equivalent.

The footprint of an RKN container is $2{,}00 \times 1{,}53 = 3{,}06\ m^2$ (Envirotainer, 2015). For the footprint of 263 RKN equivalent at total amount of $3{,}06 \times 263 = 807{,}41\ m^2$ is required in the racks, but more importantly the positions available need to be determined. For an equivalent of 263 RKN the racks need to store somewhere between 0 RKN and 132 RAP containers or 263 RKN and 0 RAP containers. The calculation is presented in appendix 16.

Decrease of the throughput time will substantially decrease the space required for storage of the ACT containers in the terminal. No exact estimations have been made on the throughput time, only that there is the need for shorter connection time. The calculations repeated with for several throughput time situations, see also appendix 16.

The effect of the decrease in throughput time on the decrease in the required storage space is given in figure 15.2.

Figure 15.2: Effect of the throughput time on the required space for ACT



COL Storage Space

In the 2°C - 8°C area the COL shipments are handled. With the same throughput time as in 2014 the maximum number of COL shipments to be stored in 2040 in the terminal is 307 shipments. The shipments are 1.155 m^3 in volume and consist of 3.165 pieces.

Opposed to with the ACT containers the footprint of a shipment cannot be determined as simple, as the shipments are build-up on a ULD or on a Europallet. The share of each is determined from the matrix in appendix 5 and differs for each of the operational profiles.

To determine the storage space required in the terminal at the peak hour the following is given:

- ULD volume: 12,59 m^3, load factor 80% (KLM builds 10 m^3)
- ULD footprint: 7,74 m^2
- Europallet volume: 0,96 m^3, load factor 80% (same as ULDs)
- Europallet footprint: 0,96 m^2
- Shipment volume COL: 3,27 m^3
- COL shipments per ULD: $\frac{10\ m3}{3{,}27\ m3} = 3{,}08\ shipment$
- Europallets per COL shipment: $\frac{3{,}27\ m3}{0{,}77\ m3} = 4{,}26\ Europallets$

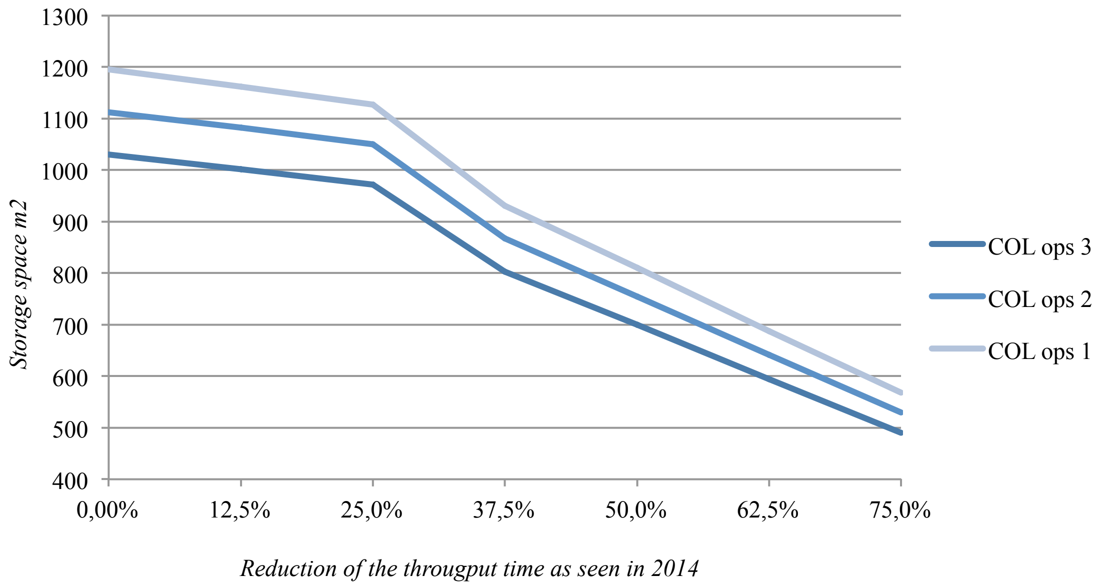
The results of the calculations in appendix 17 are presented in table 15.7.

Table 15.7: Space required for COL storage in the terminal

	Operational Profile 1	Operational Profile 2	Operational Profile 3
Shipments on Europallet	91	134	177
Shipments on ULDs	216	173	131
Europallets	447	657	867
ULDs	81	65	49
Space for Europallets (m^2)	429,12	630,72	832,32
Space for ULDs (m^2)	600,86	481,70	362,55
Total space required (m^2)	1.029,98	1.112,42	1.194,87

Decrease of the throughput time will substantially decrease the space required for storage of the COL containers in the terminal. No exact estimations have been made on the throughput time, only that there is the need for shorter connection time. The calculations are repeated with for the several throughput time situations, for the three operational scenarios. The results are shown in figure 15.3.

Figure 15.3: Effects of the throughput time and the operational profile in the required storage space for COL



CRT and PIL Storage Space

In the 15°C - 25°C area the CRT and PIL shipments are handled. With the same throughput time as in 2014 the maximum number of CRT and PIL shipments to be stored in 2040 in the terminal is 295 shipments. The shipments are 1.578 m^3 in volume and consist of 3.370 pieces.

Opposed to with the ACT containers the footprint of a shipment cannot be determined as simple, as the shipments are build-up on a ULD or on a Europallet. The share of each is determined from the matrix in appendix 5 and differs for each of the operational profiles.

To determine the storage space required in the terminal at the peak hour the following variables are used:

- ULD volume: 12,59 m^3, load factor 80% (KLM builds 10 m^3)
- ULD footprint: 7,74 m^2
- Europallet volume: 0,96 m^3, load factor 80% (same as ULDs)
- Europallet footprint: 0,96 m^2
- Shipment volume CRT and PIL: 5,96 m^3
- CRT and PIL shipments per ULD: $\frac{10\ m3}{5{,}96\ m3} = 1{,}67\ shipment$
- Europallets per COL shipment: $\frac{3{,}27\ m3}{0{,}77\ m3} = 7{,}76\ Europallets$

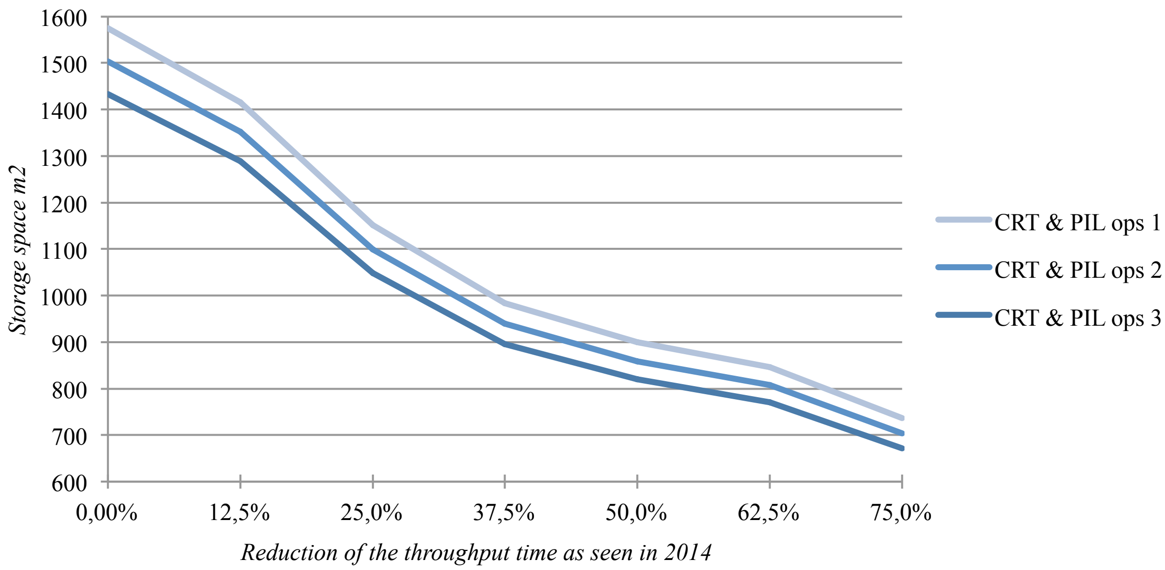
The results of the calculations in appendix 18 are presented in table 15.8.

Table 15.8: Space required for CRT and PIL storage in the terminal

	Operational Profile 1	Operational Profile 2	Operational Profile 3
Shipments on Europallet	97	123	149
Shipments on ULDs	198	172	166
Europallets	677	857	1.037
ULDs	105	92	78
Space for Europallets (m^2)	649,92	822,72	995,52
Space for ULDs (m^2)	785,47	682,90	580,47
Total space required (m^2)	1.433,33	1.505,62	1.575,99

Decrease of the throughput time will substantially decrease the space required for storage of the COL containers in the terminal. No exact estimations have been made on the throughput time, only that there is the need for shorter connection time. The calculations are repeated with for the several throughput time situations, for the three operational scenarios. The results are shown in figure 15.4

Figure 15.4: Effects of the throughput time and the operational profile in the required storage space for CRT and PIL



15.2.3. Conclusion

The description given in this chapter of the conceptual design of the system for the KLM Cargo Pharma Terminal provides overall guidance in the next development phases of the design. It will be used as a baseline for the development of more specific design specifications.

Fifth Step in the Intervention Cycle:

Evaluation

16. Conclusions and Recommendations

This chapter concludes the findings of this research and provides recommendations for the further development of the design of the KLM Cargo Pharma Terminal.

Conclusions

KLM Cargo needs to relocate their freight terminal because they need to make way for the passenger terminal expansion of AAS. In the new freight-handling situation KLM Cargo has the vision to develop a dedicated terminal solely for the handling of pharmaceutical freight. The focus on pharmaceutical freight arose after some years of poor general performance and is expected to be a valuable commodity to help maintaining the competitive position of KLM Cargo.

To make recommendations to KLM Cargo about the design of a new terminal for dedicated handling of pharmaceutical freight the research question is developed as follows:

What should the conceptual design be for the internal organization and its size
for a terminal dedicated to handle pharmaceutical shipments
for Air France – KLM – Martinair Cargo at Amsterdam Airport Schiphol?

The answers to the related central questions are:

1. *What are the requirements and assumptions for the new terminal configuration?*

The new terminal for dedicated handling of pharmaceutical freight should be able to handle the same product portfolio and flows that KLM Cargo currently handles in its AAS terminal and facilitate this in a way that is desired by the pharmaceutical industry in order to maintain its position of the preferred carrier. It also should be sustainable for future development of regulations and for growth in demand.

The pharma products offered are a closed cool-chain product (ACT) and three open cool-chain products (COL, CRT, PIL). The shipments can be palletized on mixed (M) or through (T) ULDs or be handled just in bulk as loose shipments. The temperature ranges available are 2˚C - 8˚C and 15˚C - 25˚C. The split of pharmaceutical freight is about 80% transit and 20% export and import. The facilities needed are export and import flow facilities at landside and airside, bulk buffers, ULD buffers, breakdown and build-up areas and an ACT service desk and area. Transit trucks are assumed to be 'loose' operated.

For the future a stable growth in the air cargo market, the pharmaceutical industry and the cool-chain products for KLM Cargo is expected. The pharmaceutical industry keeps focussing on supply chain integration and cool-chain improvements. It is expected that through the AAS hub in 2040, about 106.928 shipments per year are handled. From 2014 on this means a growth of 3% - 4% per year.

2. *What elements from the way the industry typically copes with similar design problems can be used and taken into account when making a conceptual design for the new terminal configuration and what systemic design for KLM Cargo can be developed from that?*

The system level design decisions that can be determined from airfreight terminal design, competitor's pharma terminals and Lean supply chain and warehousing theories is that the system should be designed as a sorting terminal processing freight with a high throughput speed, focussing on the transit flow, and staying flexible to changes in what is expected for the future. The design should provide efficient movement; effective storage; easy sortation; accurate and timely inventory control; tight security; and effective use of manpower. The most important performance indicators are holding low inventory and providing a high throughput speed.

From the competitor's pharma handling terminals can be learned that most terminals operate two temperature zones, including the acceptance areas. The dedicated facilities mainly focus on export shipments and are not designed to breakdown or build-up mixed commodity ULDs. A pharma handling terminal that facilitates import, transit and belly cargo flows has not yet been developed.

From Lean can be learned that variation should be avoided and that in order to achieve a more integrated supply chain the actors in it should be focussing mainly on their prime activity. KLM Cargo should provide a high throughput speed to keep the inventory in the chain low and focus on its transit flow. Import and export should be in the terminal as short as possible, avoiding to obtain the function of a distribution centre. Next to Lean initiatives for supply chain integration, also the operations in the terminal itself should be designed and operated in a Lean way.

3. *What are the quantitative and qualitative requirements addressing the needs and assumptions and fitting the systemic design for the new terminal configuration?*

The requirements for the internal organization of the KLM Cargo Pharma Terminal are of qualitative nature and are defined through projecting the initial requirements and assumptions for the new terminal configuration onto the system level design developed from the theory analysis and competitor assessment. The terminal is required to handle pharma shipments segregated from other commodities as fast as possible from the arrival location at the terminal to the right place for departure. For that, the system needs to sort and consolidate shipments onto the applicable containerization, to provide the possibility of a temporary buffer, and, for ACT, to perform the required service to the active containers.

The system has to achieve its primary goal while complying to GDP guidelines to maintain the product integrity and to reduce the inventory of pharmaceuticals in the supply chain. Also appropriate storage conditions and the cool-chain should be provided, by maintaining storage conditions during transportation, by getting the shipments out of the weather conditions as fast as possible and by applying just-in-time principles to the export and import flows. This all should be covered in a energy efficient system.

The qualitative requirements for the system apply to the capacity the terminal should provide. The capacity at the landside interface, the airside interface and the space required in the terminal should be sufficient to deal with the shipments expected for 2040 on a representative design peak moment.

4. *What are feasible concepts for the new terminal configuration?*

After the system level design is determined and the requirements for the internal organization of the terminal have been identified, the design can be developed further. The design needs to be further specified on eight of its functions:

1. Handling freight at the landside interface
2. Handling ULDs in the terminal
3. Handling bulk in the terminal
4. Handling ULDs at the airside interface
5. Handling bulk at the airside interface
6. Handling of ACT containers
7. Terminal refinement level
8. Flexibility to the future

The functions are applied in a Morphological Analysis and alternative ways to fulfil the functions are determined based upon airfreight terminal design theory, competitor's pharma terminals and Lean supply chain and warehousing theory. With five concepts in mind five feasible configurations of the functions for the internal organization are composed. The concepts are:

- Zero Concept - Close to the current handling with little temperature control
- Modest Concept - Basically equipped terminal for handling through manpower
- Elite Concept - High level of handling quality through an extensive cool-chain
- Compact Concept - Practical handling while maintaining product integrity
- Automated Concept - Fast, automated handling system minimizing human error

<u>The answer to the research question is:</u>

The conceptual design for KLM Cargo Pharma Terminal is based on the internal organization as proposed in the Elite Concept. Of the five proposed feasible concepts the Elite Concept is preferred. The concept provides the clearest operations, a flexible configuration to short-notice and future changes, high standards to comply with the GDP requirements and provides the most integer cool-chain. These characteristics fit best with KLM Cargo's high ambition for the handling pharmaceutical freight. The concept suggests operating the terminal in two different temperature zones.

The size of the elements in the internal organization need is shown in table 16.1.

Table 16.1: Size of the internal organization of the KLM Cargo Pharma Terminal

Quantification	15° – 25°C zone	2°C – 8 °C zone
Landside truck docks*	1 – 13	1 – 12
Airside cool dollies	21	16
Airside dollies for ACT	5	n/a
Terminal ACT storage space	807,41 m2	n/a
Terminal CRT and PIL storage space	1.433,33 m2	n/a
Terminal COL storage space	n/a	1.029,98 m2

* Dependent on the pharma shipments in one truckload.

The size of the terminal is based on the capacity expected to be required in 2040 and projected onto a representative design week in 2014. For the terminal occupancy space necessary to store the pharmaceutical shipments the calculations have been made for three operational profiles. The profiles vary on where the buffering activity in the process is located. It appears the space required is lowest if the buffering of freight activity is at the end of the process. Freight should be handled and be made ready for departure, once the freight is ready for departure it can be placed in a buffer.

Calculations are based on the throughput times as seen in 2014. Reductions in the throughput times lead to substantially smaller spaces required.

Recommendations

In the next stages of the design, the preliminary design and the detailed design, additional research is recommended to KLM Cargo into to the expected behaviour of the throughput times required. The system should be able to be responsive and provide short connections of about 1,5 hours, but that is not the throughput time to design the terminal upon. In this case the throughput time is not determined by the maximum throughput speed of the system, but as the terminal is merely a transit terminal it is about the transit time between the flights (or truck operated flights). The change of the composition of the fleet will also be of influence on this.

Another advice would be for KLM Cargo to investigate in what could be the future regulation. Currently the focus is on compliancy with GDP guidelines. Although the outcome of this research prescribes a system 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 still 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 pharmaceutical freight by setting the standard in stead of following the standard.

Whether it is for the referred future compliance, offering more distinguished services or just operating the proposed terminal configuration, the quality of the pharmaceutical product and the transportation service delivered to the customer is heavily dependent on the people operating the system. In every scenario for handling pharmaceutical freight in the future other then the solution offered with this research, I would suggest giving this team full authority and autonomy in handling the pharmaceutical freight. Next to that, it is required for official GDP compliancy to have a dedicated and trained team in place. KLM Cargo has the team, they just need to be assigned the job.

As a last recommendation I would like to propose a nuance on to the Elite Concept. The airside handling of COL, CRT and PIL UDLs is proposed to be in cool dollies. For CRT and PIL 21 should be available and for COL 16 are estimated. Cool dollies were first used by Emirates Airline in Dubai. Extreme temperatures required strong measures. In The Netherlands the weather is not as extreme and temperatures between 15°C and 25°C are quite common. To use a cool dolly to maintain a CRT or PIL shipment's temperature seems overdone, keeping in mind the shipment has already the right temperature. Next to providing the right temperature, the cool dolly provides shelter for wind, rain and sun. Considering these facts the cool function of the cool dolly is just subordinate. As came forward in the Morphological Analysis the 'Insulation Dolly' might be a more feasible alternative for airside handling of CRT and PIL shipments. The insulation dolly is not more than a large insulated and closed space to minimalize the effect of the ambient weather on the integrity of the pharmaceutical product.

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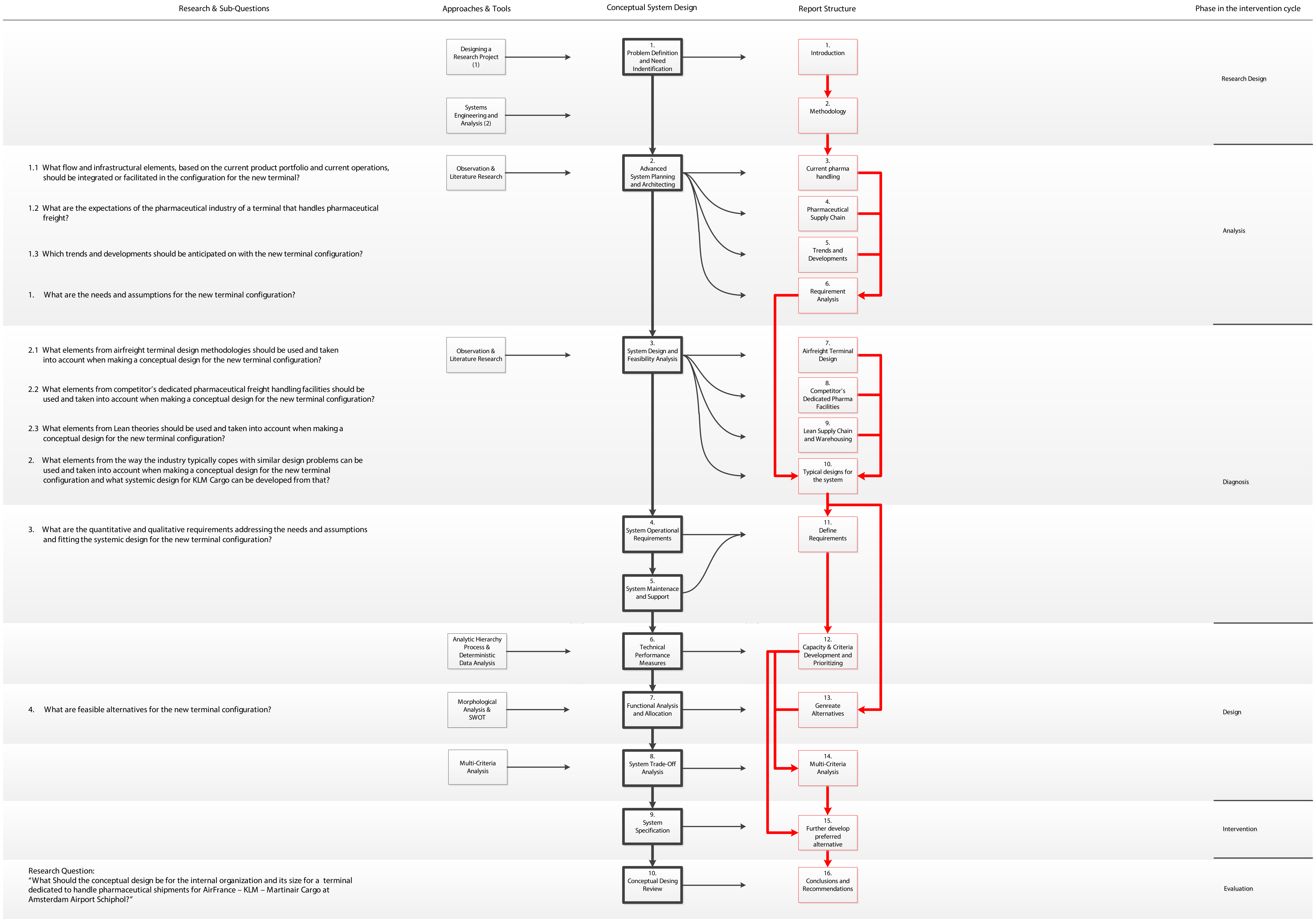
Appendix 1

Appendix 1: Research Framework



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Hugo Niemans. Delft, 25 May 2015

Appendix 2

Analytical Hierarchy Process – Saaty

The Analytical Hierarchy Process (AHP) is a decision theory basted technique to decompose a problem into comprehensible sub-problems, each of which can be analysed independently. The problem is decomposed in a goal, criteria and alternatives. In each level of the hierarchy the elements are compared pairwise. The pairwise comparison may be done with actual measurements, but can also be done with relative strength or feelings, resulting in prioritization of the elements (Saaty, 1987). Using AHP allows seemingly incomparable elements to be compared in a rational and consistent way (Mayyas & al., 2011)). An important characteristic of AHP is that great attention is given to the consistency of way the prioritization is determined.

AHP is used in various fields from multi-criteria decision making to conflict resolution (Saaty, 1987).

The steps the AHP consist of are:

1. Model the problem as a hierarchy, containing goal, criteria and alternatives. The model can have more levels than just three.

2. Within each level the elements should be compared pairwise. For this the elements are constructed into a comparison matrix [C], such as shown in Figure 1 with *n* elements:

	Element 1	Element 2	Element …	Element *n* - 1	Element *n*
Element 1	1				
Element 2		1			
Element …			1		
Element *n*-1				1	
Element *n*					1
∑ of scores	**∑ E_1**	**∑ E_2**	**∑ E…**	**∑ E $_{n-1}$**	**∑ E $_n$**

Figure 1: Pairwise comparison of n elements

3. Once the matrix is developed the elements can be compared according to the Saaty rating scale as shown in Figure 2. For instance: when element A is compared to element B, and element A is much more important than element B the score should be 5. When thereafter the elements are compared the other way around and element B is compared to element A the value should be the reciprocal of the initial score: $\frac{1}{5}$.

Intensity		Definition
1		Equal important
3	1/3	Somewhat more/ less important
5	1/5	Much more/ less imporant
7	1/7	Very much/ less more important
9	1/9	Absolutely more/ less important
2, 4, 6, 8	1/2, 1/4, 1/6, 1/8	When compromise is needed

Figure 2: Saaty rating scale

4. The scores for each element are summed up and the comparison matrix [C] is normalised. For the latter the scores in each column are divided by the column total and should now add up to 1.

5. The criteria weight {W} now is determined by taking the average value for each row.

6. After a criteria weight is determined the consistency of the comparison matrix [C] is examined.
    a. Determine a weight sums vector W_S: $\{W_S\} = [\ C\ ] \cdot \{W\}$

    b. Find the consistency vector: $\{consis\} = \{W_S\} \cdot \{\frac{1}{W}\}$

    c. Determine the eigenvalue λ: average of $\{consis\}$

    d. Determine the consistency index CI: $CI = \frac{(\lambda - n)}{(n-1)}$

    e. Determine the consistency ratio CR: $CR = \frac{CI}{RI}$

    f. Values for the random consistency index:

n	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0,00	0,00	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56

    g. If CR > 0,10 the comparison matrix [C] is considered not consistent and the judgements need to be revised.

7. If the comparison matrix [C] is consistent the criteria weights {W} can be used for further analysis of the next levels in the hierarchy.

Appendix 3

Morphological Analysis – Zwicky

For developing the alternative terminal configurations the method of Morphological Analysis (MA) is used. The definition is:

"Morphological analysis – extended by the technique of cross consistency assessment (CCA) – is a method for rigorously structuring and investigating the internal properties of inherently non-quantifiable problem complexes, which contain any number of disparate parameters. It encourages the investigation of boundary conditions and it virtually compels practitioners to examine numbers of contrasting configurations and policy solutions." (Ritchey, Fritz Zwicky, Morpologie and Policy Analysis, 1998).

General Morphological Analysis is a method developed by Fritz Zwicky in the middle of the 20th century for "structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes" (Ritchey, Stenström, & Eriksson, 2002). Although its form and conceptual range are more generalized, MA has similarities to typology construction. MA is used in a more divers spectrum of fields such as astrophysics, development of propulsive power plants and propellants, and the legal aspects of space travel and colonisation. The method is especially adequate for the development of the future scenarios because (Ritchey, 1998):

- Many factors involved are non-quantifiable;
- Problems are non-reducible;
- And the conclusions drawn need to be understandable.

In order to study all the relevant interrelations without prejudice and rash conclusions, morphologists have developed a number of powerful methods and tools to practically apply MA. Among these are (Zwicky, 1967):

- The method of Morphological Box
- The method of the Systematic Field Coverage
- The method of Negation and Construction
- The method of Extremes
- Confrontation of Perfection and Imperfection

For the development of the new KLM Cargo Pharma Terminal the method of Morphological Box is applied. It is a commonly used tool in building design, as it is able to cover all different perspectives of a design (Zeiler & Savanovic, 2009).

The method of Morphological Box

The method of Morphological Box can be seen as a morphological field containing all of the formally possible relationships involved. Zwicky refers to this as complete, systematic field coverage. From all the configurations in the morphological field the solution space can be determined (Ritchey, 1998).

The method consists of five steps, of which the first two are considered to be the analytical part of the method and the last three cover the synthesis phase (Ritchey, Stenström, & Eriksson, 2002).

1. Analysis: Formulate the problem
   The first step is that the dimensions of the problem must be identified and defined by determining the relevant issues involved: parameters P_1 to P_n (Zwicky, 1967). There are no formal constraints to mixing and comparing such different types of issues. So the character of the issues and structures that need to be compared can be, amongst others (Ritchey, 1998):

   - Shapes
   - Phenomena
   - Concepts
   - Ideas

2. Analysis: Define values for the set parameters
   After the definition of the parameters, for each parameter the range of values that the parameter possibly and relevantly can assume (Ritchey, 1998). Each value is numbered from P_{11} to P_{nj}.

3. Synthesis: Construct an internally consistent matrix
   The parameters and the values are constructed into the Morphological Box, which covers the solution space as shown in Figure 1:

Parameters	Values				
Parameter P *1*	P *1,1*	P *1,2*	P *1,…*	P *1, i-1*	P *1,i*
Parameter P *2*	P *2,1*	P *2,2*	P *2, …*	P *2, j-1*	P *2,j*
Parameter P *…*	P *…, 1*	P *…, 2*	P *…, …*	P *…, k-1*	P *…, k*
Parameter P *n-1*	P *n-1,1*	P *n-1,2*	P *n-1, …*	P *n-1, l-1*	P *n-1 ,l*
Parameter P *n*	P *n,1*	P *n,2*	P *n, ….*	P *n, m-1*	P *n, m*

Figure 1: Example of a Morphological Box

Solution spaces easily get very complex: a solution space with four parameters with each four values already presents more than 200 configurations. To reduce the number of configurations, the classical MA is extended. The extension was introduced in the '80s and was called Field Anatomy Relaxation (FAR) and Internal Consistency Analysis. Ritchey (1998) named the technique Cross-Consistency Analysis (CCA).

CCA is based upon the insight that there may be configurations containing pairs of values that are incompatible or contradictory. For this a judgement is made whether a pair of values can coexist and represents a consistent relationship. For this a cross-consistency matrix is constructed and the parameters with all their values are set against every other condition (Ritchey, 1998).

There are three types of inconsistencies:

- Logical contradictions;
- Empirical inconsistencies;
- Normative constraints.

Be careful with the normative judgement, so: first logical and empirical judgments, later normative, to distinct the possible from the desirable (Ritchey, 2013).

The solution space is reduced with the inconsistent configurations and should be manageable after CCA (Ritchey, 2013).

4. Synthesis: Evaluate the solutions
   Examining all possible configurations in a matrix would take a good deal of time and effort, that's why by hand some realistic configurations can be chosen for further evaluation (Ritchey, 1998). For the KLM Cargo Pharma terminal a configuration close to the current situation, a very basic configuration, a very ambitious configuration, a compact configuration, and an automated configuration.

5. Synthesis: Determine the best solutions
   The multi-criteria analysis (MCA) shows the relative performance of the alternatives and can determine the best of the five chosen solutions (De Haan, 2009).

According to Zwicky (1967) the advantages of MA are that:

- MA is a totality research that strives to derive all solutions in an unbiased way;
- MA helps to discover relationships and configurations that may be overlooked with other methods;
- MA encourages identifying and investigating the boundary conditions.

The method including the assessments made in the cross-consistency matrix represents, according to Ritchey (1998), a clear audit trail, which makes the judgemental process relatively traceable and reproducible. MA is based on the fundamental scientific method of alternating between analysis and synthesis. For this reason it can be trusted as useful, non-quantified method for investigating problem complexes which cannot be treated by formal mathematical methods, causal modelling and simulation.

Ritchey (1998) emphasises that the quality of the output of an analysis-synthesis cycle strongly depends on the quality of its input. Compared with general analysis-synthesis MA has some advantages on this issue. MA only works if parameters are properly defined and value ranges represent complete ranges and with this has a garbage detection system built-in.

Appendix 4

Data Analysis Pharma Products through SPL hub 01-01-2014 tm 31-12-2014

Source: Data Warehouse: Cargo - KL - CHAIN OPS

Product		Shipments	%	Containers	%	RKN equivalent *1 RAP = 2 RKN*			Average throughput time (hour)	Average nr of pieces per shipment		RKN6 Electrical		RKN2 Dry-ice		RKN0 C-SAFE		RAP8 Electrical		RAP2 Dry-ice	
ACT	**S52, C52**	**2.966**	*6%*	**6.938**	*100%*	**8.779**	*1,27*		**23**	**2,34**		**3.807**	*54,9%*	**870**	*12,5%*	**420**	*6,1%*	**478**	*6,9%*	**1.363**	*19,6%*
E-ACT	**S52, C52**	372	*13%*	1.281	*18%*	1.448	*1,13*		20	3,44		1.109	*86,6%*	1	*0,1%*	4	*0,3%*	136	*10,6%*	31	*2,4%*
I-ACT	**S52, C52**	227	*8%*	452	*7%*	614	*1,36*		10	1,99		191	*42,3%*	42	*9,3%*	57	*12,6%*	38	*8,4%*	124	*27,4%*
T-ACT	**S52, C52**	2.367	*80%*	5.205	*75%*	6.717	*1,29*		25	2,20		2.507	*48,2%*	827	*15,9%*	359	*6,9%*	304	*5,8%*	1.208	*23,2%*

		Shipments		Weight (kg)		Volume (m3)			Average throughput time (hour)	Average nr of pieces per shipment		Average volume per shipment	Nr of shipments < 8 h		Nr of shipments > 8 h		Average throughput time < 8 h (uur)	Average throughput time > 8 h (uur)
COL	**S51, C51**	**16.507**	*37,9%*	**7.238.504**	*28%*	**45.279**	*29%*		**22**	**7,39**		**3,27**	**1.811**	*11,0%*	**14.696**	*89,0%*	**6**	**31**
CRT	**S53, C53**	**5.017**	*11,5%*	**4.988.597**	*19%*	**33.159**	*21%*		**24**	**7,35**		**6,03**	**489**	*9,7%*	**4.528**	*90,3%*	**6**	**34**
PIL	**S50, C50**	**22.049**	*50,6%*	**13.721.304**	*53%*	**78.302**	*50%*		**23**	**7,64**		**4,24**	**3.215**	*14,6%*	**18.834**	*85,4%*	**6**	**33**
Export	**COL, CRT, PIL**	**3.720**	*8,5%*	**1.461.570**	*6%*	**8.316**	*5%*		**22**	**3,95**		**2,82**	**273**	*7,3%*	**3447**	*92,7%*	**7**	**26**
Import	**COL, CRT, PIL**	**5.169**	*11,9%*	**3.362.109**	*13%*	**8.317**	*5%*		**14**	**7,15**		**5,11**	**2.346**	*45,4%*	**2.823**	*54,6%*	**5**	**18**
Transit	**COL, CRT, PIL**	**34.684**	*79,6%*	**21.124.726**	*81%*	**140.108**	*89%*		**32**	**11,28**		**5,60**	**2.896**	*8,3%*	**31.788**	*91,7%*	**7**	**34**
E-COL	**S51, C51**	1.233	*33,1%*	387.172		1.970			19	4,71		1,93	122	*9,9%*	1111	*90,1%*	6	26
E-CRT	**S53, C53**	335	*9,0%*	344.478		1.286			24	3,69		3,82	13	*3,9%*	322	*96,1%*	6	25
E-PIL	**S50, C50**	2.152	*57,8%*	729.920		5.060			23	3,46		2,72	138	*6,4%*	2.014	*93,6%*	8	25
I-COL	**S51, C51**	1.154	*22,3%*	831.860		4.366			17	7,05		4,15	443	*38,4%*	711	*61,6%*	6	24
I-CRT	**S53, C53**	407	*7,9%*	363.199		2.523			13	8,68		6,47	183	*45,0%*	224	*55,0%*	5	19
I-PIL	**S50, C50**	3.608	*69,8%*	2.167.050		1.428			11	5,73		4,72	1.720	*47,7%*	1888	*52,3%*	5	16
T-COL	**S51, C51**	14.120	*40,7%*	6.019.472		38.944			29	10,40		3,75	1.246	*8,8%*	12.874	*91,2%*	7	32
T-CRT	**S53, C53**	4.275	*12,3%*	4.280.920		29.351			34	9,68		7,79	293	*6,9%*	3.982	*93,1%*	7	36
T-PIL	**S50, C50**	16.289	*47,0%*	10.824.335		71.813			34	13,75		5,27	1.357	*8,3%*	14.932	*91,7%*	7	36
Total	**COL, CRT, PIL**	**43.573**	*94%*	**25.948.405**		**156.741**												
Total	**Pharma**	**46.539**	*100%*															

Appendix 5

Data Analysis Pharma Flows through SPL hub 01-01-2014 tm 31-12-2014

source: Data Warehouse: Cargo - KL - CHAIN OPS

ACT

Departure	Arrival at warehouse								Total
	Export	Truck ACT	AC ACT	Truck T	Truck M	AC-ULD T	AC-ULD M	AC-Belly	
Import	0	18	209	0	0	0	0	0	**227**
Truck ACT	14	3	553	0	0	0	0	0	**570**
AC ACT	358	1.471	340	0	0	0	0	0	**2.169**
Truck T	0	0	0	0	0	0	0	0	**0**
Truck M	0	0	0	0	0	0	0	0	**0**
AC-ULD T	0	0	0	0	0	0	0	0	**0**
AC-ULD M	0	0	0	0	0	0	0	0	**0**
AC-Belly	0	0	0	0	0	0	0	0	**0**
Total	**372**	**1.492**	**1.102**	**0**	**0**	**0**	**0**	**0**	**2.966**

COL

Departure	Arrival at warehouse								Total
	Export	Truck ACT	AC ACT	Truck T	Truck M	AC-ULD T	AC-ULD M	AC-Belly	
Import	0	0	0	0	30		946	178	**1.154**
Truck ACT	0	0	0	0	0	0	0	0	**0**
AC ACT	0	0	0	0	0	0	0	0	**0**
Truck T	0	0	0	1	0	79	0	0	**80**
Truck M	6	0	0	0	27	0	459	16	**508**
AC-ULD T	0	0	0	1.322	0	133	0	0	**1.455**
AC-ULD M	1.137	0	0	0	7.933	0	1.227	2.069	**12.366**
AC-Belly	90	0	0	0	36	0	532	286	**944**
Total	**1.233**	**0**	**0**	**1.323**	**8.026**	**212**	**3.164**	**2.549**	**16.507**

CRT

Departure	Arrival at warehouse								Total
	Export	Truck ACT	AC ACT	Truck T	Truck M	AC-ULD T	AC-ULD M	AC-Belly	
Import	0	0	0	0	17	0	361	29	**407**
Truck ACT	0	0	0	0	0	0	0	0	**0**
AC ACT	0	0	0	0	0	0	0	0	**0**
Truck T	0	0	0	0	0	211	0	0	**211**
Truck M	1	0	0	0	3	0	242	9	**255**
AC-ULD T	0	0	0	672	0	77	0	0	**749**
AC-ULD M	332	0	0	0	2.403	0	400	173	**3.308**
AC-Belly	2	0	0	0	2	0	54	29	**87**
Total	**335**	**0**	**0**	**672**	**2.425**	**288**	**1.057**	**240**	**5.017**

PIL

Departure	Arrival at warehouse								Total
	Export	Truck ACT	AC ACT	Truck T	Truck M	AC-ULD T	AC-ULD M	AC-Belly	
Import	0	0	0	0	44	0	2.995	569	**3.608**
Truck ACT	0	0	0	0	0	0	0	0	**0**
AC ACT	0	0	0	0	0	0	0	0	**0**
Truck T	0	0	0	2	0	210	0	0	**212**
Truck M	0	0	0	0	43	0	839	10	**892**
AC-ULD T	0	0	0	2.471	0	231	0	0	**2.702**
AC-ULD M	2.078	0	0	0	8.350	0	1.431	1.495	**13.354**
AC-Belly	74	0	0	0	26	0	862	319	**1.281**
Total	**2.152**	**0**	**0**	**2.473**	**8.463**	**441**	**6.127**	**2.393**	**22.049**

Total COL, CRT PIL

Departure	Arrival at warehouse								Total
	Export	Truck ACT	AC ACT	Truck T	Truck M	AC-ULD T	AC-ULD M	AC-Belly	
Import					91		4.302	776	**5.169**
Truck ACT									
AC ACT									
Truck T				3		500			**503**
Truck M	7				73		1.540	35	**1.655**
AC-ULD T				4.465		441			**4.906**
AC-ULD M	3.547				18.686		3.058	3.737	**29.028**
AC-Belly	166				64		1.448	634	**2.312**
Total	**3.720**	**0**	**0**	**4.468**	**18.914**	**941**	**10.348**	**5.182**	**43.573**

Freight buildings and pharma facilities

Freight building 1

Freight building 1 can generally be considered as the freight building where the specialties are handled. Important elements of the freight building are:

- Safe and secure area
- Animal hotel
- Express and mail services
- Area for belly carts for loose freight (with cool room 2°C - 8°C for COL hipments)
- Active container desk
- Cool room 2°C - 8°C for COL ULDs
- Temperature-controlled room 15°C - 25°C for CRT ULD's

With the handling of pharmaceutical shipments the active container desk, the cool and temperature room and the cooling facilities for the loose pharmaceutical freight handling are involved.

1. Active container desk

The active container desk is located on a dedicated part of the shop floor in freight building 1. It is part of the CCC and is the department handling and servicing the active containers.

The facilities used by the active container desk are:

A: Office 27 m^2

The employees of the active container desk have their own office next to the handling and service area for the active container. From this office all administrative duties involved with the active containers are performed.

B: Shop floor 660 m^2 with 59 power outlets

The shop floor dedicated for handling and servicing the active container stores maximally store 21 dollies (21 RAP containers or 42 RKN containers) at a time. 1 RAP = 2 RKN = 1 dolly. For charging the electrical containers 59 power outlets have been installed. At the long end 27 power outlets can be used for 12 dollies (12 RAP or 24 RKN). At the wall side it is possible to park 9 dollies, where also 27 power outlets are available for 9 dollies (9 RAP or 18 RKN).

C: ULD service area 22 m^2

The active container desk is equipped with a service area in case of irregularities. This area contains of a special roller bed and extra power outlets to enable repairing a container.

D: Supply storage

As a standard procedure the containers are serviced, which could include replacing batteries, adding dry-ice, or labelling the container. The supplies for servicing are placed right outside the office, next to where the containers are stored and serviced.

E: Weighting facility

The active container desk is equipped with a large scale to weight the container upon departure. It is not used often as it functions merely as a final check.

2. Cool room 2°C - 8°C for COL ULDs

For properly handling temperature-sensitive freight, such as pharmaceuticals, facilities to store entire ULDs are available. The temperature in the cool room is set to be 2°C - 8°C in order to store entire ULDs with COL shipments. This cool room is called KC01. KC01 can be accessed via the CRT room with the CRT room's ETV to place the ULD in one of the 44 positions for ULDs of at least 240 cm in height.

3. Temperature controlled room 15°C - 25°C for CRT ULDs

To store entire ULDs in an other temperature range than in KC01, a temperature controlled room set to be 15°C - 25°C is added in 2013. The temperature-controlled room is called the CRT room. It is placed in front of KC01 and can be accesses from the airside side or from inside the freight building. It has an ETV inside to place the ULD in one of the 27 positions of at least 240 cm in height.

4. Cool room 2°C - 8°C for COL shipments

The shipments transported in the belly of a passenger aircraft are collected in freight building 1. For COL shipments some cooling facilities are in place. Freight building 1 has three cool rooms of 26 m^2 and with a temperature set between 2°C and 8°C. The cool rooms are called KC3.1, KC3.2 and KC3.3. Each cool room can store 4 belly carts with on each belly cart 2 shipments. In total the cool facilities in freight building 1 store 24 loose shipments.

Freight building 2

Freight building 2 is the freight building where the import and outgoing truck trans flow is handled. In general the import flow originates at airside from an aircraft and ends in a truck (import or transit) at landside. The flow interacts with the export flow in freight building 3 and the flow of specialties in freight building 1.

Important elements of freight building 2 are:

- PCHS pallet intake
- Breakdown area
- Build-up area
- Buffer for import shipments
- Buffer for transit shipments
- Cool buffer 2°C - 8°C for import/ transit COL shipments
- PCHS pallet output via ES into truck
- Documentation department

Though pharmaceutical shipment flow through all of these elements, for handling them especially the cool buffer 2°C - 8°C for shipments is of importance.

1. Cool room 2°C - 8°C for import/ transit COL shipments

For properly handling temperature-sensitive freight such as pharmaceuticals facilities to store the shipments are available. The temperature in the cool room is set to be 2°C - 8°C in order to store COL shipments. This cool room is called KC02. KC02 has 115 full-height (1 meter) and 4 half-height (0,5 meter) storage positions for Europallets. Operations of freight building 3 uses KC02 for storing transit shipments as well.

Freight building 3

Freight building 3 is the freight building where the export flow is handled. In general the export flow originates at landside from a truck (export or transit) and ends in an aircraft at airside. The flow interacts with the import flow in freight building 2 and the flow of specialties in freight building 1.

Important elements of freight building 3 are:

- Pallet intake via MTD into PCHS
- Loose export acceptance
- Short-term buffer for export/ transit shipments
- Long-term buffer (storage racks) for export/ transit COL shipments
- Cool buffer 2°C - 8°C for export shipments
- Pallet build-up area
- Pallet breakdown area
- PCHS pallet output
- Transportation department

Though pharmaceutical shipment flow through all of these elements, for handling them especially the cool buffer 2°C - 8°C for export shipments is of importance.

1. Cool room 2°C - 8°C for export COL shipments

For properly handling temperature-sensitive freight such as pharmaceuticals facilities to store the shipments are available. The temperature in the cool room is set to be 2°C - 8°C in order to store COL shipments. This cool room is called KC04. KC04 has 40 full-height storage positions for Europallets.

Appendix 6

Appendix 7

Analytical Hierarchy Process for determining the weights of the criteria for the MCA: **Strategic Management**

Determine weights for criteria

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium L Supply chain integration	
Criterium 1	Implementation time	1	1/5	1/7	1/7	1/9	1	1/9	1/7	1/3	1/9	1/9	1/9	
Criterium 2	Implementation cost	5	1	1/3	1/3	1/9	1/3	1	1/7	1/3	1/9	1/9	1/9	
Criterium 3	Lifetime costs	7	3	1	3	1/7	1/3	1	1/5	1/3	1/7	1/7	1/7	
Criterium 4	Operational costs	7	3	1/3	1	1/5	1/3	3	3	3	1/5	1/3	1/3	
Criterium 5	Throughput speed	9	9	7	5	1	3	5	5	1/3	1	3	3	
Criterium 6	Modularity installations	1	3	3	3	1/3	1	1/3	1/3	1/3	1/5	1/5	1/5	
Criterium 7	Clarity of installations	9	1	1	1/3	1/5	3	1	1	1	1	1	1	
Criterium 8	Flexibility	7	7	5	1/3	1/5	3	1	1	1/3	1/5	1/5	3	
Criterium 9	Energy efficiency	3	3	3	1/3	3	3	1	3	1	1/5	1/5	1/3	
Criterium 10	GDP compliancy	9	9	7	5	1	5	1	5	5	1	1	3	
Criterium 11	Cool chain integrity	9	9	7	3	1/3	5	1	5	5	1	1	5	
Criterium 12	Supply chain integration	9	9	7	3	1/3	5	1	1/3	3	1/3	1/5	1	
SUM		**76**	**57 1/5**	**41 4/5**	**24 1/2**	**7**	**30**	**16 4/9**	**24 1/7**	**20**	**5 1/2**	**7 1/2**	**17 1/4**	

Normalized values:

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium O Supply chain integration	**Weight W**
Criterium 1	Implementation time	0,013	0,003	0,003	0,006	0,016	0,033	0,007	0,006	0,017	0,020	0,015	0,006	**0,0122**
Criterium 2	Implementation cost	0,066	0,017	0,008	0,014	0,016	0,011	0,061	0,006	0,017	0,020	0,015	0,006	**0,0214**
Criterium 3	Lifetime costs	0,092	0,052	0,024	0,123	0,021	0,011	0,061	0,008	0,017	0,026	0,019	0,008	**0,0385**
Criterium 4	Operational costs	0,092	0,052	0,008	0,041	0,029	0,011	0,182	0,124	0,150	0,036	0,044	0,019	**0,0658**
Criterium 5	Throughput speed	0,118	0,157	0,167	0,204	0,144	0,100	0,304	0,207	0,017	0,182	0,400	0,174	**0,1812**
Criterium 6	Modularity installations	0,013	0,052	0,072	0,123	0,048	0,033	0,020	0,014	0,017	0,036	0,027	0,012	**0,0389**
Criterium 7	Clarity of installations	0,118	0,017	0,024	0,014	0,029	0,100	0,061	0,041	0,050	0,182	0,133	0,058	**0,0690**
Criterium 8	Flexibility	0,092	0,122	0,120	0,014	0,029	0,100	0,061	0,041	0,017	0,036	0,027	0,174	**0,0694**
Criterium 9	Energy efficiency	0,039	0,052	0,072	0,014	0,431	0,100	0,061	0,124	0,050	0,036	0,027	0,019	**0,0855**
Criterium 10	GDP compliancy	0,118	0,157	0,167	0,204	0,144	0,167	0,061	0,207	0,250	0,182	0,133	0,174	**0,1637**
Criterium 11	Cool chain integrity	0,118	0,157	0,167	0,123	0,048	0,167	0,061	0,207	0,250	0,182	0,133	0,290	**0,1586**
Criterium 12	Supply chain integration	0,118	0,157	0,167	0,123	0,048	0,167	0,061	0,014	0,150	0,061	0,027	0,058	**0,0959**
SUM		**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	

Consistency check

Determine weight sums vector {W}

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium O Supply chain integration	Weight sums vector Ws
Criterium 1	Implementation time	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 2	Implementation cost	1/9	0	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 3	Lifetime costs	1/4	1/9	0	1/9	0	0	0	0	0	0	0	0	**0**
Criterium 4	Operational costs	1/2	1/5	0	0	0	0	1/5	1/5	1/5	0	0	0	**1/8**
Criterium 5	Throughput speed	1 5/8	1 5/8	1 1/4	1	1/6	1/2	1	1	0	1/6	1/2	1/2	**7/9**
Criterium 6	Modularity installations	0	1/9	1/9	1/9	0	0	0	0	0	0	0	0	**0**
Criterium 7	Clarity of installations	5/8	0	0	0	0	1/5	0	0	0	0	0	0	**1/8**
Criterium 8	Flexibility	1/2	1/2	1/3	0	0	1/5	0	0	0	0	0	1/5	**1/6**
Criterium 9	Energy efficiency	1/4	1/4	1/4	0	1/4	1/4	0	1/4	0	0	0	0	**1/7**
Criterium 10	GDP compliancy	1 1/2	1 1/2	1 1/7	5/6	1/6	5/6	1/6	5/6	5/6	1/6	1/6	1/2	**5/7**
Criterium 11	Cool chain integrity	1 3/7	1 3/7	1 1/9	1/2	0	4/5	1/6	4/5	4/5	1/6	1/6	4/5	**2/3**
Criterium 12	Supply chain integration	6/7	6/7	2/3	2/7	0	1/2	0	0	2/7	0	0	0	**1/3**
SUM		**7 2/3**	**6 2/3**	**5**	**2 7/8**	**3/4**	**3 2/5**	**1 5/6**	**3 1/6**	**2 3/8**	**2/3**	**1**	**2 1/4**	

Determine consistency vector and eigenvalue

		Weight sums vector Ws	1/ Weight 1/W	Consistency vector Ws x 1/W
Criterium 1	Implementation time	0,01	280,39	3,41
Criterium 2	Implementation cost	0,02	62,86	1,35
Criterium 3	Lifetime costs	0,04	18,97	0,73
Criterium 4	Operational costs	0,07	8,39	0,55
Criterium 5	Throughput speed	0,18	1,29	0,23
Criterium 6	Modularity installations	0,04	23,87	0,93
Criterium 7	Clarity of installations	0,07	8,47	0,58
Criterium 8	Flexibility	0,07	6,12	0,42
Criterium 9	Energy efficiency	0,09	6,67	0,57
Criterium 10	GDP compliancy	0,16	1,41	0,23
Criterium 11	Cool chain integrity	0,16	1,47	0,23
Criterium 12	Supply chain integration	0,10	3,19	0,31
Eigenvalue λ (average consistency vector)				**0,80**

Scoring principles		
1/9		Absolutely less important
1/7		Very less more important
1/5		Much less imporant
1/3		Somewhat less important
1		Equally important
3		Somewhat more important
5		Much more imporant
7		Very much more important
9		Absolutely more important
2,4,6,8	1/2, 1/4, 1/6, 1/8	When compromise is needed

Strategical Management	
1. (3.)*	**Throughput speed**
2. (1.)*	**GDP compliancy**
3. (2.)*	**Cool chain integrity**
4.	**Supply chain integration**
5.	**Energy efficiency**
6.	**Flexibility**
7.	**Clarity of installations**
8.	**Operational costs**
9.	**Modularity installations**
10.	**Lifetime costs**
11.	**Implementation cost**
12.	**Implementation time**
*** Gut feeling RdW**	

Determine consistency index

Consistency index CI	-0,80

Determine consistency ratio

Consistency ratio CR	-0,538

Aantal n	1	2	3	4	5	6	7	8	9	10	11	12	13
Random index RCI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56

Consistency

Consistency ratio CR is < 0,10 for the matrix to be consistent	**This matrix is**	**CONSISTENT, excersise finished**

Analytical Hierarchy Process for determining the weights of the criteria for the MCA: **Tactical Management**

Determine weights for criteria

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium L Supply chain integration	
Criterium 1	Implementation time	1	1/3	1/7	1/3	1/7	1/7	1/9	1/7	1/3	1/7	1/3	1/5	
Criterium 2	Implementation cost	3	1	1/5	1/3	1/5	1/5	1/7	1/7	1/3	1/3	1/3	1/5	
Criterium 3	Lifetime costs	7	5	1	1/3	1/5	1/3	1/3	1/5	3	1/5	1/3	1/3	
Criterium 4	Operational costs	3	3	3	1	1/5	1/3	1	1/3	3	1/3	1/3	1	
Criterium 5	Throughput speed	7	5	5	5	1	7	1	1/5	5	1/5	1/7	1/5	
Criterium 6	Modularity installations	7	5	3	3	1/7	1	1/5	1/5	5	1/3	1/5	1/3	
Criterium 7	Clarity of installations	9	7	3	1	1	5	1	3	1/7	1	1	1	
Criterium 8	Flexibility	7	7	5	3	5	5	1/3	1	3	1	1/3	1	
Criterium 9	Energy efficiency	3	3	1/3	1/3	1/5	1/5	7	1/3	1	1/5	1/5	1	
Criterium 10	GDP compliancy	7	3	5	3	5	3	1	1	5	1	1/5	5	
Criterium 11	Cool chain integrity	3	3	3	3	7	5	1	3	5	5	1	7	
Criterium 12	Supply chain integration	5	5	3	1	5	3	1	1	1	1/5	1/7	1	
SUM		**62**	**47 1/3**	**31 2/3**	**21 1/3**	**25**	**30 1/5**	**14 1/8**	**10 5/9**	**31 4/5**	**10**	**4 5/9**	**18 1/4**	

Normalized values:

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium O Supply chain integration	Weight W
Criterium 1	Implementation time	0,016	0,007	0,005	0,016	0,006	0,005	0,008	0,014	0,010	0,014	0,073	0,011	**0,0153**
Criterium 2	Implementation cost	0,048	0,021	0,006	0,016	0,008	0,007	0,010	0,014	0,010	0,034	0,073	0,011	**0,0215**
Criterium 3	Lifetime costs	0,113	0,106	0,032	0,016	0,008	0,011	0,024	0,019	0,094	0,020	0,073	0,018	**0,0444**
Criterium 4	Operational costs	0,048	0,063	0,095	0,047	0,008	0,011	0,071	0,032	0,094	0,034	0,073	0,055	**0,0525**
Criterium 5	Throughput speed	0,113	0,106	0,158	0,234	0,040	0,232	0,071	0,019	0,157	0,020	0,031	0,011	**0,0993**
Criterium 6	Modularity installations	0,113	0,106	0,095	0,141	0,006	0,033	0,014	0,019	0,157	0,034	0,044	0,018	**0,0649**
Criterium 7	Clarity of installations	0,145	0,148	0,095	0,047	0,040	0,166	0,071	0,284	0,004	0,101	0,220	0,055	**0,1145**
Criterium 8	Flexibility	0,113	0,148	0,158	0,141	0,199	0,166	0,024	0,095	0,094	0,101	0,073	0,055	**0,1138**
Criterium 9	Energy efficiency	0,048	0,063	0,011	0,016	0,008	0,007	0,496	0,032	0,031	0,020	0,044	0,055	**0,0692**
Criterium 10	GDP compliancy	0,113	0,063	0,158	0,141	0,199	0,099	0,071	0,095	0,157	0,101	0,044	0,274	**0,1262**
Criterium 11	Cool chain integrity	0,048	0,063	0,095	0,141	0,279	0,166	0,071	0,284	0,157	0,503	0,220	0,383	**0,2008**
Criterium 12	Supply chain integration	0,081	0,106	0,095	0,047	0,199	0,099	0,071	0,095	0,031	0,020	0,031	0,055	**0,0775**
SUM		**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	

Consistency check

Determine weight sums vector {W}

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium O Supply chain integration	Weight sums vector Ws
Criterium 1	Implementation time	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 2	Implementation cost	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 3	Lifetime costs	1/3	2/9	0	0	0	0	0	0	1/8	0	0	0	**0**
Criterium 4	Operational costs	1/6	1/6	1/6	0	0	0	0	0	1/6	0	0	0	**0**
Criterium 5	Throughput speed	2/3	1/2	1/2	1/2	0	2/3	0	0	1/2	0	0	0	**1/3**
Criterium 6	Modularity installations	4/9	1/3	1/5	1/5	0	0	0	0	1/3	0	0	0	**1/7**
Criterium 7	Clarity of installations	1	4/5	1/3	1/9	1/9	4/7	1/9	1/3	0	1/9	1/9	1/9	**1/3**
Criterium 8	Flexibility	4/5	4/5	4/7	1/3	4/7	4/7	0	1/9	1/3	1/9	0	1/9	**3/8**
Criterium 9	Energy efficiency	1/5	1/5	0	0	0	0	1/2	0	0	0	0	0	**0**
Criterium 10	GDP compliancy	8/9	3/8	5/8	3/8	5/8	3/8	1/8	1/8	5/8	1/8	0	5/8	**2/5**
Criterium 11	Cool chain integrity	3/5	3/5	3/5	3/5	1 2/5	1	1/5	3/5	1	1	1/5	1 2/5	**7/9**
Criterium 12	Supply chain integration	2/5	2/5	1/4	0	2/5	1/4	0	0	0	0	0	0	**1/6**
SUM		**5 3/5**	**4 2/5**	**3 1/3**	**2 1/3**	**3 1/4**	**3 4/7**	**1 2/9**	**1 1/3**	**3 1/4**	**1 1/2**	**1/2**	**2 1/2**	

Determine consistency vector and eigenvalue

		Weight sums vector Ws	1/ Weight 1/W	Consistency vector Ws x 1/W
Criterium 1	Implementation time	0,02	232,81	3,57
Criterium 2	Implementation cost	0,02	86,99	1,87
Criterium 3	Lifetime costs	0,04	14,78	0,66
Criterium 4	Operational costs	0,05	13,81	0,73
Criterium 5	Throughput speed	0,10	3,29	0,33
Criterium 6	Modularity installations	0,06	7,28	0,47
Criterium 7	Clarity of installations	0,11	3,16	0,36
Criterium 8	Flexibility	0,11	2,73	0,31
Criterium 9	Energy efficiency	0,07	10,33	0,71
Criterium 10	GDP compliancy	0,13	2,43	0,31
Criterium 11	Cool chain integrity	0,20	1,30	0,26
Criterium 12	Supply chain integration	0,08	5,88	0,46
Eigenvalue λ (average consistency vector)				**0,84**

Scoring principles		
1/9		Absolutely less important
1/7		Very less more important
1/5		Much less imporant
1/3		Somewhat less important
1		Equally important
3		Somewhat more important
5		Much more imporant
7		Very much more important
9		Absolutely more important
2,4,6,8	1/2, 1/4, 1/6, 1/8	When compromise is needed

Tactical Management	
1.	**Cool chain integrity**
2.	**GDP compliancy**
3.	**Clarity of installations**
4.	**Flexibility**
5.	**Throughput speed**
6.	**Supply chain integration**
7.	**Energy efficiency**
8.	**Modularity installations**
9.	**Operational costs**
10.	**Lifetime costs**
11.	**Implementation cost**
12.	**Implementation time**

Determine consistency index

Consistency index CI	-0,84

Determine consistency ratio

Consistency ratio CR	-0,565

Aantal n	1	2	3	4	5	6	7	8	9	10	11	12	13
Random index RCI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56

Consistency

Consistency ratio CR is < 0,10 for the matrix to be consistent	**This matrix is**	**CONSISTENT, excersise finished**

Analytical Hierarchy Process for determining the weights of the criteria for the MCA: **Operational Management**

Determine weights for criteria

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium L Supply chain integration	
Criterium 1	Implementation time	1	1/5	1/7	1/7	1/5	1/3	1/5	1/3	1/7	1/3	1/7	1/3	
Criterium 2	Implementation cost	5	1	1/5	1/5	1/5	1/5	1/7	1/3	1/7	1/5	1/5	1/3	
Criterium 3	Lifetime costs	7	5	1	1	1/3	1/7	1	1/3	1/4	1/5	1/5	1	
Criterium 4	Operational costs	7	5	1	1	1/3	1/5	1/3	1/3	1	1/5	1/5	1/3	
Criterium 5	Throughput speed	5	5	3	3	1	1/5	3	1/3	3	1/3	1/3	1	
Criterium 6	Modularity installations	3	5	7	5	5	1	3	3	5	3	1/3	3	
Criterium 7	Clarity of installations	5	7	1	3	1/3	1/3	1	5	5	5	1/3	4	
Criterium 8	Flexibility	3	3	3	3	3	1/3	1/5	1	3	5	1/5	3	
Criterium 9	Energy efficiency	7	7	4	1	1/3	1/5	1/5	1/3	1	3	1/5	1	
Criterium 10	GDP compliancy	3	5	5	5	3	1/3	1/5	1/5	1/3	1	1/3	5	
Criterium 11	Cool chain integrity	7	5	5	5	3	3	3	5	5	3	1	7	
Criterium 12	Supply chain integration	3	3	1	3	1	1/3	1/4	1/3	1	1/5	1/7	1	
SUM		**56**	**51 1/5**	**31 1/3**	**30 1/3**	**17 3/4**	**6 3/5**	**12 1/2**	**16 1/2**	**24 7/8**	**21 1/2**	**3 5/8**	**27**	

Normalized values:

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium O Supply chain integration	Weight W
Criterium 1	Implementation time	0,018	0,004	0,005	0,005	0,011	0,050	0,016	0,020	0,006	0,016	0,039	0,012	**0,0168**
Criterium 2	Implementation cost	0,089	0,020	0,006	0,007	0,011	0,030	0,011	0,020	0,006	0,009	0,055	0,012	**0,0231**
Criterium 3	Lifetime costs	0,125	0,098	0,032	0,033	0,019	0,022	0,080	0,020	0,010	0,009	0,055	0,037	**0,0450**
Criterium 4	Operational costs	0,125	0,098	0,032	0,033	0,019	0,030	0,027	0,020	0,040	0,009	0,055	0,012	**0,0417**
Criterium 5	Throughput speed	0,089	0,098	0,096	0,099	0,056	0,030	0,239	0,020	0,121	0,016	0,092	0,037	**0,0828**
Criterium 6	Modularity installations	0,054	0,098	0,223	0,165	0,282	0,151	0,239	0,181	0,201	0,140	0,092	0,111	**0,1615**
Criterium 7	Clarity of installations	0,089	0,137	0,032	0,099	0,019	0,050	0,080	0,302	0,201	0,233	0,092	0,148	**0,1235**
Criterium 8	Flexibility	0,054	0,059	0,096	0,099	0,169	0,050	0,016	0,060	0,121	0,233	0,055	0,111	**0,0936**
Criterium 9	Energy efficiency	0,125	0,137	0,128	0,033	0,019	0,030	0,016	0,020	0,040	0,140	0,055	0,037	**0,0650**
Criterium 10	GDP compliancy	0,054	0,098	0,160	0,165	0,169	0,050	0,016	0,012	0,013	0,047	0,092	0,185	**0,0884**
Criterium 11	Cool chain integrity	0,125	0,098	0,160	0,165	0,169	0,454	0,239	0,302	0,201	0,140	0,276	0,259	**0,2157**
Criterium 12	Supply chain integration	0,054	0,059	0,032	0,099	0,056	0,050	0,020	0,020	0,040	0,009	0,039	0,037	**0,0430**
SUM		**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	

Consistency check

Determine weight sums vector {W}

		Criterium A Implementation time	Criterium B Implementation cost	Criterium C Lifetime costs	Criterium D Operational costs	Criterium E Throughput speed	Criterium F Modularity installations	Criterium G Clarity of installations	Criterium H Flexibility	Criterium I Energy efficiency	Criterium J GDP compliancy	Criterium K Cool chain integrity	Criterium O Supply chain integration	Weight sums vector Ws
Criterium 1	Implementation time	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 2	Implementation cost	1/9	0	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 3	Lifetime costs	1/3	2/9	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 4	Operational costs	2/7	1/5	0	0	0	0	0	0	0	0	0	0	**0**
Criterium 5	Throughput speed	2/5	2/5	1/4	1/4	0	0	1/4	0	1/4	0	0	0	**1/6**
Criterium 6	Modularity installations	1/2	4/5	1 1/8	4/5	4/5	1/6	1/2	1/2	4/5	1/2	0	1/2	**4/7**
Criterium 7	Clarity of installations	5/8	6/7	1/8	3/8	0	0	1/8	5/8	5/8	5/8	0	1/2	**3/8**
Criterium 8	Flexibility	2/7	2/7	2/7	2/7	2/7	0	0	0	2/7	1/2	0	2/7	**2/9**
Criterium 9	Energy efficiency	1/2	1/2	1/4	0	0	0	0	0	0	1/5	0	0	**1/7**
Criterium 10	GDP compliancy	1/4	4/9	4/9	4/9	1/4	0	0	0	0	0	0	4/9	**1/5**
Criterium 11	Cool chain integrity	1 1/2	1	1	1	2/3	2/3	2/3	1	1	2/3	2/9	1 1/2	**1**
Criterium 12	Supply chain integration	1/8	1/8	0	1/8	0	0	0	0	0	0	0	0	**0**
SUM		**4 8/9**	**5**	**3 2/3**	**3 1/2**	**2 2/9**	**1**	**1 5/8**	**2 2/5**	**3 2/9**	**2 4/7**	**3/7**	**3 1/2**	

Determine consistency vector and eigenvalue

		Weight sums vector Ws	1/ Weight 1/W	Consistency vector Ws x 1/W
Criterium 1	Implementation time	0,02	203,44	3,42
Criterium 2	Implementation cost	0,02	63,64	1,47
Criterium 3	Lifetime costs	0,04	15,28	0,69
Criterium 4	Operational costs	0,04	16,99	0,71
Criterium 5	Throughput speed	0,08	5,75	0,48
Criterium 6	Modularity installations	0,16	1,72	0,28
Criterium 7	Clarity of installations	0,12	2,63	0,32
Criterium 8	Flexibility	0,09	4,62	0,43
Criterium 9	Energy efficiency	0,06	7,31	0,47
Criterium 10	GDP compliancy	0,09	4,78	0,42
Criterium 11	Cool chain integrity	0,22	1,07	0,23
Criterium 12	Supply chain integration	0,04	19,57	0,84
Eigenvalue λ (average consistency vector)				**0,81**

Scoring principles		
1/9		Absolutely less important
1/7		Very less more important
1/5		Much less imporant
1/3		Somewhat less important
1		Equally important
3		Somewhat more important
5		Much more imporant
7		Very much more important
9		Absolutely more important
2,4,6,8	1/2, 1/4, 1/6, 1/8	When compromise is needed

Operational Management	
1.	**Cool chain integrity**
2.	**Modularity installations**
3.	**Clarity of installations**
4.	**Flexibility**
5.	**GDP compliancy**
6.	**Throughput speed**
7.	**Energy efficiency**
8.	**Supply chain integration**
9.	**Lifetime costs**
10.	**Operational costs**
11.	**Implementation cost**
12.	**Implementation time**

Determine consistency index

Consistency index CI	-0,81

Determine consistency ratio

Consistency ratio CR	-0,550

Aantal n	1	2	3	4	5	6	7	8	9	10	11	12	13
Random index RCI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56

Consistency

Consistency ratio CR is < 0,10 for the matrix to be consistent	**This matrix is**	**CONSISTENT, excersise finished**

Appendix 8

Arrival and Departure Patterns at the Terminal for All Pharma Products

Figure 1: Landside Movements Pattern in the Representative Peak Week for All Pharma: Maximum 19 shipments per hour

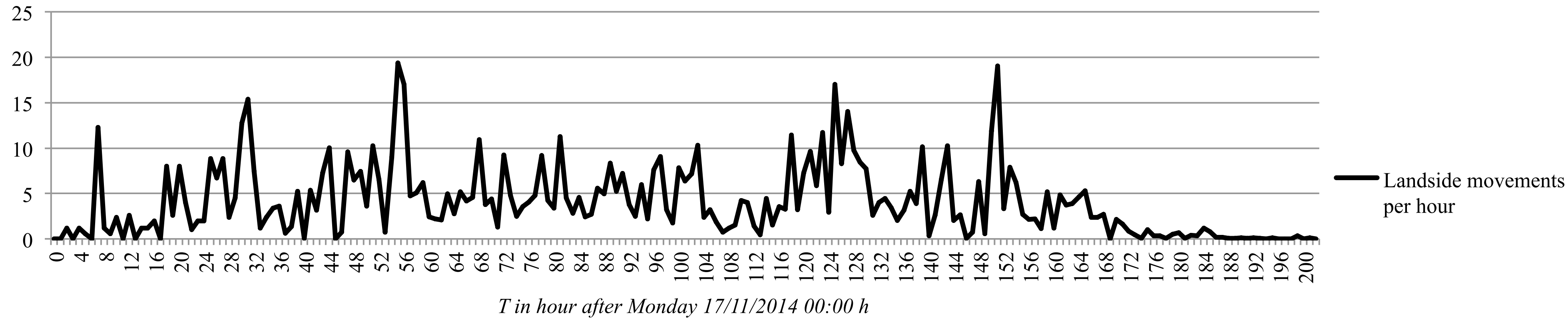
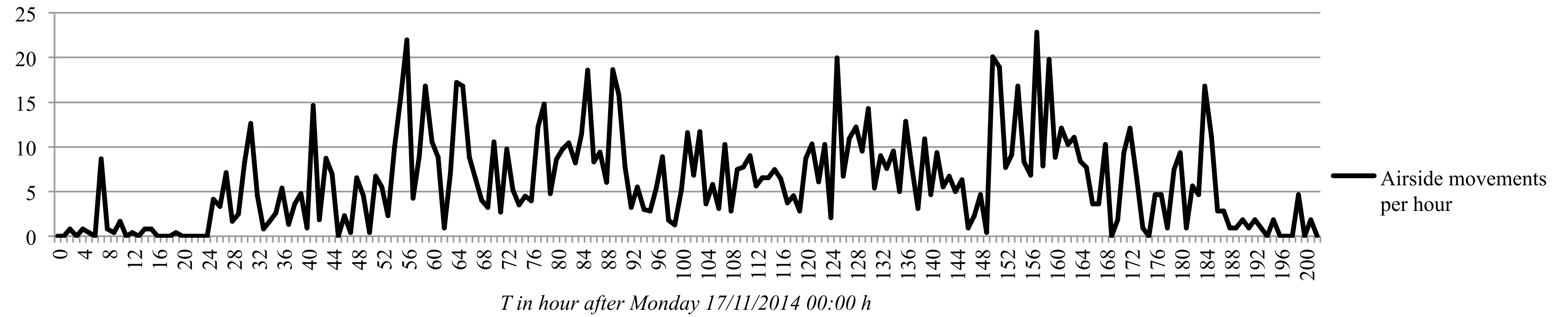


Figure 2: Airside Movements Pattern in the Representative Peak Week for all Pharma: Maximum 23 shipments per hour



Arrival and Departure Patterns at the Terminal for COL Products

Figure 1: Landside Movements Pattern in the Representative Peak Week for COL: Maximum 9 shipments per hour

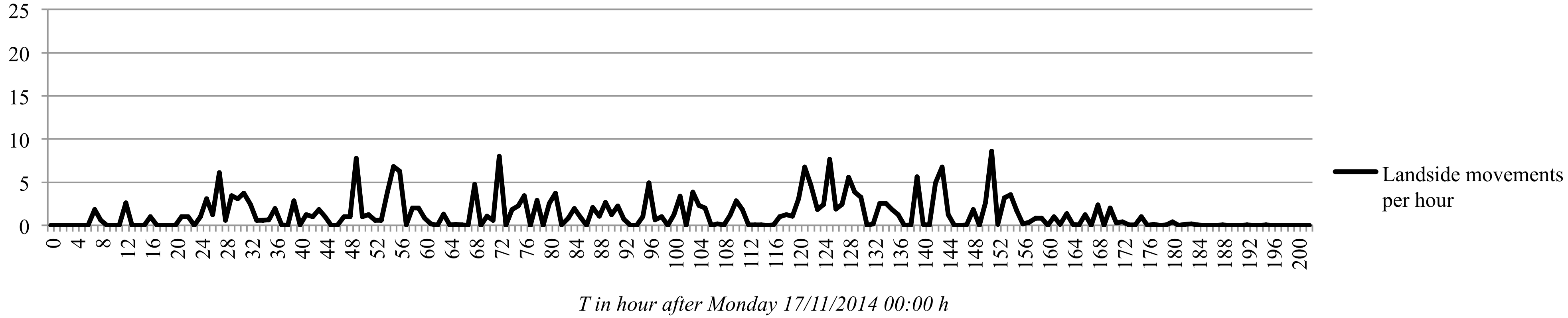
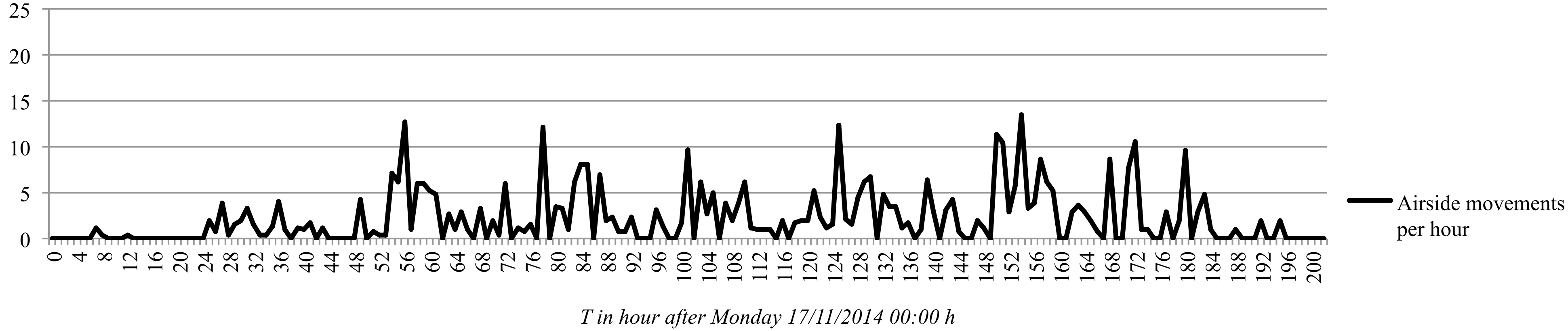


Figure 2: Airside Movements Pattern in the Representative Peak Week for COL: Maximum 13 shipments per hour



Arrival and Departure Patterns at the Terminal for ACT, CRT and PIL Products

Figure 1: Landside Movements Pattern in the Representative Peak Week for ACT, CRT and PIL: Maximum 13 shipments per hour

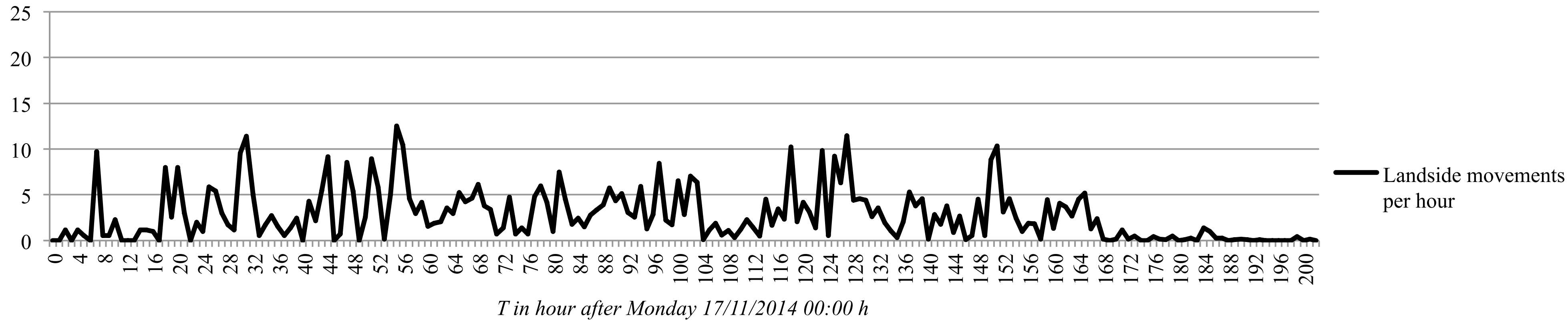
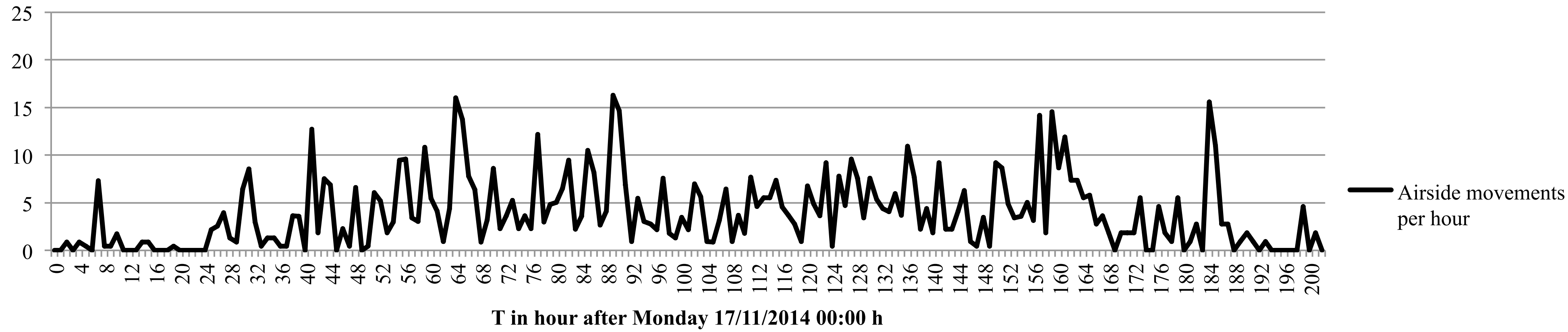


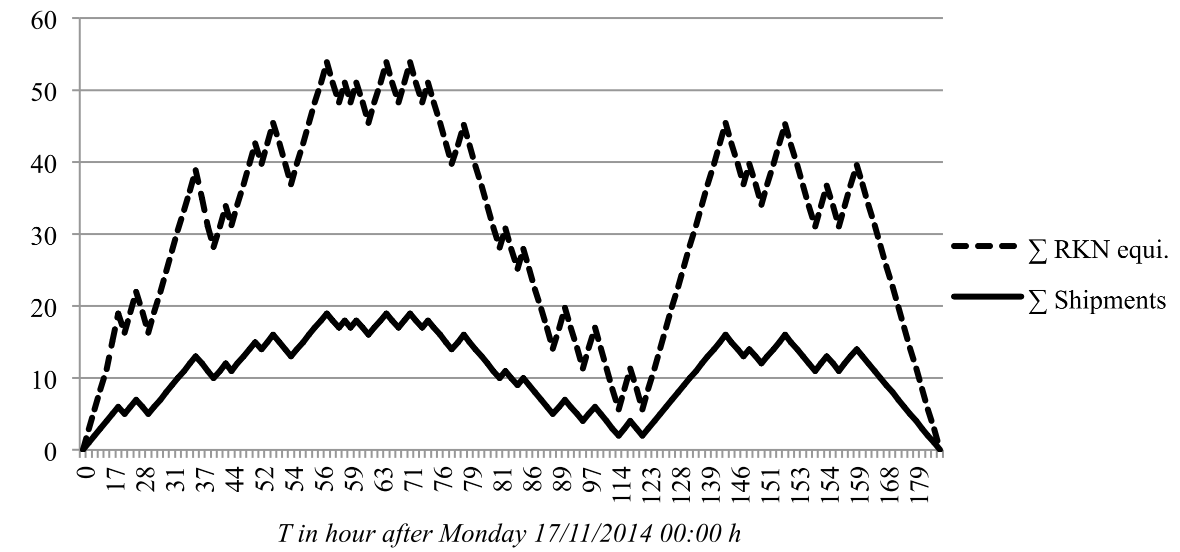
Figure 2: Airside Movements Pattern in the Representative Peak Week for ACT, CRT and PIL: Maximum 16 shipments per hour



Appendix 9

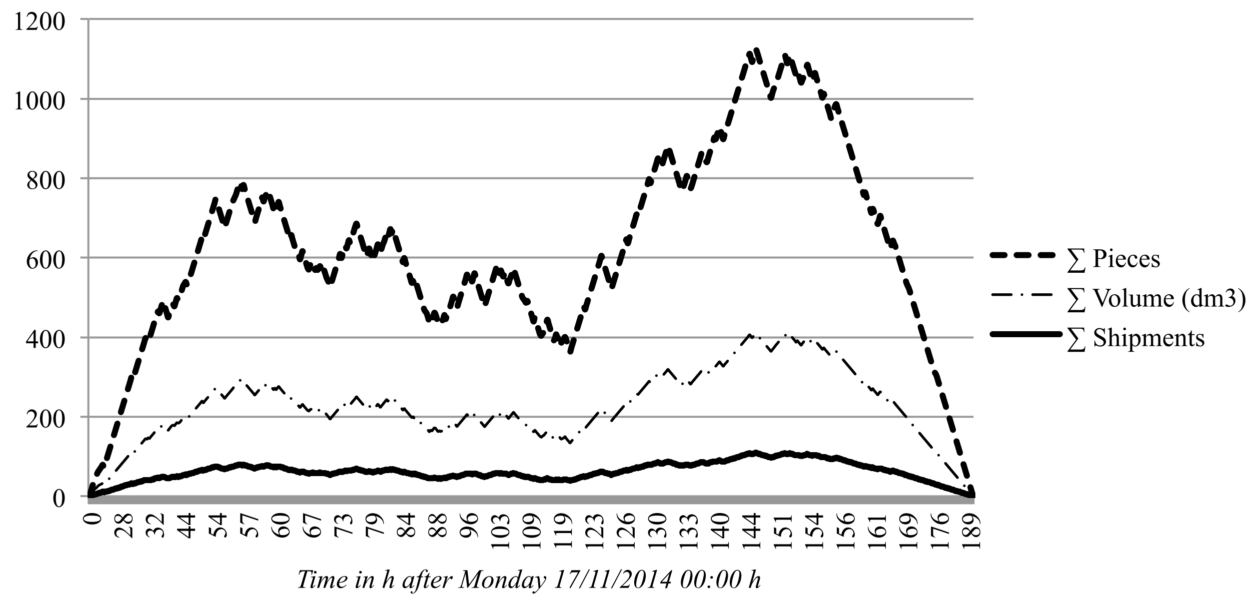
Terminal Occupation Pattern for Pharma Products

Figure 1: Terminal Occupation in the Representative Peak Week for ACT



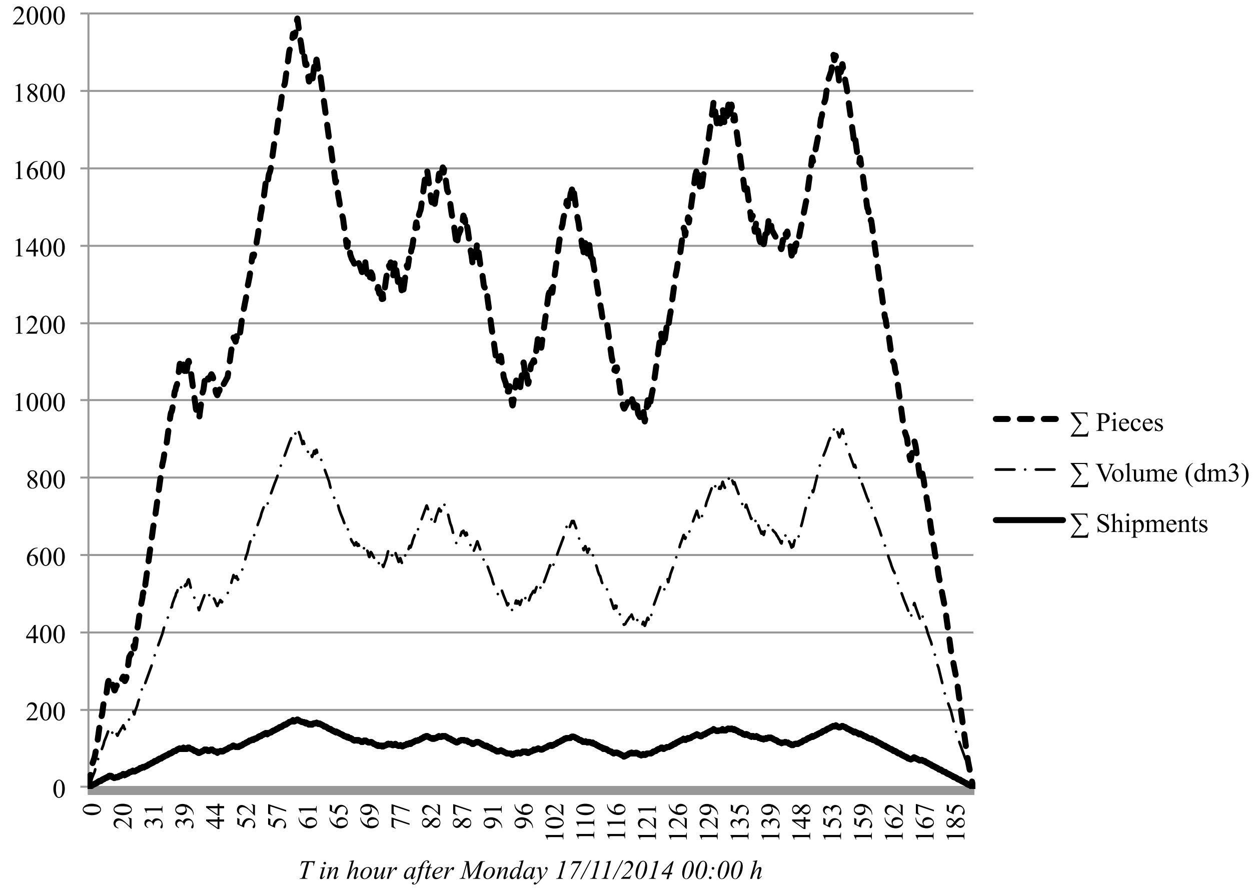
Maximum: 19 shipments or 54 RKN equivalent

Figure 2: Terminal Occupation in the Representative Peak Week for COL



Maximum: 109 shipments, 410 m^3 or 1.124 pieces

Figure 3: Terminal Occupation in the Representative Peak Week for CRT and PIL



Maximum: 174 shipments, 931 m^3 or 1.988 pieces

Appendix 10

Morphological Analysis for System of KLM Cargo Pharma Terminal

Morphological Box

Parameters	Parameter value 1	Parameter value 2	Parameter value 3	Parameter value 4	Parameter value 5
1 Handling Freight at the Landside Interface	**PV1.1** Outside truck unloading bay, unloading with forklifts	**PV1.2** Controlled truck unloading dock, unloading with forklifts	**PV1.3** Controlled truck unloading bay, unloading with automatic system		
2 Handling ULDs in the Terminal	**PV2.1** Fully mechanized system to handle ULDs	**PV2.2** Semi mechanized system and airside PCHS to handle ULDs	**PV2.3** Manual system to handle ULDs	**PV2.4** Cool dollies to handle ULDs	
3 Handling Bulk in the Terminal	**PV3.1** Forklifts to handle individual shipments	**PV3.2** Compact stackers to handle individual shipments	**PV3.3** Hand pallet trucks to handle individual shipments	**PV3.4** Sorter system to handle individual shipments	
4 Handling ULD at Airside	**PV4.1** Tractors and dollies to transport ULDs	**PV4.2** Tractor and cool dollies to transport all pharma ULDs	**PV4.3** Tractor and cool dollies to transport COL and CRT ULDs	**PV4.4** Tractor and cool dollies to transport COL ULDs	**PV4.5** Insulation dollies to transport ULDs
5 Handling Bulk at Airside	**PV5.1** Belly carts to transport airside bulk belly freight	**PV5.2** Dedicated van to transport airside bulk belly freight	**PV5.3** Cool dolly to transport airside bulk belly freight		
6 Handling of ACT Containers	**PV6.1** Tractors and dollies to handle ACT containers	**PV6.2** Pallet slaves, racks, tractors and dollies to handle ACT containers	**PV6.3** Roller- and ball beds, tractors and dollies to handle ACT containers	**PV6.4** Connection to PCHS, tractors and dollies to handle ACT containers	
7 Terminal Refinement Level	**PV7.1** Terminal with clinical finishing and two temperature zones (15-25 and 2-8)	**PV7.2** Terminal with clincal finishing and general temperature control in 15-25	**PV7.3** Terminal with industrial finishing and two temperature zones (15-25 and 2-8)	**PV7.4** Terminal with industrial finishing and general temperature control in 15-25	**PV7.5** Terminal with industrial finishing and no general temperature control
8 Flexibility to the Future	**PV8.1** Terminal is designed to fit 2040 demand	**PV8.2** Terminal is designed to fit 2040 demand but is able to adapt short-term fluctuations	**PV8.3** Terminal is desfigned to gradually adapt to the forecasted demand		

Parameter Value Descriptions

Parameter 1: Handling Freight at the Landside Interface

Handling bulk freight at landside contains the unloading of export, loading of import and the loading and unloading of transit trucks. Export and import is handled in bulk and the transit trucks are considered to be operated as loose trucking, which means the freight is build-up on warehouse skids. The export, import or transit trucks also could contain ULDs, such as ACT containers. The way the bulk freight, the warehouse pallets and the occasional ULDs are handled at landside is described in this parameter.

Parameter value 1.1: Outside truck unloading bay, unloading with forklifts

The handling of the trucks could be done outside under a roof. Once export and transit trucks have the freight have unloaded, the freight is delivered inside the terminal where the systems in the terminal take over. For loading import delivery and transit the trucks the process is the other way around.

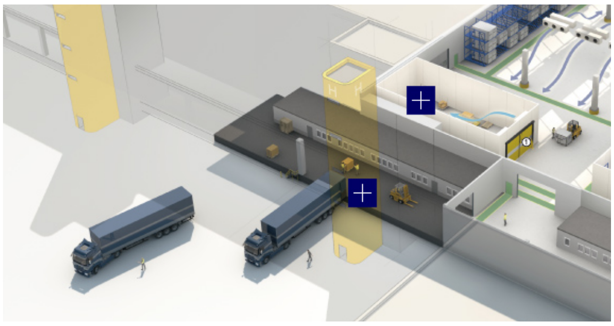


Figure 1: Outside truck unloading bay from Lufthansa

The disadvantages of this option are that the outside temperature cannot be controlled and that the temperature in the truck or the shipment cannot be checked with accuracy. In Figure 1 a part of the schematic of the Lufthansa Cargo Cool Center (also described in chapter 8) is given and it shows a way an outside truck unloading bay could be configured.

Parameter value 1.2: Controlled truck unloading dock, unloading with forklifts

A more controlled and often used system for loading and unloading trucks is to directly connect the trucks to the terminal through a (controlled) truck dock, see Figure 2. With this system the shipments arrive directly in the terminal's bulk handling system, while preserving the temperature in the truck, the terminal and the shipment.

Figure 2: Controlled truck docks

The use of cool docks enables the operation to perform accurate temperature checks upon arrival of the goods.

Parameter value 1.3: Controlled truck unloading bay, unloading with automatic system

Besides unloading docked trucks with forklifts, it is an option to install an automated unloading system. It would allow trucks to be handled at once and within minutes. A system like that is developed by Ancra Systems B.V. in Boxtel, The Netherlands. Implementing one of their systems requires an automation in both the trailer and the terminal. The involvement of trailers make the system more suitable for transit trucks then for export delivery vehicles.

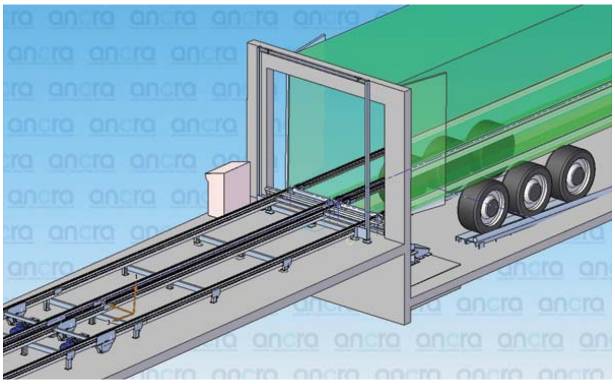


Figure 3: Automated truck loading and unloading system

The advantage of an automated truck loading and unloading system is that less personnel, less handling equipment such as forklifts and less truck docks are required. The flow of freight through the terminal is promised to be of a more condensed nature. The disadvantage is that implementation is complex, as initial investments needs to be made in money, time and effort for convincing the truck companies to adapt their trucks to the new system. Next to that, the system is less suitable for export.

Parameter 2: Handling ULDs in the Terminal

This parameter describes the way the ULDs are handled within the terminal. Handling contains build-up/ breakdown, movement, buffer and storage of the ULD. The flows that are considered in this parameter are the incoming ULD flows and the outgoing ULD flows for ULDs that are built-up in the terminal and ULDs that just pass through and do not need any alteration. ULDs mainly move at the airside of the terminal.

Parameter value 2.1: Fully mechanized system to handle ULDs

A highly automated system for handling ULDs is most suitable for handling high (Kazda & Caves, 2007). It is a system using (elevating) transfer vehicles and automatic storage and retrieval systems, see Figure 4. It does not need to be easily accessible and so can be installed in the attic of the terminal, as is the case in the current KLM Cargo Amsterdam hub for general freight in freight buildings 2 and 3.

Figure 4: Mechanization in the terminal

Right before departure of the ULDs to the aircraft they are gathered at an airside department of the pallet/ container handling system (PCHS), which is close to the output lanes accessing the airside. In the PCHS special temperature controlled boxes for ULDs containing perishable freight can be facilitated, see Figure 5.

Parameter value 2.2: Semi mechanized system and airside PCHS to handle ULDs

A semi mechanized system contains of powered roller conveyors and ball beds for ULD movement. In the Luxair Cargo terminal the system is combined with a small airside, 2 level airside PCHS see Figure 5.

Because of the cost of a fully mechanized system, a combination as presented here needs to be considered for the pharma volumes expected for the future. The advantages of mechanization reducing labour, decreasing handling damage and decreasing the risk mishandling can be included in the design by only using mechanization for the airside part of the terminal.

Figure 5: Airside PCHS in Luxemburg

Parameter value 2.3: Manual system to handle ULDs

The lowest level of mechanization would be a manual system without any automatically moving elements. Movement and storage is located on ground level. Manpower and roller- and ball beds or forklifts generate the movement.

The picture in Figure 6 shows the moving and storing of an ULD in the Hyderabad Menzies, India terminal by manpower and ball beds. In Europe a similar use of manpower could be considered as inefficient.

Figure 6: Manual movement of ULDs

Parameter value 2.4: Cool dollies to handle ULDs

A very sophisticated option to avoid the terminal as a storage area would be to place the ULD directly after arrival (T-ULD) or build-up (M-ULD) in a temperature controlled cool dolly and to buffer the dollies until departure to the aircraft.

Cool dollies are relatively new inventions and used in Dubai by Emirates and by Lufthansa in Frankfurt as well. A cool dolly is very expensive; in 2005 Emirates paid about AED 1.000.000 (€ 250.000) for 6 cool dollies (American Journal of Transportation, 2005). They were developed by a Dutch company: Van Riemsdijk Rotterdam B.V. (VRR, 2015)

Figure 7: Emitate's cool dolly

Parameter 3: Handling Bulk in the Terminal
The terminal functions as a node connecting all the freight flows. Individual shipments are moved, stored and buffered in the right conditions and environments in order to be build-up on a ULD or to leave the terminal in bulk.

The origin of freight handled in bulk in the terminal could at landside be from export or transit trucks or at airside from broken down ULDs or bulk belly freight. The destination of bulk freight in the terminal could be at landside import delivery or a transit truck or at airside bulk could ne build-up on a ULD or leave the terminal as bulk belly freight. An overview of all origins and destinations of bulk freight through the terminal is shown in Table 1:

Table 1: Ways of bulk freight coming in and going out of the terminal

Incoming		**Outgoing**	
Landside:	Export acceptance	Landside:	Import delivery
Landside:	Transit truck arrival	Landside:	Transit truck departure
Airside:	ULD breakdown	Airside:	ULD build-up
Airside:	Belly arrival	Airside:	Belly departure

Functions of the terminal for handling bulk freight:

- Moving the shipment;
- Provide appropriate buffer and storage space;
- Sort the shipment;
- Maintaining the shipment in the right temperature ranges.

The pharmaceuticals shipments need to be handled in the required temperature zone. It could be that facilities need to be separated from each other in order to provide so. Modularity in these facilities can be used to increase the flexible use of the installations in place.

<u>Parameter value 3.1: Forklifts to handle individual shipments</u>

Moving shipments through a terminal is often done by forklifts, such as shown in Figure 8. Currently the KLM Cargo operations work with this system. Each shipment is always placed on an Europallet and therefore easily transportable with a forklift.

Figure 8: Forklift

The forklift enables the use of racks to store the shipments in multiple levels. Mostly three, as most forklifts can reach up to 7 meters (Crown, 2015).

Depending on the further configuration, the forklift is able to enter special cool area's to store shipments there. Just as in the KLM Cargo Amsterdam terminal, the cool area's need to have large entrances and space for manoeuvre.

Parameter value 3.2: Compact stackers to handle individual shipments

A more refined option for handling shipments through the terminal on Europallets is the use of the smaller pallet trucks, as shown in Figure 9. For operations with compact stackers the shipments still need to be placed on a Europallet.

Figure 9: Compact stackers

The trucks are especially helpful with working in smaller spaces and encourage working more careful.

Unfortunately they are unable to stack high racks. A reach is about up to 4,5 meters (Crown, 2015)

Parameter value 3.3: Hand pallet trucks to handle individual shipments

As the most manual option for handling individual shipments on Europallets pallet trucks could be suggested. The system depends on manpower and stores only in one level.

Figure 10: Hand pallet trucks

As the compact stackers, the pallet trucks are easily manoeuvrable and do not require large areas for making them.

Parameter value 3.4: Sorter system to handle individual shipments

A system without involvement of manpower or Europallets would be an automated sorter system. The sorter would be able to store the shipments in the right temperature very efficiently and deliver the shipments in time at the right location for import delivery, ULD build-up or bulk belly departure.

Figure 11: Example of a sorter system

There is no precedent in the pharmaceutical industry, yet it has proven to be a good solution for light and small shipments; characteristics that would fit pharmaceutical freight.

Parameter 4: Handling ULDs at the Airside Interface

The airside is an important interface for the handling of both the departing and arriving ULDs. Before flight the ULDs are gathered at the airside interface in order to be transported to the aircraft. Upon arrival the ULDs are gathered there before being processed into the terminal, which can be for breakdown of M-ULDs or for only buffer and storage of T-ULDs. The time ULDs are exposed to ambient temperatures should be as short as possible. It is important the handling system in the terminal fits the typical volume and weight of pharmaceutical freight and that it is able to provide the required responsiveness.

Parameter value 4.1: Tractors and dollies to transport ULDs

General freight on ULDs is mostly transported to the aircrafts on dollies, see Figure 12. The dollies are connected to a tractor and towed with five dollies in a train. The freight is exposed to an uncontrolled and unprotected environment. Not only temperature is of issue here, but wind and rain are also unfavourable for the integrity of the pharmaceutical product.

Figure 12: ULDs on dollies upon delivery at the aircraft

Parameter value 4.2: Tractors and cool dollies to transport all pharma ULDs

To protect the shipments from ambient temperatures and (negative) weather influences cool dollies have been developed, one is shown in Figure 7. The temperature can be adjusted to the required level. As most temperature excursions occur on the tarmac (see paragraph 4.2.2), finding a solution to protect the freight on the tarmac is off essence here.

Parameter value 4.3: Tractors and cool dollies to transport COL and CRT ULDs

Keeping the substantial initial investment for a cool dolly into account, it can be argued that only the freight with the most strict temperature requirements is facilitated into the cool dollies. PIL (2˚C - 25˚C) shipments could be considered as general cargo.

Parameter value 4.4: Tractors and cool dollies to transport COL ULDs

A step more prudent would be to only have cool dollies for ULDs with COL shipments. One could argue that the climate in The Netherlands is generally not that damaging to CRT and PIL shipments.

Parameter value 4.5: Insulation dollies to transport ULDs

In addition to making a combination of cool dollies and regular dollies, the use of another dolly could be considered for the transport of ULDs at airside: the insulation dolly. It could be seen as the passive alternative of the cool dolly, aiming to preserve the temperature the shipment already has and protecting it from rain and wind. As the cool dollies are used in Dubai, where the outside temperature is almost always higher than the maximum temperature for pharmaceutical shipments (25˚C) (Klimaatinfo.nl, 2015), they might be considered as an overqualified measure for use in The Netherlands where the average temperatures are between 0˚C and 22˚C (Klimaatinfo.nl, 2015)In The Netherlands the measure needs to preserve the temperature of the shipment and to shutter it from sun, rain and wind.

Parameter 5: Handling Bulk at the Airside Interface

Freight to be transported in the hull of the aircraft is not build-up onto ULDs but transported in bulk. Also the delivery and collection of the freight at the aircraft is in bulk. The mode of transport from and to the belly needs to take the integrity of the product into account. For the collection of the shipments before departure and after arrival different systems can be used.

Parameter value 5.1: Belly carts to transport airside bulk belly freight

Currently the bulk belly freight is gathered in baggage carts (see Figure 13) lined up in freight building 1. As the sorting of the shipments in the carts is based upon flight and not upon destination, buffering the carts requires a large space.

Upon departure the carts are transported to the aircraft and the bulk belly freight is loaded in the hull of the aircraft. The carts are not temperature controlled and the shipments are generally exposed to the elements too long.

Figure 13: Schematic of a belly/ baggage cart

As pharmaceutical freight is a time-sensitive product it relatively often transported as bulk belly. It is a flow that needs to be well considered.

Parameter value 5.2: Dedicated van to transport airside bulk belly freight

A more dedicated way of working would be the use of a cool van for dedicated delivery of pharmaceutical bulk shipments. The shipments are collected by the driver and delivered at the aircraft, the other way around the driver will enter the bulk belly freight arriving at the terminal in the regular flows for further handling. This option facilitates an integer cool chain and minimizes exposure to uncontrolled temperature and weather, and the delay posed by handling bulk belly in general flows.

Figure 14: Example of a cool van

Parameter value 5.3: Cool dolly to transport airside bulk belly freight

Instead of collecting the shipments in uncontrolled belly carts the shipments can also be collected in cool dollies in different temperatures. The cool dollies can be attached to the (cool) dolly trains with pharma ULDs and/ or ACT containers.

Parameter 6: Handling of ACT containers

Handling the ACT containers is considered a to be a specialized activity. From the landside acceptance until the airside delivery the ACT container needs different and careful attention. The degree the ACT container (passive or active) flows through the general process depends on the caution in the general process. Once arrived at the buffer area the container needs special servicing and storage. Upon departure the ACT container needs to be delivered to the right destination, this can be import delivery, transit truck departure or aircraft departure. It is important for the reliability and the performance of the container that it is held out of temperature extremes and within controlled areas as long as possible.

<u>Parameter value 6.1: Tractors and dollies to handle ACT containers</u>

In all cases the ACT containers are transported from the platform to the terminal on dollies towed by tractors. As is the case now, the dollies are even towed into the terminal and disconnected there for further servicing of the container. The containers are not taken off the dollies. The inefficient use of space is a disadvantage of handling and storing the ACT containers this way.

Figure 15: A tractor with dollies loaded with ACT containers

<u>Parameter value 6.2: Pallet slaves, racks, tractors and dollies to handle ACT containers</u>

As is the case with Lufthansa (see Figure 16) the containers are taken of the dollies with a pallet slave and placed into a three story high rack. The positions in the racks are accessible from the back to connect the power or refill the dry-ice and the batteries. In front of the racks there is the possibility to position some containers on the floor as well.

The advantage of the racks it that they can be expanded by adding another level onto it and that by storing them in the vertical plane very good use is made of the space available.

Figure 16: ACT containers stored in a rack by using a pallet slave

<u>Parameter value 6.3: Roller- and ball beds, tractors and dollies to handle ACT containers</u>

A way without the necessity of lifting and manoeuvring with the ACT containers is to unload them from the dolly onto a roller- and ball bed system and push them to the right location for servicing, see Figure 17.

The advantages are that the ACT container is less likely to get damaged, the disadvantage is that the flexibility for expansion is limited as all is in one level and it all is one big facility.

Figure 17: Manual movement of ACT containers

Parameter value 6.4: Connection to PCHS, tractors and dollies to handle ACT containers

As an alternative way to handle ACT containers, the handling can be up to a large extend be integrated into the automation of the terminal. The ACT container is transported within the PCHS to a dedicated storage location in the system from where it is possible to service the containers as required. After servicing the container is released for departure and the PCHS in its turn takes the container in the right time to the right final destination.

Parameter 7: Terminal Refinement Level

The required finishing of the terminal to a large extend determined in the GDP regulations. Proper finishing and nifty details are in order to keep the facility clean, pest free and easily maintainable. Next to that, the refinement level of the terminal depends on the ambition level of KLM Cargo. They could decide to only make the minimum of installations upon the regulatory required level or decide that the entire terminal should be created to show their professionalism to the customer and communicate the delicacy of the product and the therefore required mind set to the personnel.

<u>Parameter value 7.1: Terminal with clinical finishing and two temperature zones (15-25 and 2-8)</u>

The maximum refinement level of terminal would be to facilitate two temperature zones, 2˚C - 8˚C and 15˚C - 25˚C, with each their own access to landside (truck doors) and access to airside.

The power floated coated concrete floors give the terminal a clinical look and ensure an easy maintainable floor, see Figure 18.

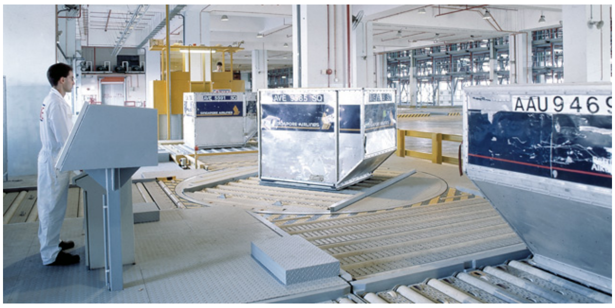


Figure 18: Highly refined terminal

<u>Parameter value 7.2: Terminal with clinical finishing and general temperature control in 15-25</u>

As a variation on the terminal refinement level in parameter value 7.1, the terminal could be equipped with only one temperature zone, namely 15˚C - 25˚C.

To also facilitate storage for COL shipments special cool rooms for individual shipments and ULDs in 2˚C - 8˚C are added in the terminal, as is the case in the Brussels Aviapartner terminal see Figure 19.

Figure 19: Temperature facilitation in a 15-25 highly refined environment

<u>Parameter value 7.3: Terminal with industrial finishing and two temperature zones (15-25 and 2-8)</u>

For the product integrity the clinical look is not necessary. Many terminals have a more industrial look with just power coated floors and good cleaning programs.

To facilitate the two temperatures the terminal has separate facilities for both temperature ranges both accessible from landside and airside to provide an equal cool chain for both 2˚C - 8˚C and shipments. This is the case at the Luxair pharma terminal in Luxemburg, see Figure 20.

Figure 20: Industrial environment with two temperature zones

Parameter value 7.4: Terminal with industrial finishing and general temperature control in 15-25

Another level for the refinement of the terminal would be to provide an industrial environment with one temperature range 15˚C - 25˚C in which the 2˚C - 8˚C dedicated cool rooms for COL shipments and ULDs are facilitated. This is the case in the terminal of Lufthansa in Frankfurt, the Lufthansa Cargo Control Center.

Parameter value 7.5: Terminal with industrial finishing and no general temperature control

The minimal level of refinement level presented here would be to propose an industrial looking terminal with no general control over temperature and humidity. Both temperature ranges 15˚C - 25˚C and 2˚C - 8˚C are facilitated in dedicated rooms for shipments and ULDs and are closely temperature controlled. This is the case in the current KLM Cargo terminal.

Parameter 8: Flexibility to the Future

The ability of the terminal to adapt to the increasing or decreasing demand, to changes in the expectations for future demand, the development of unforeseen product requirements on the long term, but also short-term peaks and drops in demand, are considered in this variable. It determines the flexibility of the terminal to cope with all these changes in demand.

<u>Parameter value 8.1: Terminal is designed to fit 2040 demand</u>

The design tries to accommodate the forecasted demand for 2040 at once and all elements of the system are determined and made definite for the whole design horizon. Facilities are dedicated to the operations and products they are designed for. The disadvantage is that this system could be operating with a large overcapacity in the first years and that the demand for capacity forecasted does not fit the future reality caused by yet unforeseen influences.

<u>Parameter value 8.2: Terminal is designed to fit 2040 demand, but is able to adapt short fluctuation</u>

Another thought could be to design a system sized by the future expectations, but internally organized in such a way that the elements in the systems can be used interchangeable to accommodate changing, unexpected or shifting demand. Modularity is an important factor for that, see Figure 21.

Figure 21: Modular cool facilities

All is within the total expected demand for capacity in 2040, but through modular organization of the elements fundamental shifts or incidental peaks or lows in operations can be anticipated.

<u>Parameter value 8.3: Terminal is designed to gradually adapt to the forecasted demand</u>

The most flexible of the three values presented here would be a flexibility concept driven by the awareness that the forecasted demand for 2040 might change over time and that it is not wise to already provide all the capacity at once. Instead of operating with substantial overcapacity, this alternative is set up modular and reserves space in the horizontal and vertical plane to expand and to adequately adapt to the true future demand. It is important to have the required capacity at hand, not be restricted by it but certainly not to have an overcapacity.

Short term variations on the forecast, daily peaks (up or down) in certain products, can be adapted to with this system as well. The modularity allows the system to be used in an interchangeable way.

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Appendix 11

Explanation of the scores given in the MCA

Criterion 1: Implementation Time

The Zero Concept [0]

The implementation time of a terminal similar to the current pharma handling facilities is determined mainly by the installation of the automation (PCHS) system and the controlled truck docks. Only a few cooling facilities have to be installed, which would be possible in a small amount of time.

The Modest Concept [++]

Compared to the Zero Concept the Modest Concept is easier to implement. No automation or complex interface systems need to be installed. For this Concept though, the installation of a temperature control system in the terminal and the 2°C – 8°C facilities need to be installed. This Concept is considered to be implementable in a considerably less amount of time than the Zero Concept.

The Elite Concept [+]

A semi-mechanized system is less complex to install then the fully automated PCHS system in the Zero Concept. On the other hand is this Concept more complex in applying the two different independent temperature zones in the terminal. Overall this Concept is considered to be faster to implement than the Zero Concept.

The Compact Concept [++]

In the Compact Concept only one temperature zone needs to be installed which would reduce the implementation time compared to the Elite Concept's implementation time, being considerably shorter then the Zero Concept.

The Automated Concept [--]

In this Concept much more automation and temperature control measures need to be installed than in the Zero Concept, increasing the relative implementation time.

Criterion 2: Implementation Cost

The Zero Concept [0]

The implementation cost of the Zero Concept is determined by the high degree of automation and the low degree of specialized equipment. Although the system is equipped with a PCHS, the rest of the equipment such as forklifts, dollies and tractors are considered to be basic.

The Modest Concept [++]

The modest Concept is considered to require a substantially smaller initial investment as only basic equipment is proposed and the system works with roller/ ball beds and dollies with tractors.

The Elite Concept [-]

This Concept imposes only an airside PCHS and assumes extensive use of cool dollies. An ambitious level of finishing and future flexibility is also part of this Concept. It is considered to be as expensive as the Zero Concept.

The Compact Concept [0]

Compared to the Elite Concept this configuration is a little more careful with the initial resources, as only 2°C – 8°C shipments will be provided with cool dollies. The terminal is finished appropriate, though modest.

The Automated Concept [--]

The PCHS, sorter, cool dollies, automated truck unloading system require large initial investments, as does the high level of finishing. A system largely automated is considered to be very much more expensive than the Zero Concept.

Criterion 3: Lifetime Cost

The Zero Concept [0]

The lifetime costs of this Concept are largely determined by the maintenance of the PCHS. The rest of the system is relatively low-maintenance.

The Modest Concept [++]

There are barely any mechanized systems in this Concept that would require maintenance. Some more maintenance is required for the slightly more elaborate temperature controlled system. This Concept requires much less lifetime costs than the Zero Concept.

The Elite Concept [0]

For this Concept the mechanization level is a degree lower then the Zero Concept but the Concept contains the cool dollies and extensive temperature facilities, which require more lifetime costs. The Elite Concept is considered to be performing equal to the Zero Concept on this criteria.

The Compact Concept [+]

The Compact Concept approximates the elite Concept but is composed in a more prudent way to be conscious with resources, practise and the level of service that is required. Only one temperature zone and less cool dollies make this Concept more favourable on this criterion that the Zero Concept.

The Automated Concept [--]

The most maintenance sensitive system is the Automated Concept. The automated truck unloading, the sorter and the PCHS, with the cool dolly and the two temperature zones make this system preform much worst on the lifetime cost criterion.

Criterion 4: Operational Cost

The Zero Concept [0]

As the point of reference the Zero Concept makes the basis for the operational cost point of view. The level of cost of the operation is determined by the labour. For the Zero Concept the labour costs are limited, as the system operates with a highly automated PCHS.

The Modest Concept [--]

This Concept without mechanization relies much more on human labour and so is considered to perform worse than the Zero Concept.

The Elite Concept [-]

As the Elite Concept focuses on quality of the service and product integrity, mechanization is present in selected parts of the system and is combined with the personal handling and care of employees. The Concept is considered to score worse than the Zero Concept but better than the Modest Concept.

The Compact Concept [-]

In terms of the division of the work over automated systems and human labour, this Concept scores equal to the Elite Concept.

The Automated Concept [+]

Of the five Concepts the Automated Concept is based on the smallest amount of human labour. As the Zero Concept is also already highly mechanized this Concept scores just somewhat better.

Criterion 5: Throughput Speed

The Zero Concept [0]

The highly mechanized PCHS does not fit the volumes of pharmaceutical freight that will need to be processed in the future, what will cause the system to be overcomplicated an slow down the operations and for that the throughput speed.

The Modest Concept [0]

With the Modest Concept the situation is exactly the opposite of the problem at the Zero Concept; the manual operation does not fit the processed volumes either. A certain level mechanization would fit the operations for pharmaceutical freight and having none slows down the operation speed as much as is the case at the Zero Concept.

The Elite Concept [+]

This Concept is very much focussed on delivering a high level of service and maintaining optimally the product integrity. Despite a suitable level of mechanization the devious facilities and operations slow down the throughput speed. The Elite Concept is still considered to be performing better than the Zero Concept.

The Compact Concept [+]

The level of mechanization in the Compact Concept is as adequate as the mechanization in the Elite Concept, but the organization of the rest of the system is less devious and precise causing a better performance on throughput compared to the Zero Concept.

The Automated Concept [++]

The PCHS included in the Automated Concept does not precisely facilitates a high throughput speed for the applying volumes of freight, but the automated truck unloading and sorter systems are expected to decrease the throughput speed as set in the Zero Concept. This Concept therefore scores a better then the Elite and Compact Concept.

Criterion 6: Modularity

The Zero Concept [0]

The modularity of the Zero Concept is the standard for the comparison of the other Concepts. It is determined by the presence of an airside PCHS, the use of (cool) dollies and the interchangeability of the facility as a whole.

The Modest Concept [-]

In the Modest Concept is no airside PCHS available, roller/ ball beds have a static capacity and storage rooms for ULDs are considered to be not interchangeable. This Concept is considered to score lightly worse than the Zero Concept.

The Elite Concept [+]

The use of an airside PCHS and cool dollies make the system relatively modular. The Elite Concept is more modular than the Zero Concept.

The Compact Concept [++]

Practically the interchangeability of the comes to the best advantage in this Concept. The systems operate within each other and can be used for more temperatures and back-up situations. The performance on modularity is much better than the performance of the Zero Concept.

The Automated Concept [-]

By applying all automated systems the capacity for certain processes is quite defined. Despite the interchangeability of the storage rooms for ULDs and shipments (temperature be set to both temperature scopes) the Concept is considered to be less modular than the Zero Concept.

Criterion 7: Clarity

The Zero Concept [0]

The reference level for the operational clarity for customers and employees to see what is happening in the terminal and to provide improved handling and working environment with that, is determined by the Zero Concept. The visibility automated systems, the human error that is allowed and the split of departments in the terminal influences the clarity.

The Modest Concept [-]

The manual terminal shows what is happening with the freight but is also a system very vulnerable to the human deviation from the standardized processes and systems. Although invisibility in the PCHS in the Zero Concept, the threat of cluttered processes is making this Concept be worse.

The Elite Concept [++]

The Elite Concept works with an airside PCHS, which clears the shop floor effectively and operates two terminal temperatures indicating very clearly which product is handled where and what product is dealt with. This Concept scores much better on the clarity criterion than the Zero Concept.

The Compact Concept [+]

This Concept is almost equally clear as the Elite Concept, but only operates one temperature zone. It therefore scores a little worse, but still better than the Zero Concept.

The Automated Concept [-]

In the Automated Concept almost all processes are invisible as they are accommodated in automated systems. To see if the system operates upon expectation monitoring and control will be more important, as it is not clear to see how freight is processed. Because the Zero Concept is also already quite invisible, this Concept just scores a little less.

Criterion 8: Flexibility

The Zero Concept [0]

The flexibility criterion is determined by the ability of the system to adapt to unforeseen changes in demand in the short and long term. In short term the system needs to be able to adapt to daily or hourly peaks and in the long term the fundamental capacity of the terminal needs to be easily adaptable to developments. The Zero Concept operates in a static environment.

The Modest Concept [0]

This Concept is designed to a static demand, but as it is very dependable on human labour it is relatively easy to add. The nature of the capacity allows expansion and shrinkage, but the system would be less fit to unforeseen need for expansion as that would imply volumes go up and that would fit less with the unmechanized concept. Operating with manpower is limiting the expansion possibilities. The Concept scores the same as the Zero Concept.

The Elite Concept [++]

The small mechanization, combined with the used of human labour and stackers and two independently temperature controllable departments in the terminal makes this a configuration much more flexible than the Zero Concept.

The Compact Concept [+]

This Concept performs slightly less well than the Elite Concept as it only operates one terminal temperature and with that does not provide the possibility to add modules for more demand.

The Automated Concept [-]

The capacity for the mechanization in the Automated Concept should be well estimated as it is not a very flexible system. It might be possible to add capacity, but once it has been installed it is wasteful to operate with overcapacity in case of a drop in demand. This Concept scores worse.

Criterion 9: Energy Efficiency

The Zero Concept [0]

Only the vital elements in the system of the Zero Concept are temperature controlled. Futhermore can the PCHS be considered as an energy using element in the system.

The Modest Concept [0]

In this Concept there is no energy needed for the use of automated systems and the terminal is kept within 15°C - 25°C. The temperature control is not that extreme considering the climate in The Netherlands, and for the 2°C - 8°C shipments only the vital elements in the system are temperature controlled. This terminal therefore scores equal as the Zero Concept.

The Elite Concept [-]

This Concept operates cool dollies, a cool van and two independent temperature zones. It is not possible to shut down the temperature-controlled facilities if not used. In favour of this Concept is the airside PCHS The energy efficiency of the Elite Concept is less favourable than the energy efficiency of the Zero Concept.

The Compact Concept [+]

On this criterion the Compact Concept differs much from the Elite Concept. It operates also the airside PCHS, less cool dollies and maintains only the range of 15°C - 25°C in the terminal, and provides for the 2°C - 8°C shipments only the vital elements in the system. This Concept is assumed to be performing better than the Zero Concept.

The Automated Concept [-]

This Concept is assumed to be performing the same as the Elite Concept as cool dollies are used widely and the automated systems operate in temperature controlled departments in the terminal.

Criterion 10: GDP Compliance

The Zero Concept [0]

Every Concept proposed here is GDP compliant. This criterion determines the readiness of the system to cope with tightening of the regulations and determines the ambition the Concepts try to comply with these rules. In the Zero Concept the terminal is not temperature controlled and the system is not poorly maintainable as the finishing is not of a high level.

The Modest Concept [+]

The terminal operates an outside truck unloading dock and a basic temperature controlled terminal and regular dollies. The GDP compliance is just some better than the Zero Concept.

The Elite Concept [++]

This high ambition terminal is very well ready for tightening regulation and is a showcase of this ambition. The use of cool docks, two temperature zones and the clinical finishing of the terminal make this Concept score much better than the Zero Concept.

The Compact Concept [+]

The GDP compliance of this Concept is based upon the use of cool docks and a terminal in one temperature zone. The industrial finishing of the terminal does not add to the performance on this criterion. Compared to the Zero Concept it scores slightly better.

The Automated Concept [++]

In the mostly automated terminal the use of pallets is minimized, two temperature zones are operated, trucks are unloaded very fast and the human error is reduced. This Concept is very sustainable to future regulation, and therefore scores much better than the Zero Concept.

Criterion 11: Cool Chain Integrity

The Zero Concept [0]

As the GDP compliance considers terminal safety and cleanliness, the cool chain integrity involves in the level the system has the ability to provide a corridor of controlled temperature from landside to airside and back. The only temperature control by in the Zero Concept is in the buffer and storage rooms.

The Modest Concept [-]

In this almost primitive system the acceptance/ delivery at airside and the movements made at airside are uncontrolled. The system scores slightly less than the Zero Concept.

The Elite Concept [++]

This Concept provides a very thorough temperature controlled corridor from landside to airside. Two temperature ranges for landside handling and cool dollies and a special delivery van for airside movements. The Concept scores much better than the Zero Concept.

The Compact Concept [+]

The somewhat more practical system proposed in the compact Concept provides only one temperature (15°C - 25°C) for landside movements and will only provide temperature-controlled handling at airside for 2°C - 8°C shipments. As operations are designed flexible this is not considered a limitation and the Concept will still perform better than the Zero Concept.

The Automated Concept [++]

As handling from airside on in this automated Concept is relatively fast and flawless the cool chain is very much embedded in this Concept. The two temperature zones the terminal operates and the use of cool dollies at landside, this Concept's score is very well compared to the Zero Concept.

Criterion 12: Supply Chain Optimization

The Zero Concept [0]

The supply chain optimization criterion aims to judge the Concepts on the way they best facilitate the transit flow and thereafter fit in the export and import flow in without creating deviations in the transit process. The Zero Concept requires no special export and import facilities.

The Modest Concept [--]

Although the export and import is integateable in the processes the handling of these shipments take a lot of effort to handle manually. Compared to the Zero Concept this Concept scores less well.

The Elite Concept [-]

The terminal is very focussed on the airside movements and the transit trucks. Due to the handling in two temperature zones the effect of the disruptions of export and import at landside are double and the Zero Concept outperforms this Concept.

The Compact Concept [0]

The terminal is very focussed on the airside movements and the transit trucks. Export and import is easy to integrate in the landside handling as there is only one temperature zone it disrupts. This Concept scores equal as the Zero Concept.

The Automated Concept [+]

The export and import can just be handled by the automated system without interfering operations, automatic messages can be sent to the agents for pick-up. The terminal is very focussed on transit, especially on landside with the automated truck unloading system. KLM Cargo cannot expect agents to adapt to these systems, but still this Concept makes sure there is minimal disruption because of export and import shipments.

Appendix 12

Multi-Criteria Analyses

MCA with Strategic Weights

MCA with Strategic Weights		Scores					Absolute Scores				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1
Total Score											

MCA with Strategic Weights		Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
			Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Strategic	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	4	0,50	1,00	0,75	1,00	0,00	1,2%	0,608	1,217	0,913	1,217	0,000
Criterium 2	Implementation cost	4	0,50	1,00	0,25	0,50	0,00	2,1%	1,070	2,140	0,535	1,070	0,000
Criterium 3	Lifetime costs	4	0,50	1,00	0,50	0,75	0,00	3,8%	1,924	3,848	1,924	2,886	0,000
Criterium 4	Operational costs	3	0,67	0,00	0,33	0,33	1,00	6,6%	4,389	0,000	2,195	2,195	6,584
Criterium 5	Throughput speed	2	0,00	0,00	0,50	0,50	1,00	18,1%	0,000	0,000	9,062	9,062	18,124
Criterium 6	Modularity installations	3	0,33	0,00	0,67	1,00	0,00	3,9%	1,296	0,000	2,592	3,888	0,000
Criterium 7	Clarity of installations	4	0,50	0,25	1,00	0,75	0,00	6,9%	3,448	1,724	6,897	5,173	0,000
Criterium 8	Flexibility	3	0,33	0,33	1,00	0,67	0,00	6,9%	2,312	2,312	6,937	4,625	0,000
Criterium 9	Energy efficiency	2	0,50	0,50	0,00	1,00	0,00	8,5%	4,273	4,273	0,000	8,545	0,000
Criterium 10	GDP compliancy	2	0,00	0,50	1,00	0,50	1,00	16,4%	0,000	8,187	16,374	8,187	16,374
Criterium 11	Cool chain integrity	3	0,33	0,00	1,00	0,67	1,00	15,9%	5,288	0,000	15,863	10,575	15,863
Criterium 12	Supply chain integration	3	0,67	0,00	0,33	0,67	1,00	9,6%	6,390	0,000	3,195	6,390	9,585
Total Score								100,0%	30,998	23,701	66,485	63,811	66,529

MCA with Tactical Weights

MCA with Tactical Weights		Scores					Absolute Scores				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1
Total Score											

MCA with Tactical Weights		Range	Normalized Scores					Weights	Normalized Scores with Tactical Weights				
			Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Tactical	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,767	1,535	1,151	1,535	0,000
Criterium 2	Implementation cost	4	0,50	1,00	0,25	0,50	0,00	2,1%	1,074	2,149	0,537	1,074	0,000
Criterium 3	Lifetime costs	4	0,50	1,00	0,50	0,75	0,00	4,4%	2,222	4,443	2,222	3,332	0,000
Criterium 4	Operational costs	3	0,67	0,00	0,33	0,33	1,00	5,3%	3,503	0,000	1,752	1,752	5,255
Criterium 5	Throughput speed	2	0,00	0,00	0,50	0,50	1,00	9,9%	0,000	0,000	4,966	4,966	9,931
Criterium 6	Modularity installations	3	0,33	0,00	0,67	1,00	0,00	6,5%	2,163	0,000	4,326	6,489	0,000
Criterium 7	Clarity of installations	4	0,50	0,25	1,00	0,75	0,00	11,5%	5,727	2,864	11,455	8,591	0,000
Criterium 8	Flexibility	3	0,33	0,33	1,00	0,67	0,00	11,4%	3,793	3,793	11,378	7,585	0,000
Criterium 9	Energy efficiency	2	0,50	0,50	0,00	1,00	0,00	6,9%	3,459	3,459	0,000	6,917	0,000
Criterium 10	GDP compliancy	2	0,00	0,50	1,00	0,50	1,00	12,6%	0,000	6,310	12,620	6,310	12,620
Criterium 11	Cool chain integrity	3	0,33	0,00	1,00	0,67	1,00	20,1%	6,694	0,000	20,081	13,387	20,081
Criterium 12	Supply chain integration	3	0,67	0,00	0,33	0,67	1,00	7,7%	5,165	0,000	2,583	5,165	7,748
Total Score								100,0%	34,567	24,552	73,069	67,104	55,634

MCA with Operational Weights

MCA with Operational Weights		Scores					Absolute Scores				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1
Total Score											

MCA with Operational Weights		Range	Normalized Scores					Weights	Normalized Scores with Operational Weights				
			Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Operational	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	4	0,50	1,00	0,75	1,00	0,00	1,7%	0,841	1,683	1,262	1,683	0,000
Criterium 2	Implementation cost	4	0,50	1,00	0,25	0,50	0,00	2,3%	1,157	2,313	0,578	1,157	0,000
Criterium 3	Lifetime costs	4	0,50	1,00	0,50	0,75	0,00	4,5%	2,248	4,497	2,248	3,372	0,000
Criterium 4	Operational costs	3	0,67	0,00	0,33	0,33	1,00	4,2%	2,780	0,000	1,390	1,390	4,171
Criterium 5	Throughput speed	2	0,00	0,00	0,50	0,50	1,00	8,3%	0,000	0,000	4,138	4,138	8,276
Criterium 6	Modularity installations	3	0,33	0,00	0,67	1,00	0,00	16,1%	5,382	0,000	10,764	16,146	0,000
Criterium 7	Clarity of installations	4	0,50	0,25	1,00	0,75	0,00	12,4%	6,177	3,089	12,354	9,266	0,000
Criterium 8	Flexibility	3	0,33	0,33	1,00	0,67	0,00	9,4%	3,119	3,119	9,356	6,237	0,000
Criterium 9	Energy efficiency	2	0,50	0,50	0,00	1,00	0,00	6,5%	3,249	3,249	0,000	6,498	0,000
Criterium 10	GDP compliancy	2	0,00	0,50	1,00	0,50	1,00	8,8%	0,000	4,419	8,837	4,419	8,837
Criterium 11	Cool chain integrity	3	0,33	0,00	1,00	0,67	1,00	21,6%	7,190	0,000	21,569	14,380	21,569
Criterium 12	Supply chain integration	3	0,67	0,00	0,33	0,67	1,00	4,3%	2,866	0,000	1,433	2,866	4,299
Total Score								100,0%	35,010	22,367	73,931	71,552	47,153

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Average Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Strategic	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,739	1,478	1,109	1,478	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,100	2,201	0,550	1,100	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,131	4,263	2,131	3,197	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,3%	3,558	0,000	1,779	1,779	5,336
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,1%	0,000	0,000	6,055	6,055	12,110
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,8%	2,947	0,000	5,894	8,841	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,2%	5,118	2,559	10,235	7,676	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,2%	3,075	3,075	9,224	6,149	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,3%	3,660	3,660	0,000	7,320	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,6%	0,000	6,305	12,610	6,305	12,610
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,2%	6,390	0,000	19,171	12,781	19,171
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,2%	4,807	0,000	2,404	4,807	7,211
Total Score																		100,0%	33,525	23,540	71,162	67,489	56,439

Appendix 13

Sensitivity Analysis on the MCA with Average Weights

MCA with Average Weights		Scores					Absolute Scores				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1
Total Score											

MCA with Average Weights		Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
			Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,0073905	0,0147811	0,0110858	0,0147811	0,0000000
Criterium 2	Implementation cost	4	0,50	1,00	0,25	0,50	0,00	2,2%	0,0110032	0,0220064	0,0055016	0,0110032	0,0000000
Criterium 3	Lifetime costs	4	0,50	1,00	0,50	0,75	0,00	4,3%	0,0213129	0,0426258	0,0213129	0,0319693	0,0000000
Criterium 4	Operational costs	3	0,67	0,00	0,33	0,33	1,00	5,3%	0,0355754	0,0000000	0,0177877	0,0177877	0,0533631
Criterium 5	Throughput speed	2	0,00	0,00	0,50	0,50	1,00	12,1%	0,0000000	0,0000000	0,0605516	0,0605516	0,1211032
Criterium 6	Modularity installations	3	0,33	0,00	0,67	1,00	0,00	8,8%	0,0294700	0,0000000	0,0589399	0,0884099	0,0000000
Criterium 7	Clarity of installations	4	0,50	0,25	1,00	0,75	0,00	10,2%	0,0511766	0,0255883	0,1023532	0,0767649	0,0000000
Criterium 8	Flexibility	3	0,33	0,33	1,00	0,67	0,00	9,2%	0,0307452	0,0307452	0,0922355	0,0614903	0,0000000
Criterium 9	Energy efficiency	2	0,50	0,50	0,00	1,00	0,00	7,3%	0,0366003	0,0366003	0,0000000	0,0732007	0,0000000
Criterium 10	GDP compliancy	2	0,00	0,50	1,00	0,50	1,00	12,6%	0,0000000	0,0630518	0,1261036	0,0630518	0,1261036
Criterium 11	Cool chain integrity	3	0,33	0,00	1,00	0,67	1,00	19,2%	0,0639031	0,0000000	0,1917094	0,1278063	0,1917094
Criterium 12	Supply chain integration	3	0,67	0,00	0,33	0,67	1,00	7,2%	0,0480720	0,0000000	0,0240360	0,0480720	0,0721081
Total Score								100,0%	0,3352493	0,2353989	0,7116173	0,6748889	0,5643874

MCA with Average Weights Criterion 1: -10%		Scores					Absolute Scores				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1
Total Score											

MCA with Average Weights Criterion 1: -10%		Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
			Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	4	0,50	1,00	0,75	1,00	0,00	1,3%	0,665	1,330	0,998	1,330	0,000
Criterium 2	Implementation cost	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,102	2,204	0,551	1,102	0,000
Criterium 3	Lifetime costs	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,134	4,269	2,134	3,202	0,000
Criterium 4	Operational costs	3	0,67	0,00	0,33	0,33	1,00	5,3%	3,563	0,000	1,781	1,781	5,344
Criterium 5	Throughput speed	2	0,00	0,00	0,50	0,50	1,00	12,1%	0,000	0,000	6,064	6,064	12,128
Criterium 6	Modularity installations	3	0,33	0,00	0,67	1,00	0,00	8,9%	2,951	0,000	5,903	8,854	0,000
Criterium 7	Clarity of installations	4	0,50	0,25	1,00	0,75	0,00	10,3%	5,125	2,563	10,251	7,688	0,000
Criterium 8	Flexibility	3	0,33	0,33	1,00	0,67	0,00	9,2%	3,079	3,079	9,237	6,158	0,000
Criterium 9	Energy efficiency	2	0,50	0,50	0,00	1,00	0,00	7,3%	3,666	3,666	0,000	7,331	0,000
Criterium 10	GDP compliancy	2	0,00	0,50	1,00	0,50	1,00	12,6%	0,000	6,315	12,629	6,315	12,629
Criterium 11	Cool chain integrity	3	0,33	0,00	1,00	0,67	1,00	19,2%	6,400	0,000	19,200	12,800	19,200
Criterium 12	Supply chain integration	3	0,67	0,00	0,33	0,67	1,00	7,2%	4,814	0,000	2,407	4,814	7,222
Total Score								100,0%	33,500	23,425	71,156	67,440	56,523

MCA with Average Weights Criterion 2: -10%		Scores					Absolute Scores				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1
Total Score											

MCA with Average Weights Criterion 2: -10%		Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
			Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,741	1,481	1,111	1,481	0,000
Criterium 2	Implementation cost	4	0,50	1,00	0,25	0,50	0,00	2,0%	0,990	1,981	0,495	0,990	0,000
Criterium 3	Lifetime costs	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,136	4,272	2,136	3,204	0,000
Criterium 4	Operational costs	3	0,67	0,00	0,33	0,33	1,00	5,3%	3,566	0,000	1,783	1,783	5,348
Criterium 5	Throughput speed	2	0,00	0,00	0,50	0,50	1,00	12,1%	0,000	0,000	6,069	6,069	12,138
Criterium 6	Modularity installations	3	0,33	0,00	0,67	1,00	0,00	8,9%	2,954	0,000	5,907	8,861	0,000
Criterium 7	Clarity of installations	4	0,50	0,25	1,00	0,75	0,00	10,3%	5,129	2,565	10,258	7,694	0,000
Criterium 8	Flexibility	3	0,33	0,33	1,00	0,67	0,00	9,2%	3,081	3,081	9,244	6,163	0,000
Criterium 9	Energy efficiency	2	0,50	0,50	0,00	1,00	0,00	7,3%	3,668	3,668	0,000	7,337	0,000
Criterium 10	GDP compliancy	2	0,00	0,50	1,00	0,50	1,00	12,6%	0,000	6,319	12,639	6,319	12,639
Criterium 11	Cool chain integrity	3	0,33	0,00	1,00	0,67	1,00	19,2%	6,405	0,000	19,214	12,809	19,214
Criterium 12	Supply chain integration	3	0,67	0,00	0,33	0,67	1,00	7,2%	4,818	0,000	2,409	4,818	7,227
Total Score								100,0%	33,488	23,368	71,266	67,528	56,566

MCA with Average Weights	Criterion 3: -10%	Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,742	1,485	1,114	1,485	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,105	2,210	0,553	1,105	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	3,8%	1,918	3,836	1,918	2,877	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,573	0,000	1,787	1,787	5,360
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,2%	0,000	0,000	6,082	6,082	12,164
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,9%	2,960	0,000	5,920	8,880	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,3%	5,140	2,570	10,281	7,711	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,3%	3,088	3,088	9,265	6,176	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,676	3,676	0,000	7,353	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,7%	0,000	6,333	12,667	6,333	12,667
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,3%	6,419	0,000	19,256	12,838	19,256
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,2%	4,829	0,000	2,414	4,829	7,243
Total Score																		100,0%	33,452	23,199	71,256	67,455	56,690

MCA with Average Weights	Criterion 4: -10%	Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,743	1,486	1,115	1,486	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,107	2,213	0,553	1,107	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,143	4,287	2,143	3,215	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	4,8%	3,202	0,000	1,601	1,601	4,803
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,2%	0,000	0,000	6,089	6,089	12,179
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,9%	2,964	0,000	5,927	8,891	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,3%	5,147	2,573	10,293	7,720	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,3%	3,092	3,092	9,276	6,184	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,681	3,681	0,000	7,361	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,7%	0,000	6,341	12,681	6,341	12,681
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,3%	6,426	0,000	19,279	12,853	19,279
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,834	0,000	2,417	4,834	7,251
Total Score																		100,0%	33,338	23,673	71,375	67,681	56,193

MCA with Average Weights	Criterion 5: -10%	Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,749	1,498	1,124	1,498	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,115	2,231	0,558	1,115	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,161	4,321	2,161	3,241	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,607	0,000	1,803	1,803	5,410
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	10,9%	0,000	0,000	5,450	5,450	10,899
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,0%	2,988	0,000	5,975	8,963	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,4%	5,188	2,594	10,376	7,782	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,4%	3,117	3,117	9,351	6,234	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,710	3,710	0,000	7,421	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,8%	0,000	6,392	12,784	6,392	12,784
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,4%	6,478	0,000	19,435	12,957	19,435
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,873	0,000	2,437	4,873	7,310
Total Score																		100,0%	33,987	23,864	71,453	67,730	55,839

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 6:	-10%	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,746	1,492	1,119	1,492	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,111	2,222	0,555	1,111	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,152	4,304	2,152	3,228	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,592	0,000	1,796	1,796	5,388
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,2%	0,000	0,000	6,114	6,114	12,228
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,0%	2,652	0,000	5,305	7,957	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,3%	5,167	2,584	10,335	7,751	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,3%	3,104	3,104	9,313	6,209	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,696	3,696	0,000	7,391	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,7%	0,000	6,366	12,733	6,366	12,733
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,4%	6,452	0,000	19,357	12,905	19,357
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,854	0,000	2,427	4,854	7,281
Total Score																		100,0%	33,527	23,768	71,205	67,174	56,986

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 7:	-10%	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,747	1,495	1,121	1,495	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,113	2,226	0,556	1,113	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,156	4,311	2,156	3,233	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,598	0,000	1,799	1,799	5,397
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,2%	0,000	0,000	6,124	6,124	12,248
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,9%	2,981	0,000	5,961	8,942	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	9,2%	4,606	2,303	9,212	6,909	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,3%	3,110	3,110	9,329	6,219	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,702	3,702	0,000	7,404	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,8%	0,000	6,377	12,754	6,377	12,754
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,4%	6,463	0,000	19,390	12,926	19,390
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,862	0,000	2,431	4,862	7,293
Total Score																		100,0%	33,337	23,523	70,833	67,403	57,082

MCA with average weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 8:	-10%	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,747	1,493	1,120	1,493	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,112	2,223	0,556	1,112	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,153	4,306	2,153	3,229	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,594	0,000	1,797	1,797	5,391
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,2%	0,000	0,000	6,117	6,117	12,233
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,9%	2,977	0,000	5,954	8,931	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,3%	5,170	2,585	10,339	7,754	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	8,3%	2,767	2,767	8,301	5,534	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,697	3,697	0,000	7,394	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,7%	0,000	6,369	12,738	6,369	12,738
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,4%	6,455	0,000	19,366	12,910	19,366
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,856	0,000	2,428	4,856	7,284
Total Score																		100,0%	33,527	23,440	70,869	67,497	57,012

MCA with Average Weights	Criterion 9: -10%	Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,745	1,490	1,117	1,490	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,109	2,218	0,555	1,109	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,148	4,296	2,148	3,222	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,586	0,000	1,793	1,793	5,378
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,2%	0,000	0,000	6,103	6,103	12,206
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,9%	2,970	0,000	5,941	8,911	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,3%	5,158	2,579	10,316	7,737	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,3%	3,099	3,099	9,296	6,198	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	6,6%	3,294	3,294	0,000	6,588	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,7%	0,000	6,355	12,710	6,355	12,710
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,3%	6,441	0,000	19,322	12,882	19,322
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,845	0,000	2,423	4,845	7,268
Total Score																		100,0%	33,395	23,331	71,724	67,232	56,885

MCA with Average Weights	Criterion 10: -10%	Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,750	1,499	1,125	1,499	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,116	2,232	0,558	1,116	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,162	4,324	2,162	3,243	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,609	0,000	1,804	1,804	5,413
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,3%	0,000	0,000	6,143	6,143	12,285
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,0%	2,990	0,000	5,979	8,969	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,4%	5,192	2,596	10,383	7,787	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,4%	3,119	3,119	9,357	6,238	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,713	3,713	0,000	7,426	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	11,3%	0,000	5,675	11,349	5,675	11,349
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,4%	6,483	0,000	19,448	12,965	19,448
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,877	0,000	2,438	4,877	7,315
Total Score																		100,0%	34,009	23,158	70,746	67,741	55,810

MCA with Average Weights	Criterion 11: -10%	Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,757	1,513	1,135	1,513	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,3%	1,126	2,253	0,563	1,126	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,4%	2,182	4,364	2,182	3,273	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,5%	3,642	0,000	1,821	1,821	5,463
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,4%	0,000	0,000	6,199	6,199	12,398
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,1%	3,017	0,000	6,034	9,051	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,5%	5,239	2,620	10,478	7,859	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,4%	3,147	3,147	9,442	6,295	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,5%	3,747	3,747	0,000	7,494	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,9%	0,000	6,455	12,909	6,455	12,909
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	17,3%	5,751	0,000	17,254	11,503	17,254
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,4%	4,921	0,000	2,461	4,921	7,382
Total Score																		100,0%	33,529	24,098	70,478	67,508	55,406

MCA with Average Weights
Criterion 12: -10%

		Scores					Absolute Scores					Range
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3
Total Score												

		Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0,50	1,00	0,75	1,00	0,00	1,5%	0,745	1,490	1,117	1,490	0,000
Criterium 2	Implementation cost	0,50	1,00	0,25	0,50	0,00	2,2%	1,109	2,218	0,554	1,109	0,000
Criterium 3	Lifetime costs	0,50	1,00	0,50	0,75	0,00	4,3%	2,148	4,296	2,148	3,222	0,000
Criterium 4	Operational costs	0,67	0,00	0,33	0,33	1,00	5,4%	3,585	0,000	1,793	1,793	5,378
Criterium 5	Throughput speed	0,00	0,00	0,50	0,50	1,00	12,2%	0,000	0,000	6,102	6,102	12,204
Criterium 6	Modularity installations	0,33	0,00	0,67	1,00	0,00	8,9%	2,970	0,000	5,940	8,910	0,000
Criterium 7	Clarity of installations	0,50	0,25	1,00	0,75	0,00	10,3%	5,157	2,579	10,315	7,736	0,000
Criterium 8	Flexibility	0,33	0,33	1,00	0,67	0,00	9,3%	3,098	3,098	9,295	6,197	0,000
Criterium 9	Energy efficiency	0,50	0,50	0,00	1,00	0,00	7,4%	3,688	3,688	0,000	7,377	0,000
Criterium 10	GDP compliancy	0,00	0,50	1,00	0,50	1,00	12,7%	0,000	6,354	12,708	6,354	12,708
Criterium 11	Cool chain integrity	0,33	0,00	1,00	0,67	1,00	19,3%	6,440	0,000	19,320	12,880	19,320
Criterium 12	Supply chain integration	0,67	0,00	0,33	0,67	1,00	6,5%	4,326	0,000	2,163	4,326	6,490
Total Score							100,0%	33,267	23,723	71,456	67,495	56,100

Appendix 14

Extreme Conditions Test on the MCA with Average Weights

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Average Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,739	1,478	1,109	1,478	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,100	2,201	0,550	1,100	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,131	4,263	2,131	3,197	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,3%	3,558	0,000	1,779	1,779	5,336
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,1%	0,000	0,000	6,055	6,055	12,110
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	8,8%	2,947	0,000	5,894	8,841	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,2%	5,118	2,559	10,235	7,676	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,2%	3,075	3,075	9,224	6,149	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,3%	3,660	3,660	0,000	7,320	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,6%	0,000	6,305	12,610	6,305	12,610
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,2%	6,390	0,000	19,171	12,781	19,171
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,2%	4,807	0,000	2,404	4,807	7,211
Total Score																		100,0%	33,525	23,540	71,162	67,489	56,439

MCA with Average Weights Criterion 1: -100%		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,2%	1,117	2,234	0,558	1,117	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,3%	2,163	4,327	2,163	3,245	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,4%	3,611	0,000	1,805	1,805	5,416
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,3%	0,000	0,000	6,146	6,146	12,292
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,0%	2,991	0,000	5,982	8,974	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,4%	5,194	2,597	10,389	7,792	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,4%	3,121	3,121	9,362	6,241	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,4%	3,715	3,715	0,000	7,430	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,8%	0,000	6,400	12,800	6,400	12,800
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,5%	6,486	0,000	19,459	12,972	19,459
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,3%	4,879	0,000	2,440	4,879	7,319
Total Score																		100,0%	33,278	22,393	71,104	67,001	57,285

MCA with Average Weights Criterion 2: -100%		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,756	1,511	1,134	1,511	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,4%	2,179	4,358	2,179	3,269	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,5%	3,638	0,000	1,819	1,819	5,456
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,4%	0,000	0,000	6,191	6,191	12,383
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,0%	3,013	0,000	6,027	9,040	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,5%	5,233	2,616	10,466	7,849	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,4%	3,144	3,144	9,431	6,287	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,5%	3,742	3,742	0,000	7,485	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	12,9%	0,000	6,447	12,894	6,447	12,894
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	19,6%	6,534	0,000	19,602	13,068	19,602
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,4%	4,915	0,000	2,458	4,915	7,373
Total Score																		100,0%	33,154	21,819	72,200	67,882	57,709

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 3:	**-100%**	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,5%	0,772	1,544	1,158	1,544	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,3%	1,149	2,299	0,575	1,149	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,6%	3,716	0,000	1,858	1,858	5,574
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,6%	0,000	0,000	6,325	6,325	12,650
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,2%	3,078	0,000	6,156	9,235	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,7%	5,346	2,673	10,691	8,018	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,6%	3,211	3,211	9,634	6,423	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,6%	3,823	3,823	0,000	7,646	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	13,2%	0,000	6,586	13,172	6,586	13,172
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	20,0%	6,675	0,000	20,024	13,350	20,024
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,5%	5,021	0,000	2,511	5,021	7,532
Total Score																		100,0%	32,791	20,136	72,104	67,154	58,952

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 4:	**-100%**	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,6%	0,781	1,561	1,171	1,561	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,3%	1,162	2,325	0,581	1,162	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,5%	2,251	4,503	2,251	3,377	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	12,8%	0,000	0,000	6,396	6,396	12,793
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,3%	3,113	0,000	6,226	9,339	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	10,8%	5,406	2,703	10,812	8,109	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,7%	3,248	3,248	9,743	6,496	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,7%	3,866	3,866	0,000	7,733	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	13,3%	0,000	6,661	13,321	6,661	13,321
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	20,3%	6,751	0,000	20,252	13,501	20,252
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,6%	5,078	0,000	2,539	5,078	7,617
Total Score																		100,0%	31,657	24,867	73,294	69,414	53,983

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 5:	**-100%**	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,7%	0,841	1,682	1,261	1,682	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,5%	1,252	2,504	0,626	1,252	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,8%	2,425	4,850	2,425	3,637	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	6,1%	4,048	0,000	2,024	2,024	6,072
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	10,1%	3,353	0,000	6,706	10,059	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	11,6%	5,823	2,911	11,646	8,734	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	10,5%	3,498	3,498	10,494	6,996	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	8,3%	4,164	4,164	0,000	8,329	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	14,3%	0,000	7,174	14,348	7,174	14,348
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	21,8%	7,271	0,000	21,813	14,542	21,813
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	8,2%	5,470	0,000	2,735	5,470	8,204
Total Score																		100,0%	38,144	26,783	74,078	69,899	50,436

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 6:	**-100%**	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,6%	0,811	1,621	1,216	1,621	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,4%	1,207	2,414	0,604	1,207	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,7%	2,338	4,676	2,338	3,507	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,9%	3,903	0,000	1,951	1,951	5,854
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	13,3%	0,000	0,000	6,642	6,642	13,285
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	11,2%	5,614	2,807	11,228	8,421	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	10,1%	3,373	3,373	10,118	6,745	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	8,0%	4,015	4,015	0,000	8,030	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	13,8%	0,000	6,917	13,833	6,917	13,833
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	21,0%	7,010	0,000	21,030	14,020	21,030
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,9%	5,273	0,000	2,637	5,273	7,910
Total Score																		100,0%	33,544	25,823	71,598	64,336	61,912

MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 7:	**-100%**	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,6%	0,823	1,647	1,235	1,647	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,5%	1,226	2,452	0,613	1,226	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,7%	2,374	4,749	2,374	3,561	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,9%	3,963	0,000	1,982	1,982	5,945
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	13,5%	0,000	0,000	6,746	6,746	13,491
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,8%	3,283	0,000	6,566	9,849	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	10,3%	3,425	3,425	10,275	6,850	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	8,2%	4,077	4,077	0,000	8,155	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	14,0%	0,000	7,024	14,048	7,024	14,048
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	21,4%	7,119	0,000	21,357	14,238	21,357
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	8,0%	5,355	0,000	2,678	5,355	8,033
Total Score																		100,0%	31,646	23,373	67,873	66,632	62,874

MCA with average weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 8:	**-100%**	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,6%	0,814	1,628	1,221	1,628	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,4%	1,212	2,424	0,606	1,212	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,7%	2,348	4,696	2,348	3,522	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,9%	3,919	0,000	1,960	1,960	5,879
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	13,3%	0,000	0,000	6,670	6,670	13,341
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,7%	3,246	0,000	6,493	9,739	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	11,3%	5,638	2,819	11,275	8,456	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	8,1%	4,032	4,032	0,000	8,064	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	13,9%	0,000	6,946	13,892	6,946	13,892
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	21,1%	7,040	0,000	21,119	14,079	21,119
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,9%	5,296	0,000	2,648	5,296	7,943
Total Score																		100,0%	33,544	22,545	68,232	67,572	62,173

MCA with Average Weights Criterion 9: -100%		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,6%	0,797	1,595	1,196	1,595	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,4%	1,187	2,374	0,594	1,187	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,6%	2,300	4,599	2,300	3,449	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,8%	3,839	0,000	1,919	1,919	5,758
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	13,1%	0,000	0,000	6,533	6,533	13,067
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,5%	3,180	0,000	6,360	9,539	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	11,0%	5,522	2,761	11,044	8,283	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	10,0%	3,317	3,317	9,952	6,635	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	13,6%	0,000	6,803	13,606	6,803	13,606
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	20,7%	6,895	0,000	20,685	13,790	20,685
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	7,8%	5,187	0,000	2,593	5,187	7,780
Total Score																		100,0%	32,224	21,450	76,782	64,921	60,896

MCA with Average Weights Criterion 10: -100%		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,7%	0,846	1,691	1,269	1,691	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,5%	1,259	2,518	0,630	1,259	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,9%	2,439	4,878	2,439	3,658	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	6,1%	4,071	0,000	2,035	2,035	6,106
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	13,9%	0,000	0,000	6,929	6,929	13,858
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	10,1%	3,372	0,000	6,744	10,117	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	11,7%	5,856	2,928	11,712	8,784	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	10,6%	3,518	3,518	10,555	7,036	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	8,4%	4,188	4,188	0,000	8,376	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	21,9%	7,312	0,000	21,937	14,625	21,937
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	8,3%	5,501	0,000	2,750	5,501	8,251
Total Score																		100,0%	38,363	19,722	67,000	70,013	50,153

MCA with Average Weights Criterion 11: -100%		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,8%	0,914	1,829	1,372	1,829	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,7%	1,361	2,723	0,681	1,361	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	5,3%	2,637	5,274	2,637	3,955	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	6,6%	4,401	0,000	2,201	2,201	6,602
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	15,0%	0,000	0,000	7,491	7,491	14,983
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	10,9%	3,646	0,000	7,292	10,938	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	12,7%	6,331	3,166	12,663	9,497	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	11,4%	3,804	3,804	11,411	7,607	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	9,1%	4,528	4,528	0,000	9,056	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	15,6%	0,000	7,801	15,601	7,801	15,601
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	0,0%	0,000	0,000	0,000	0,000	0,000
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	8,9%	5,947	0,000	2,974	5,947	8,921
Total Score																		100,0%	33,570	29,123	64,322	67,684	46,107

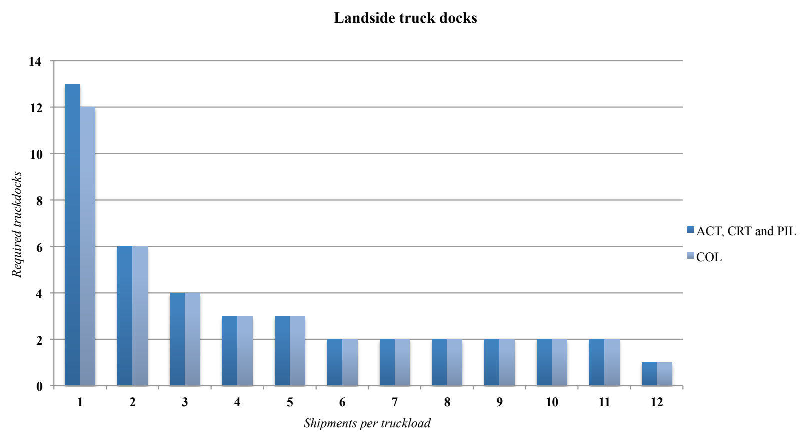
MCA with Average Weights		Scores					Absolute Scores					Range	Normalized Scores					Weights	Normalized Scores with Strategic Weights				
Criterion 12:	-100%	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept		Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept	Average	Zero Concept	Modest Concept	Elite Concept	Compact Concept	Automated Concept
Criterium 1	Implementation time	0	++	+	++	--	0	2	1	2	-2	4	0,50	1,00	0,75	1,00	0,00	1,6%	0,796	1,593	1,195	1,593	0,000
Criterium 2	Implementation cost	0	++	-	0	--	0	2	-1	0	-2	4	0,50	1,00	0,25	0,50	0,00	2,4%	1,186	2,372	0,593	1,186	0,000
Criterium 3	Lifetime costs	0	++	0	+	--	0	2	0	1	-2	4	0,50	1,00	0,50	0,75	0,00	4,6%	2,297	4,594	2,297	3,445	0,000
Criterium 4	Operational costs	0	--	-	-	+	0	-2	-1	-1	1	3	0,67	0,00	0,33	0,33	1,00	5,8%	3,834	0,000	1,917	1,917	5,751
Criterium 5	Throughput speed	0	0	+	+	++	0	0	1	1	2	2	0,00	0,00	0,50	0,50	1,00	13,1%	0,000	0,000	6,526	6,526	13,051
Criterium 6	Modularity installations	0	-	+	++	-	0	-1	1	2	-1	3	0,33	0,00	0,67	1,00	0,00	9,5%	3,176	0,000	6,352	9,528	0,000
Criterium 7	Clarity of installations	0	-	++	+	-	0	-1	2	1	-2	4	0,50	0,25	1,00	0,75	0,00	11,0%	5,515	2,758	11,031	8,273	0,000
Criterium 8	Flexibility	0	0	++	+	-	0	0	2	1	-1	3	0,33	0,33	1,00	0,67	0,00	9,9%	3,313	3,313	9,940	6,627	0,000
Criterium 9	Energy efficiency	0	0	-	+	-	0	0	-1	1	-1	2	0,50	0,50	0,00	1,00	0,00	7,9%	3,944	3,944	0,000	7,889	0,000
Criterium 10	GDP compliancy	0	+	++	+	++	0	1	2	1	2	2	0,00	0,50	1,00	0,50	1,00	13,6%	0,000	6,795	13,590	6,795	13,590
Criterium 11	Cool chain integrity	0	-	++	+	++	0	-1	2	1	2	3	0,33	0,00	1,00	0,67	1,00	20,7%	6,887	0,000	20,661	13,774	20,661
Criterium 12	Supply chain integration	0	--	-	0	+	0	-2	-1	0	1	3	0,67	0,00	0,33	0,67	1,00	0,0%	0,000	0,000	0,000	0,000	0,000
Total Score																		100,0%	30,949	25,369	74,101	67,553	53,054

Appendix 15

Landside and Airside Interface Sizing Calculation ACT,COL, CRT and PIL 2040

ACT, CRT and PIL characteristics	2014	2040	Growth factor	Average volume per shipment
Annual ACT shipments	**2.966**	**14.478**	**4,881**	**2,96 RKN equivalent**
Annual COL shipments	**16.507**	**46.488**	**2,816**	**3,27 m3**
Annual CRT and PIL shipments	**27.066**	**45.962**	**1,698**	**5,96 m3**
ACT, CRT and PIL land- and airside peak shipm./ hour				
Landside				
Incoming transit truck	12	23		
Incoming export delivery	0	0		
Outgoing transit truck	0	0		
Outgoing import delivery	1	2		
Total	**13**	**25**		
Airside				
Incoming	3	7		
Outgoing	13	26		
Total	**16**	**33**		
COL land- and airside peak shipments/ hour				
Landside				
Incoming transit truck	8	20		
Incoming export delivery	0	0		
Outgoing transit truck	0	1		
Outgoing import delivery	1	3		
Total	**9**	**24**		
Airside				
Incoming	2	5		
Outgoing	11	33		
Total	**13**	**38**		

Landside capacity calculations	ACT, CRT and PIL	COL
Landside assumptions		
Loading/ unloading time of a transit truck	0,5 hour	0,5 hour
Loading/ unloadin time of import truck	0,5 hour	0,5 hour
Truck docks required		
Truck docks required =	(un)loading time x shipments / shipments per truckload	(un)loading time x shipments / shipments per truckload
Calculation		
Shipments per truckload	**Truck docks**	**Truck docks**
1	13	12
2	**6**	6
3	4	4
4	3	3
5	3	3
6	2	2
7	2	2
8	2	2
9	2	2
10	2	2
11	2	2
12	1	1



Airside capacity calculations	ACT, CRT and PIL	COL
Airside flow characteristics		
Incoming % bulk belly	5,8%	43,0%
Incoming % ULD	85,0%	57,0%
Incoming % ACT	9,2%	n/a
Outgoing % bulk belly	22,6%	6,4%
Outgoing % ULD	67,9%	93,6%
Outgoing % ACT	9,5%	n/a
Flows in peak moment		
Incoming shipments as bulk belly	0	2
Incoming shipments on ULD	6	3
Incoming shipments ACT	1	n/a
Outgoing shipments as bulk belly	6	2
Outgoing shipments on ULD	18	31
Outgoing shipments ACT	2	n/a
Total shipments as bulk belly	6	34
Total shipments on ULDs	24	4
Total shipments ACT	3	n/a
Airside assumptions		
Airside handling time	1,5 hour	1,5 hour
Volume on ULD	12,59 m3	12,59 m3
Load factor ULD	80%	80%
Shipments per ULD	1,69	3,08
Handling of ULDs	cool dollies	cool dollies
Handling of bulk belly	delivery van	delivery van
Handling of ACT	dollies	n/a
Incoming trains	5 (cool) dollies	5 (cool) dollies
Outgoing trains	5 (cool) dollies	5 (cool) dollies
Cool dollies required for ULDs		
Cool dollies required	(un)loading time x shipments / shipments per ULD	(un)loading time x shipments / shipments per ULD
Calculation for ULDs		
Cool dollies required	**21**	**16**
Calculation for ACTs		
Dollies required for ACT (2RKN equi./ dolly)	**5**	n/a
Airside PHCS access		
Incoming	**5** doors	shared with ACT, CRT and PIL
Outgoing	**5** doors	shared with ACT, CRT and PIL

Appendix 16

Terminal Capacity Calculation ACT 2040

ACT terminal characteristics	2014	2040	Growth factor	Average volume per shipment
Annual ACT shipments	2.966	14.478	4,881	RKN equivalent
ACT terminal peak occupation: TT: - 0,0%				
Shipments	19	93		
RKN equivalent	54	263		
ACT terminal peak occupation: TT: - 12,5%				
Shipments	18	88		
RKN equivalent	51	250		
ACT terminal peak occupation: TT -25,0%				
Shipments	17	83		
RKN equivalent	48	235		
ACT terminal peak occupation: TT -37,5%				
Shipments	15	73		
RKN equivalent	43	208		
ACT terminal peak occupation: TT -50,0%				
Shipments	14	68		
RKN equivalent	40	194		
ACT terminal peak occupation: TT -62,5%				
Shipments	13	63		
RKN equivalent	37	180		
ACT terminal peak occupation: TT -75,0%				
Shipments	11	54		
RKN equivalent	31	152		

ACT terminal capacity calculations	TT 2014 - 0,0%					
Calculation of space required in the terminal						
Storage for ACTs	263 RKN equi.	foot print	2,00 x 1,53 m = 3,06 m2	805,35	m2	h = 1,63m

ACT terminal capacity calculations	TT 2014 - 12,5%					
Calculation of space required in the terminal						
Storage for ACTs	250 RKN equi.	foot print	2,00 x 1,53 m = 3,06 m2	763,56	m2	h = 1,63m

ACT terminal capacity calculations	TT 2014 - 25,0%					
Calculation of space required in the terminal						
Storage for ACTs	235 RKN equi.	foot print	2,00 x 1,53 m = 3,06 m2	720,57	m2	h = 1,63m

ACT terminal capacity calculations	TT 2014 - 37,5%					
Calculation of space required in the terminal						
Storage for ACTs	208 RKN equi.	foot print	2,00 x 1,53 m = 3,06 m2	635,80	m2	h = 1,63m

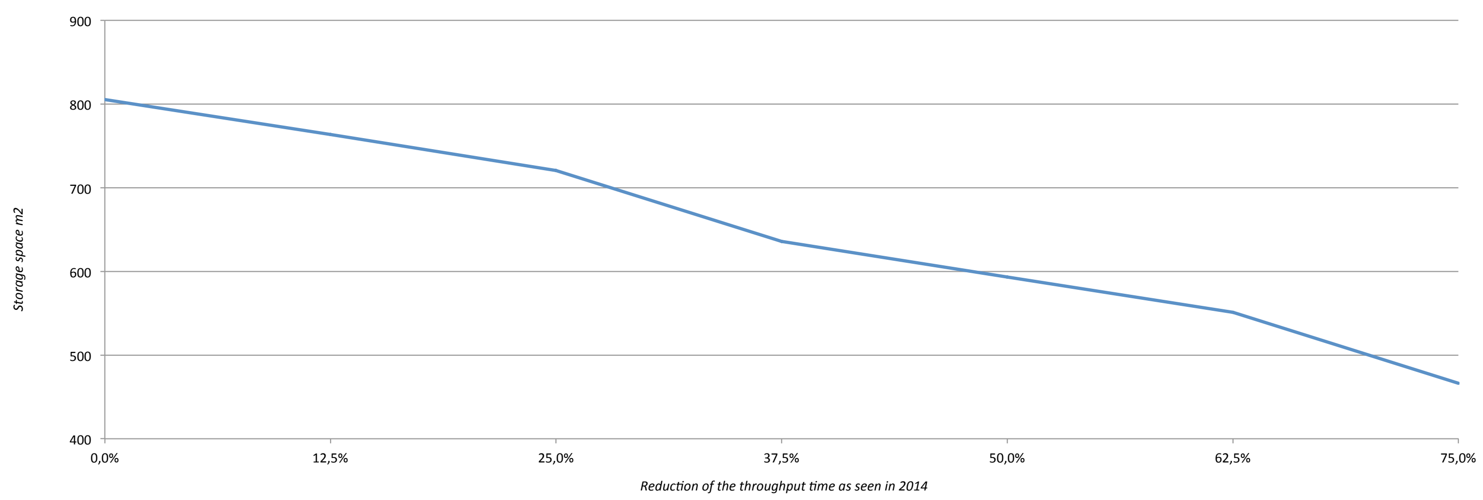
ACT terminal capacity calculations	TT 2014 - 50,0%					
Calculation of space required in the terminal						
Storage for ACTs	194 RKN equi.	foot print	2,00 x 1,53 m = 3,06 m2	593,41	m2	h = 1,63m

ACT terminal capacity calculations	TT 2014 - 62,5%					
Calculation of space required in the terminal						
Storage for ACTs	180 RKN equi.	foot print	2,00 x 1,53 m = 3,06 m2	551,03	m2	h = 1,63m

ACT terminal capacity calculations	TT 2014 - 75,0%					
Calculation of space required in the terminal						
Storage for ACTs	152 RKN equi.	foot print	2,00 x 1,53 m = 3,06 m2	466,25	m2	h = 1,63m

ACT terminal capacity calculations

Effect of the throughput time (TT) on the required storage space for ACT



Appendix 17

Terminal Capacity Calculation COL 2040

COL characteristics	2014	2040	Growth factor	Average volume per shipment
Annual COL shipments	**16.507**	**46.488**	**2,816**	**3,27** m3
COL terminal peak occupation: TT - 0,0%				
Shipments	**109**	**307**		
Volume (m3)	410	1.155		
Pieces	1.124	3.164		
COL terminal peak occupation: TT - 12,5%				
Shipments	**106**	**299**		
Volume (m3)	399	1.123		
Pieces	1.096	3.086		
COL terminal peak occupation: TT - 25,0%				
Shipments	**103**	**290**		
Volume (m3)	387	1.090		
Pieces	1.065	2.998		
COL terminal peak occupation: TT - 37,5%				
Shipments	**85**	**239**		
Volume (m3)	320	900		
Pieces	877	2.471		
COL terminal peak occupation: TT - 50,0%				
Shipments	**74**	**208**		
Volume (m3)	278	784		
Pieces	763	2.149		
COL terminal peak occupation: TT - 62,5%				
Shipments	**63**	**177**		
Volume (m3)	236	665		
Pieces	655	1.845		
COL terminal peak occupation: TT - 75,0%				
Shipments	**52**	**146**		
Volume (m3)	195	549		
Pieces	541	1.523		

COL terminal capacity calculations					
Terminal assumptions	**Ops profile 1**	**Ops profile 2**	**Ops profile 3**	**Flow characteristics**	
Shipments in the mode they arrived	25%	50%	75%	Europallets required to be stored	volume loose shipments / volume on Europallet x load factor
Shipments in the mode they depart	75%	50%	25%		
Volume on Europallet	0,96 m3				
Volume on ULD	12,59 m3			ULDs required to be stored	volume M and T ULD shipments / volume on ULD x load factor
Load factor Europallet	80%				
Load factor ULD	80%				
Flow characteristics					
Arrival					
Loose	71,5%				
M-ULD	19,2%				
T-ULD	9,3%				
Departure					
Loose	15,8%				
M-ULD	74,9%				
T-ULD	9,3%				

COL terminal capacity calculations	TT 2014 - 0,0%					
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**		
Loose	91	343	941	29,7%		
M-ULD	187	704	1.929	61,0%		
T-ULD	29	107	294	9,3%		
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**		
Loose	134	504	1.382	43,7%		
M-ULD	144	543	1.488	47,0%		
T-ULD	29	107	294	9,3%		
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**		
Loose	177	665	1.822	57,6%		
M-ULD	102	382	1.047	33,1%		
T-ULD	29	107	294	9,3%		
Calculation of space required in the terminal						
Storage for Europallets (loose)	**447** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**429,12** m2		h= 1,00 m
Storage for ULDs	**81** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**600,86** m2		h= 1,60 m
				1.029,98 m2		
Calculation of space required in the terminal						
Storage for Europallets (loose)	**657** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**630,72** m2		h= 1,00 m
Storage for ULDs	**65** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**481,70** m2		h= 1,60 m
				1.112,42 m2		
Calculation of space required in the terminal						
Storage for Europallets (loose)	**867** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**832,32** m2		h= 1,00 m
Storage for ULDs	**49** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**362,55** m2		h= 1,60 m
				1.194,87 m2		

COL terminal capacity calculations	TT 2014 - 12,5%					
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**		
Loose	89	334	917	29,7%		
M-ULD	182	685	1.882	61,0%		
T-ULD	28	104	287	9,3%		
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**		
Loose	130	490	1.347	43,7%		
M-ULD	140	528	1.452	47,0%		
T-ULD	28	104	287	9,3%		
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**		
Loose	172	647	1.777	57,6%		
M-ULD	99	372	1.022	33,1%		
T-ULD	28	104	287	9,3%		
Calculation of space required in the terminal						
Storage for Europallets (loose)	**435** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**417,60** m2		h= 1,00 m
Storage for ULDs	**78** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**584,23** m2		h= 1,60 m
				1.001,83 m2		
Calculation of space required in the terminal						
Storage for Europallets (loose)	**639** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**613,44** m2		h= 1,00 m
Storage for ULDs	**63** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**468,37** m2		h= 1,60 m
				1.081,81 m2		
Calculation of space required in the terminal						
Storage for Europallets (loose)	**843** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**809,28** m2		h= 1,00 m
Storage for ULDs	**47** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**352,51** m2		h= 1,60 m
				1.161,79 m2		

COL terminal capacity calculations	TT 2014 - 25,0%			
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	86	324	891	29,7%
M-ULD	177	665	1.828	61,0%
T-ULD	27	101	279	9,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	127	476	1.309	43,7%
M-ULD	136	513	1.410	47,0%
T-ULD	27	101	279	9,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	167	628	1.727	57,6%
M-ULD	96	361	992	33,1%
T-ULD	27	101	279	9,3%

Calculation of space required in the terminal					
Storage for Europallets (loose)	**422** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**405,12** m2	h= 1,00 m
Storage for ULDs	**76** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**567,16** m2	h= 1,60 m
				972,28 m2	
Calculation of space required in the terminal					
Storage for Europallets (loose)	**620** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**595,20** m2	h= 1,00 m
Storage for ULDs	**61** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**454,68** m2	h= 1,60 m
				1.049,88 m2	
Calculation of space required in the terminal					
Storage for Europallets (loose)	**818** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**785,28** m2	h= 1,00 m
Storage for ULDs	**46** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**342,21** m2	h= 1,60 m
				1.127,49 m2	

COL terminal capacity calculations	TT 2014 - 37,5%			
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	71	267	734	29,7%
M-ULD	146	549	1.507	61,0%
T-ULD	22	84	230	9,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	105	393	1.079	43,7%
M-ULD	113	423	1.162	47,0%
T-ULD	22	84	230	9,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	138	518	1.423	57,6%
M-ULD	79	298	818	33,1%
T-ULD	22	84	230	9,3%

Calculation of space required in the terminal					
Storage for Europallets (loose)	**349** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**335,04** m2	h= 1,00 m
Storage for ULDs	**63** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**468,25** m2	h= 1,60 m
				803,29 m2	
Calculation of space required in the terminal					
Storage for Europallets (loose)	**512** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**491,52** m2	h= 1,00 m
Storage for ULDs	**50** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**375,39** m2	h= 1,60 m
				866,91 m2	
Calculation of space required in the terminal					
Storage for Europallets (loose)	**675** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**648,00** m2	h= 1,00 m
Storage for ULDs	**38** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**282,53** m2	h= 1,60 m
				930,53 m2	

COL terminal capacity calculations	TT 2014 - 50,0%			
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	62	233	639	29,7%
M-ULD	127	478	1.310	61,0%
T-ULD	19	73	200	9,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	91	342	938	43,7%
M-ULD	98	369	1.011	47,0%
T-ULD	19	73	200	9,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	120	451	1.237	57,6%
M-ULD	69	259	711	33,1%
T-ULD	19	73	200	9,3%

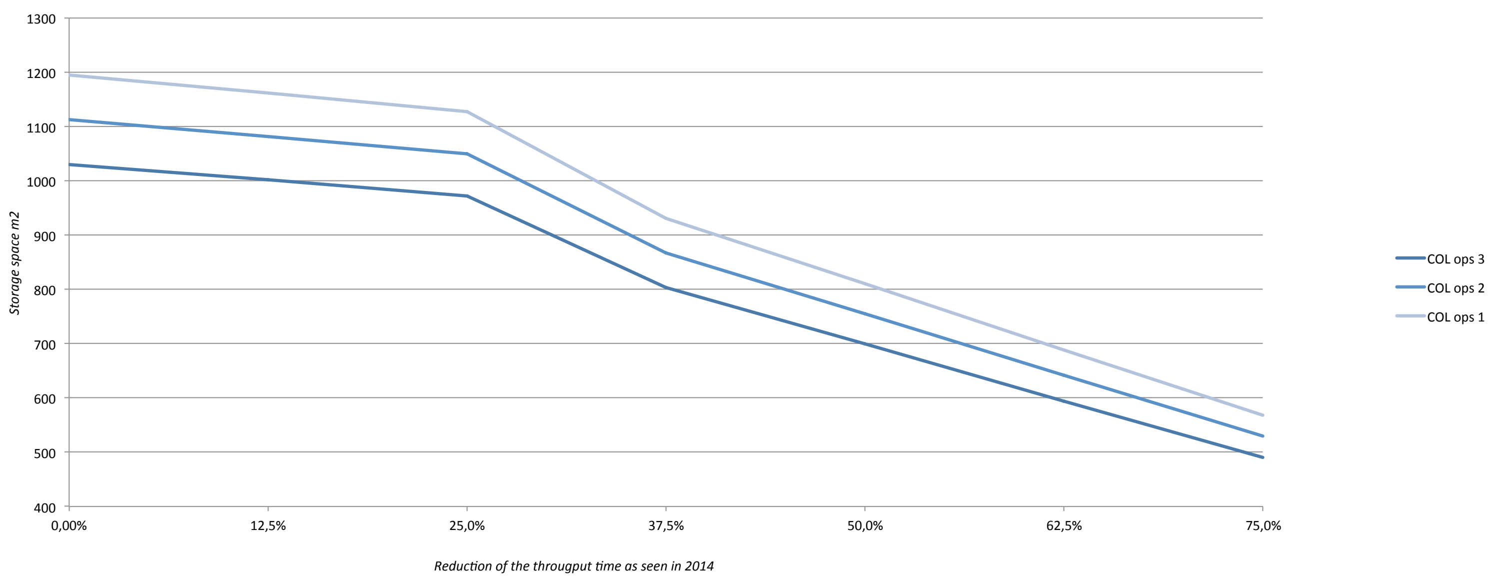
Calculation of space required in the terminal					
Storage for Europallets (loose)	**304** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**291,84** m2	h= 1,00 m
Storage for ULDs	**55** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**407,80** m2	h= 1,60 m
				699,64 m2	
Calculation of space required in the terminal					
Storage for Europallets (loose)	**446** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**428,16** m2	h= 1,00 m
Storage for ULDs	**44** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**326,93** m2	h= 1,60 m
				755,09 m2	
Calculation of space required in the terminal					
Storage for Europallets (loose)	**588** Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**564,48** m2	h= 1,00 m
Storage for ULDs	**33** ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**246,06** m2	h= 1,60 m
				810,54 m2	

COL terminal capacity calculations	TT 2014 - 62,5%								
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**		**Volume (m3)**		**Pieces**	**Percentage**			
Loose	53		198		548	29,7%			
M-ULD	108		406		1.125	61,0%			
T-ULD	16		62		172	9,3%			
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**		**Volume (m3)**		**Pieces**	**Percentage**			
Loose	77		290		806	43,7%			
M-ULD	83		313		868	47,0%			
T-ULD	16		62		172	9,3%			
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**		**Volume (m3)**		**Pieces**	**Percentage**			
Loose	102		383		1.063	57,6%			
M-ULD	59		220		611	33,1%			
T-ULD	16		62		172	9,3%			
Calculation of space required in the terminal									
Storage for Europallets (loose)	**258**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**247,68**	m2		h= 1,00 m
Storage for ULDs	**46**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**346,18**	m2		h= 1,60 m
						593,86	m2		
Calculation of space required in the terminal									
Storage for Europallets (loose)	**379**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**363,84**	m2		h= 1,00 m
Storage for ULDs	**37**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**277,53**	m2		h= 1,60 m
						641,37	m2		
Calculation of space required in the terminal									
Storage for Europallets (loose)	**499**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**479,04**	m2		h= 1,00 m
Storage for ULDs	**28**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**208,88**	m2		h= 1,60 m
						687,92	m2		

COL terminal capacity calculations	TT 2014 - 75,0%								
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**		**Volume (m3)**		**Pieces**	**Percentage**			
Loose	44		163		453	29,7%			
M-ULD	89		335		929	61,0%			
T-ULD	14		51		142	9,3%			
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**		**Volume (m3)**		**Pieces**	**Percentage**			
Loose	64		240		665	43,7%			
M-ULD	69		258		716	47,0%			
T-ULD	14		51		142	9,3%			
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**		**Volume (m3)**		**Pieces**	**Percentage**			
Loose	84		316		877	57,6%			
M-ULD	48		182		504	33,1%			
T-ULD	14		51		142	9,3%			
Calculation of space required in the terminal									
Storage for Europallets (loose)	**213**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**204,48**	m2		h= 1,00 m
Storage for ULDs	**38**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**285,74**	m2		h= 1,60 m
						490,22	m2		
Calculation of space required in the terminal									
Storage for Europallets (loose)	**313**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**300,48**	m2		h= 1,00 m
Storage for ULDs	**31**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**229,07**	m2		h= 1,60 m
						529,55	m2		
Calculation of space required in the terminal									
Storage for Europallets (loose)	**412**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**395,52**	m2		h= 1,00 m
Storage for ULDs	**23**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**172,41**	m2		h= 1,60 m
						567,93	m2		

COL terminal capacity calculations

Effect of the throughput time (TT) on the required storage space for COL



Appendix 18

Terminal Capacity Calculation CRT and PIL 2040

CRT and PIL characteristics	2014	2040	Growth factor	Average volume per shipment
Annual CRT and PIL shipments	**27.066**	**45.962**	**1,698**	**5,96 m3**
CRT and PIL terminal peak occupation: TT - 0,0%				
Shipments	**174**	**295**		
Volume (m3)	931	1.580		
Pieces	1.988	3.375		
CRT and PIL terminal peak occupation: TT - 12,5%				
Shipments	**158**	**268**		
Volume (m3)	835	1.419		
Pieces	1.777	3.018		
CRT and PIL terminal peak occupation: TT - 25,0%				
Shipments	**121**	**205**		
Volume (m3)	680	1.154		
Pieces	1.381	2.346		
CRT and PIL terminal peak occupation: TT - 37,5%				
Shipments	**111**	**188**		
Volume (m3)	581	986		
Pieces	1.286	2.183		
CRT and PIL terminal peak occupation: TT - 50,0%				
Shipments	**96**	**163**		
Volume (m3)	531	902		
Pieces	1.180	2.004		
CRT and PIL terminal peak occupation: TT - 62,5%				
Shipments	**89**	**151**		
Volume (m3)	499	848		
Pieces	1.120	1.901		
CRT and PIL terminal peak occupation: TT - 75,0%				
Shipments	**77**	**131**		
Volume (m3)	435	738		
Pieces	975	1.655		

CRT and PIL terminal capacity calculations

Terminal assumptions	Ops profile 1	Ops profile 2	Ops profile 3	Required storage	
Shipments in the mode they arrived	25%	50%	75%	Europallets required to be stored	volume loose shipments / volume on Europallet x load factor
Shipments in the mode they depart	75%	50%	25%		
Volume on Europallet	0,96 m3				
Volume on ULD	12,59 m3			ULDs required to be stored	volume M and T ULD shipments / volume on ULD x load factor
Load factor Europallet	80%				
Load factor ULD	80%				
Flow characteristics					
Arrival					
Loose	59,1%				
M-ULD	26,5%				
T-ULD	14,3%				
Departure					
Loose	24,1%				
M-ULD	61,6%				
T-ULD	14,3%				

CRT and PIL terminal capacity calculations — **TT 2014 - 0,0%**

Calculation of occupancy in the terminal: Ops prof.1	Shipments	Volume (m3)	Pieces	Percentage
Loose	97	520	1.110	32,9%
M-ULD	156	835	1.782	52,8%
T-ULD	42	226	483	14,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	123	658	1.405	41,6%
M-ULD	130	696	1.487	44,1%
T-ULD	42	226	483	14,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	149	796	1.701	50,4%
M-ULD	104	558	1.191	35,3%
T-ULD	42	226	483	14,3%

Calculation of space required in the terminal	Number	Unit		Dimensions	Area	Height
Storage for Europallets (loose)	**677**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**649,92** m2	h= 1,00 m
Storage for ULDs	**105**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**785,34** m2	h= 1,60 m
					1.435,26 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**857**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**822,72** m2	h= 1,00 m
Storage for ULDs	**92**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**682,90** m2	h= 1,60 m
					1.505,62 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**1037**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**995,52** m2	h= 1,00 m
Storage for ULDs	**78**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**580,47** m2	h= 1,60 m
					1.575,99 m2	

CRT and PIL terminal capacity calculations — **TT 2014 - 12,5%**

Calculation of occupancy in the terminal: Ops prof.1	Shipments	Volume (m3)	Pieces	Percentage
Loose	88	466	992	32,9%
M-ULD	142	749	1.594	52,8%
T-ULD	38	203	432	14,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	112	591	1.257	41,6%
M-ULD	118	625	1.329	44,1%
T-ULD	38	203	432	14,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	135	715	1.521	50,4%
M-ULD	95	501	1.065	35,3%
T-ULD	38	203	432	14,3%

Calculation of space required in the terminal	Number	Unit		Dimensions	Area	Height
Storage for Europallets (loose)	**608**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**583,68** m2	h= 1,00 m
Storage for ULDs	**95**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**704,93** m2	h= 1,60 m
					1.288,61 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**770**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**739,20** m2	h= 1,00 m
Storage for ULDs	**82**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**612,99** m2	h= 1,60 m
					1.352,19 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**931**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**893,76** m2	h= 1,00 m
Storage for ULDs	**70**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**521,04** m2	h= 1,60 m
					1.414,80 m2	

CRT and PIL terminal capacity calculations	TT 2014 - 25,0%			
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	68	379	771	32,9%
M-ULD	109	609	1.239	52,8%
T-ULD	29	165	336	14,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	86	480	977	41,6%
M-ULD	91	508	1.033	44,1%
T-ULD	29	165	336	14,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	104	582	1.182	50,4%
M-ULD	73	407	828	35,3%
T-ULD	29	165	336	14,3%

Calculation of space required in the terminal						
Storage for Europallets (loose)	**495**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**475,20** m2	h= 1,00 m
Storage for ULDs	**77**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**573,49** m2	h= 1,60 m
					1.048,69 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**626**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**600,96** m2	h= 1,00 m
Storage for ULDs	**67**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**498,69** m2	h= 1,60 m
					1.099,65 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**758**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**727,68** m2	h= 1,00 m
Storage for ULDs	**57**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**423,89** m2	h= 1,60 m
					1.151,57 m2	

CRT and PIL terminal capacity calculations	TT 2014 - 37,5%			
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	62	324	718	32,9%
M-ULD	100	521	1.153	52,8%
T-ULD	27	141	312	14,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	78	411	909	41,6%
M-ULD	83	434	962	44,1%
T-ULD	27	141	312	14,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	95	497	1.100	50,4%
M-ULD	67	348	771	35,3%
T-ULD	27	141	312	14,3%

Calculation of space required in the terminal						
Storage for Europallets (loose)	**423**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**406,08** m2	h= 1,00 m
Storage for ULDs	**66**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**490,01** m2	h= 1,60 m
					896,09 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**535**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**513,60** m2	h= 1,00 m
Storage for ULDs	**57**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**426,10** m2	h= 1,60 m
					939,70 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**647**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**621,12** m2	h= 1,00 m
Storage for ULDs	**49**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**362,19** m2	h= 1,60 m
					983,31 m2	

CRT and PIL terminal capacity calculations	TT 2014 - 50,0%			
Calculation of occupancy in the terminal: Ops prof.1	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	54	297	659	32,9%
M-ULD	86	476	1.058	52,8%
T-ULD	23	129	287	14,3%
Calculation of occupancy in the terminal: Ops prof. 2	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	68	376	835	41,6%
M-ULD	72	397	883	44,1%
T-ULD	23	129	287	14,3%
Calculation of occupancy in the terminal: Ops prof. 3	**Shipments**	**Volume (m3)**	**Pieces**	**Percentage**
Loose	82	454	1.010	50,4%
M-ULD	58	318	707	35,3%
T-ULD	23	129	287	14,3%

Calculation of space required in the terminal						
Storage for Europallets (loose)	**387**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**371,52** m2	h= 1,00 m
Storage for ULDs	**60**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**448,20** m2	h= 1,60 m
					819,72 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**489**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**469,44** m2	h= 1,00 m
Storage for ULDs	**52**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**389,74** m2	h= 1,60 m
					859,18 m2	
Calculation of space required in the terminal						
Storage for Europallets (loose)	**592**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2	**568,32** m2	h= 1,00 m
Storage for ULDs	**44**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2	**331,28** m2	h= 1,60 m
					899,60 m2	

CRT and PIL terminal capacity calculations	TT 2014 - 62,5%							
Calculation of occupancy in the terminal: Ops prof.1	Shipments			Volume (m3)	Pieces	Percentage		
Loose	50			279	625	32,9%		
M-ULD	80			448	1.004	52,8%		
T-ULD	22			121	272	14,3%		
Calculation of occupancy in the terminal: Ops prof. 2	Shipments			Volume (m3)	Pieces	Percentage		
Loose	63			353	792	41,6%		
M-ULD	67			374	838	44,1%		
T-ULD	22			121	272	14,3%		
Calculation of occupancy in the terminal: Ops prof. 3	Shipments			Volume (m3)	Pieces	Percentage		
Loose	76			427	958	50,4%		
M-ULD	53			299	671	35,3%		
T-ULD	22			121	272	14,3%		
Calculation of space required in the terminal								
Storage for Europallets (loose)	**364**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**349,44**	m2	h= 1,00 m
Storage for ULDs	**57**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**421,40**	m2	h= 1,60 m
						770,84	m2	
Calculation of space required in the terminal								
Storage for Europallets (loose)	**460**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**441,60**	m2	h= 1,00 m
Storage for ULDs	**49**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**366,43**	m2	h= 1,60 m
						808,03	m2	
Calculation of space required in the terminal								
Storage for Europallets (loose)	**557**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**534,72**	m2	h= 1,00 m
Storage for ULDs	**42**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**311,47**	m2	h= 1,60 m
						846,19	m2	

CRT and PIL terminal capacity calculations	TT 2014 - 75,0%							
Calculation of occupancy in the terminal: Ops prof.1	Shipments			Volume (m3)	Pieces	Percentage		
Loose	43			243	544	32,9%		
M-ULD	69			390	874	52,8%		
T-ULD	19			106	237	14,3%		
Calculation of occupancy in the terminal: Ops prof. 2	Shipments			Volume (m3)	Pieces	Percentage		
Loose	54			307	689	41,6%		
M-ULD	58			325	729	44,1%		
T-ULD	19			106	237	14,3%		
Calculation of occupancy in the terminal: Ops prof. 3	Shipments			Volume (m3)	Pieces	Percentage		
Loose	66			372	834	50,4%		
M-ULD	46			261	584	35,3%		
T-ULD	19			106	237	14,3%		
Calculation of space required in the terminal								
Storage for Europallets (loose)	**317**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**304,32**	m2	h= 1,00 m
Storage for ULDs	**49**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**366,83**	m2	h= 1,60 m
						671,15	m2	
Calculation of space required in the terminal								
Storage for Europallets (loose)	**401**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**384,96**	m2	h= 1,00 m
Storage for ULDs	**43**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**318,99**	m2	h= 1,60 m
						703,95	m2	
Calculation of space required in the terminal								
Storage for Europallets (loose)	**485**	Europallets	foot print	0,80 x 1,20 m = 0,96 m2		**465,60**	m2	h= 1,00 m
Storage for ULDs	**36**	ULDs	foot print	2,44 x 3,18 m = 7,74 m2		**271,14**	m2	h= 1,60 m
						736,74	m2	

CRT and PIL terminal capacity calculations

Effect of the throughput time (TT) on the required storage space for COL